



Colorado Water

Newsletter of the Water Center at Colorado State University

June 2006

Produced Waters articles inside:

How much water is there?, p. 5

What are the economics?, p. 9

How do we make use of it?, p. 11



Dave Stewart explains produced water treatment process to workshop participants.

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EDITORIAL

Produced Waters – A New Resource or an Old Problem?

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

The Colorado Water Resources Research Institute recently co-sponsored a national workshop to create a dialog on the potential opportunities for putting produced water to beneficial use. Water that is brought to the surface during oil and gas production is commonly known as ‘produced waters’. Prior to the recent large-scale development of coal bed natural gas (or coal bed methane), this water was generally considered of insufficient quality to be used beneficially. Hence, energy companies have developed methods to reinject or otherwise dispose of this by-product as efficiently and cheaply as possible.

What has changed to make us reconsider produced waters? First and foremost, the pace of coal bed natural gas development in the West has been frenzied due to current energy prices. These coal formations act as aquifers that must be de-watered to allow gas extraction. Produced water must be dealt with, but traditional methods of disposal usually result in these waters being lost for further human use and in some cases creating problems for downstream landowners. The water shortages of recent years have prompted many to ask if we are wise to sacrifice one vital resource in order to gain another.

Technology exists today to treat impaired waters to meet beneficial-use standards. In certain situations there appear to be favorable economic trade-offs between water disposal costs and treatment for resale. However, to make produced water a viable and reliable source of water, the energy industry, water industry, water-user interests, environmental interests, as well as Federal, State and local governments must come together to overcome the constraints hindering development of this resource. The various parties must collaborate to overcome the legal impediments to simultaneously developing energy and water.

Water and energy businesses operate within different markets and, consequently, within very different incentive structures and time frames. Oil and gas producers react quickly to swings in the energy market, while water suppliers enjoy a more steady market without large swings in price (except in periods of drought). As a result, energy companies work quickly in developing their non-renewable supplies, while raw water suppliers (generally government organizations) work over long time frames in planning new water projects. Energy companies often work with high risk, while water utilities/districts try to reduce risk to the lowest possible levels. Energy and water are two very different cultures, a point which was apparent many times during the workshop.

A number of other common summary points were apparent through the talks and audience discussions concerning benefi-

cial use of these waters:

- Currently, there are institutional barriers within state water law, policy and administration that limit or confound the beneficial use of produced water. States play the key role in water management and administration and must lead on changing laws and policies to facilitate beneficial uses of produced waters.
- The most promising opportunities to convert produced waters to beneficial use are where produced water sources geographically align with markets for water.
- Water markets and the costs of disposal versus treatment will drive the value of produced waters and will be the fundamental factor in determining if produced waters are converted to beneficial use.
- Current water purification technology is generally adequate to treat produced waters, where it makes sense to do so. There is a portfolio of technologies available depending on site-specific factors. Managing the concentrated brine was mentioned several times as a problem that needs further research.
- Social science research could help facilitate the removal of institutional and social barriers limiting the beneficial use of produced waters.
- Science and data gaps also need to be addressed to better understand and manage the long-term adverse impacts to lands, ground waters, and ecosystems.
- Sustainability is a concern. The water will only last as long as the oil and gas development is in production. However, the water produced over the next two decades may buy time for additional water conservation measures and infrastructure to be developed.

This issue of the Colorado Water newsletter provides a brief overview of selected papers delivered during the Produced Waters Workshop held April 4-5, 2006 in Fort Collins. Nearly 200 participants from government, energy companies, water users, water supply planners, government agency staff, researchers, and industry representatives met and held lively discussions on the needs and challenges of putting this water to beneficial use. For those with further interest in this topic, we will publish the conference proceedings both on-line and in printed form within the next month. Please access <http://cwri.colostate.edu/> in July to find or order a copy of the proceedings.

MEETING BRIEFS

Produced Waters Workshop

Energy and Water: How Can We Get Both for the Price of One?

Potential use of produced water was discussed at a workshop held at the Marriott Hotel in Fort Collins, Colorado on April 4 and 5. Produced water is water associated with oil and gas reservoirs that is extracted when the oil and gas are extracted. The workshop goal was to enhance understanding of opportunities and challenges involved in converting produced waters to beneficial use.

Discussion of possible solutions began with the assembly of people representing academic disciplines and other entities that could provide information and perspectives to characterize produced water sources, issues, and opportunities. Looking for responsible identification and development of realistic beneficial uses, the workshop featured seminars concerning quantity, "how to", and the role of various government agencies.

Participants included lawyers, geologists, oil and gas companies, private environmental agencies, extension agents, and

state and federal agency representatives. The Powder River Basin in Wyoming was used as a primary example of how produced waters could be put to use, as many panel members were from Wyoming, and that basin deals with uses of large amounts of produced waters.

Highlights of the workshop included a keynote address by Mark Limbaugh, Assistant Secretary for Water and Science for the U.S. Department of Interior, and a panel discussion between oil and gas lawyer, Jack Palma, Laurie Goodman with Trout Unlimited, and Kate Fox, Wyoming attorney. There were approximately 200 people who attended the conference.

Along with various speakers, there were panels open for discussion throughout the two-day event. This gave all who attended the conference a chance to ask questions and offer opinions and solutions about produced waters.

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PRODUCED WATERS WORKSHOP

How Much Water Are We Talking About?

Energy outlook in the West relative to extractive industries and disposition of produced waters

*Gary Bryner, Natural Resources Law Center
University of Colorado*

Natural gas provides 24 percent of the energy used in the United States and represents 27 percent of total domestic production. The United States produces 85 percent of the gas it uses and imports the rest from Canada. Since virtually all of the gas used in the United States is supplied either domestically or from its northern neighbor, it contributes to national energy security. It is also a major source of revenue for all levels of government, particularly in the Rocky Mountain States where much of the natural gas is developed on federal and state lands and private property.

Demand for natural gas is currently growing at about 1 trillion cubic feet (tcf) per year. The U.S. Department of Energy (DOE), whose data are used to project the national energy policy, suggests that natural gas use will increase between 2000 and 2020 from 22.8 to 34.7 tcf; another estimate suggested consumption will climb to 31 tcf by 2015. Others project an even more rapid increase in consumption.¹ Natural gas is the cleanest burning fossil fuel, releasing less CO₂ and other pollutants than coal or oil, making it an attractive fuel and, for some energy analysts, the key to the transition from fossil fuels to alternative energy sources. Figure 1 illustrates the history of

U.S. reliance on natural gas and projects steady growth in the demand for natural gas.

Coalbed methane development in the western United States

Coalbed methane (CBM) is a source of natural gas that is of growing importance as a domestic source of energy at a time when demand is rapidly increasing and output from some conventional sources of natural gas has peaked. CBM accounts for seven percent of total natural gas production and eight percent of gas reserves in the United States.²

CBM from the intermountain states has played a significant role in meeting U.S. demand for natural gas, particularly the states of Colorado, New Mexico, Utah, and Wyoming. Some 80 percent of the total CBM production in the United States has come from the Rocky Mountains. The San Juan Basin in southern Colorado/northern New Mexico has been the major regional source of CBM. The Powder River Basin in northwest Wyoming is the area of CBM production that is growing the most rapidly. There is little agreement over the size of the natural gas resources remaining in the interior West, but given the exploding demand for natural gas, there will be pressure

to find and develop as much of the region's gas as possible.³

Environmental impacts associated with CBM development include the construction of roads, drill pads, and water disposal; noise from pumps, compressors, and traffic that disturbs residents and wildlife; the creation of air pollution; the disruption of isolated areas valued for undisturbed vistas and solitude; and the impact of water

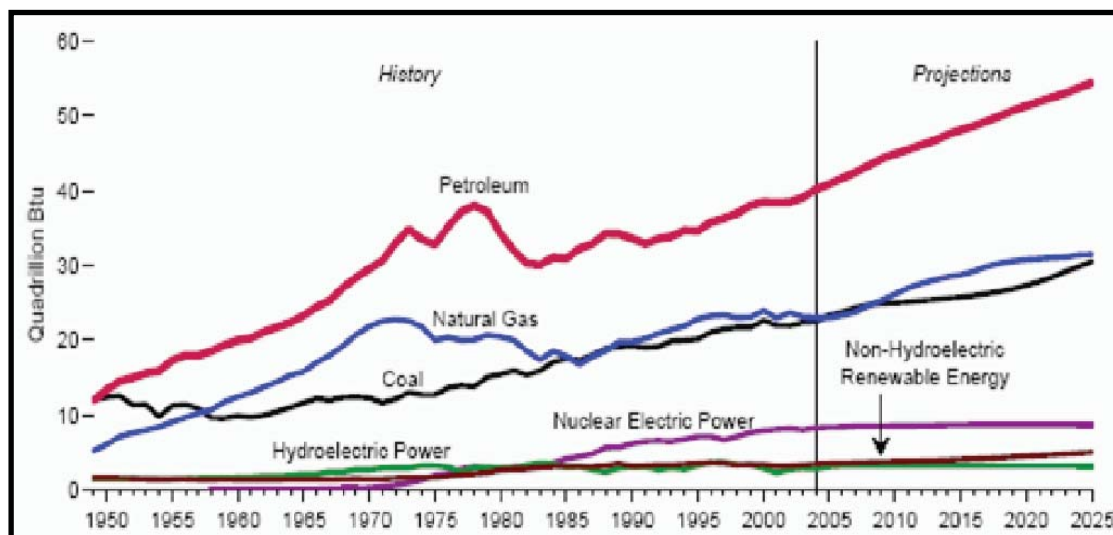


Figure 1. U.S. Energy Consumption History and Outlook, 1949-2025

Source: U.S. Department of Energy, Energy Information Agency, "Energy Perspectives." http://www.eia.doe.gov/emeu/aer/ep/ep_frame.html

quality and supplies. Much of the conflict is rooted in widely discussed changes in the population of the West as recreational and preservationist interests increasingly clash with traditional extractive industries.⁴

CBM and produced water

CBM is trapped within coal seams. Methane attaches to the surface areas of coal and is held in place by water pressure. Methane remains in a coalbed as long as the water table is higher than the coal. When the water is released, the gas flows through the fractures into a well bore or migrates to the surface. Drilling initially produces primarily water; gas production eventually increases and water production declines. When the CBM is extracted, the water must be separated, the gas is sent to pipes, and the water is dumped into ponds or injected back into the ground. In order to develop the resource, companies must first pump large quantities of water from the ground, about 12,000 gallons a day on average for each well, to release the methane.

The development transforms the landscape with pipes, roads, compressor stations and power lines, and discharged water that is often not useable for irrigation and, in some places, is reinjected into underground regions (Figure 2).

Here's the average water production from CBM wells, in gallons per well per day:	
Powder River	16,800
Raton	11,172
San Juan	1,050
Uinta	9,030
San Juan Basin	1,200 wells have produced 36 billion gallons of water
Wyoming portion of the Powder River Basin	in the next 15 years, approximately 51,000 wells will have produced over 1.4 trillion gallons of water

Managing produced water

The development of CBM has sometimes pitted energy developers against other users of the affected water. Issues surrounding CBM development and water include:

- (1) underground water quantity and the possibility that drilling for CBM contaminates aquifers with water of lower quality;
- (2) water rights and underground water supplies that may be diminished as dewatering occurs;
- (3) groundwater that may be contaminated by discharged water that is polluted; and

(4) aquatic areas, stream beds, and local ecosystems that are unaccustomed to receiving such large volumes of water.

Options for dealing with the large quantities of water released include the following (costs generally increase as one moves down the list):⁵

- Traditional surface discharge: water is allowed to travel downstream and be absorbed or evaporate as it moves.
- Irrigation: water released to agricultural areas.
- Treatment: water is treated to improve quality.
- Containment with reservoirs: water is piped to a surface impoundment where it is absorbed or

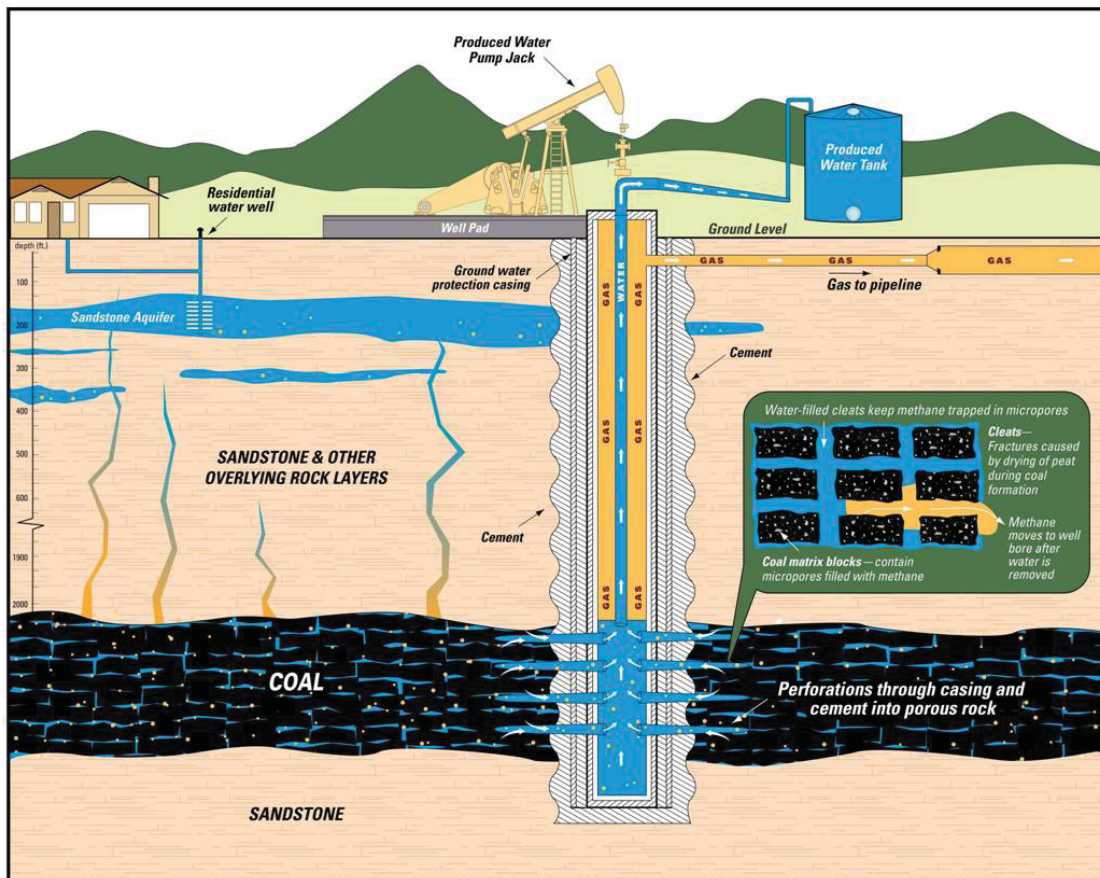


Figure 2. Coalbed Methane Development Avoids Contamination of Water Supplies

evaporates, or may be used to water cattle.

- Atomization: water evaporates more quickly than normal through the use of misters placed in surface impoundments.
- Shallow injection or aquifer recharge: water is pumped into freshwater aquifers.
- Deep injection: salty water is typically reinjected deep into the ground.⁶

The quality of produced water varies considerably across and even within basins, depending on the depth of the methane, geology, and environment of the deposition. In general, the deeper the coalbed, the less the volume of water in the fractures, but the more saline it becomes.

Landowner concerns

In general, water quality is highest in the Southeast, and diminishes to the West and North, where total dissolved solids increase. A major challenge in a semi-arid landscape is managing the tremendous increase in produced water. Even if water quality is high, salts may concentrate during evaporation or may overwhelm the semi-arid environment, inundating vegetation and causing erosion. Stock reservoirs have been created, and while some ranchers have wanted the water source, others do not since the reservoirs take land out of production.⁷ Ranchers are faced with soils damaged by the salts and metals remaining after evaporation; less grass is available for cattle; clay soils become hard pan; and dead cottonwood trees, dead grass, and weeds result from CBM development.⁸

In some areas where water quality is good, CBM companies and landowners have negotiated agreements to provide produced water for stock. Company officials report that there is more demand for water than they can supply. Produced water in the Powder River and Raton Basins has contributed to municipal water supplies. Such examples are evidence that CBM development can occur in partnership with landowners in ways that profit both. But conflicts frequently arise between land owners, especially when they do not own the gas leases under their property. Transporting water from where it is produced to where it can be used may be expensive in many cases, and that is a significant limit to efforts to ensure beneficial use of the produced water.

Water quality regulation⁹

Under the Clean Water Act, CBM development is governed by water quality standards to protect designated uses of water such as drinking water, agriculture, or fisheries.¹⁰ Standards include pollution limits to protect state water quality standards, anti-degradation requirements beyond water quality standards, and total maximum daily loads – maximum daily pollutant discharges that are assigned to point and non-point sources to ensure total pollution levels are not exceeded. The standards consist of numeric pollution limits as well as narrative or descriptive standards that are typically applied to each category of use. If a body of water has more than one designated use, the more stringent standard applies.¹¹

Section 401 of the Clean Water Act requires CBM companies to apply for and receive a National Pollution Discharge Elimination System (NPDES) permit if they are discharging produced water into surface waters of the state.

If technology-based limitations are insufficient to ensure water quality standards are met, states must develop “total maximum daily loads” (TMDLs) for each pollutant for which standards are being violated.¹² The TMDL determines the maximum amount of the pollutant that the water body can receive daily; states apportion the total load point and non-point sources. Once the TMDL is fully allocated, no further discharges of pollutants into the water body are allowed.

The Safe Drinking Water Act (SDWA) governs reinjection of water produced from CBM extraction.¹³ No underground injection is allowed without a permit. With CBM, most reinjection is done into Class II wells that address fluids that are either brought to the surface in connection with oil and gas development or are used to enhance the recovery of oil and gas.¹⁴

State water law governing CBM produced water

Given the importance of clean water in the arid West, no environmental issue has been more contentious or critical to the future of CBM development than that of the impacts on local water. One of the most important challenges surrounding CBM development is finding beneficial uses for the produced water.

Given the aridity of the West, the region’s water is at least as valuable as its natural gas. Water law is tremendously important in shaping water use, but the legal framework surrounding the use of CBM-produced water is not well developed. All states require that appropriated water be put to beneficial use, but the assumption underlying each state’s regulation of water produced from CBM development is that it is waste and that state oil and gas commissions have jurisdiction over the produced water. While this may have made sense when the produced water was largely the brine resulting from conventional deep oil and gas drilling, it does not make sense for CBM water. Many of these statutes were passed in Utah, New Mexico, Colorado, Montana and Wyoming in the 1950s and early 1960s, when the produced water was highly polluted. CBM production did not start until the late 1980’s, with the real boom occurring in the mid-1990s.

The Rocky Mountain states have all adopted the prior-appropriation approach to water law. Under prior appropriation, ownership of land does not result in ownership of water, but water rights are created when water is diverted and used or appropriated for a beneficial purpose.

Addressing CBM challenges

Given the lack of water in the Rocky Mountain West, it is important to explore whether the existing water management uses are optimal. Companies and landowners may find op-

portunities to work together to capture produced water, and, if quality permits, sell it to users. Existing water law can help ensure produced water is put to beneficial use, but the current legal framework does not create incentives for companies to take such actions.

There are considerable advantages that can come as states clarify the ownership of produced water and owners take responsibility for ensuring that it is put to beneficial use. For example, the Powder River Basin Council petitioned the state in 2006 to require produced water be put to measurable beneficial use. A 2006 state district court decision also strengthened the control of surface owners over produced water in ruling that if produced waters are not discharged into natural watercourses, surface owners have more control over what happens to the water. Wyoming also enacted a split estates act in 2005 that gave surface owners more voice in the development of resources under their property, and other states are considering similar legislation. The Montana Board of Environmental Review has established a no degradation of stream water quality resulting from discharged water. These are important first steps in developing state laws that clarify the ownership of produced waters and ensuring that these waters are used carefully and productively.

Stakeholders in CBM basins can come together to develop guidelines for the development within their regions. Watershed groups and other community-based initiatives have been developed in the West to bring parties together to overcome political fragmentation, reduce litigation, and encourage innovative and cooperative solutions to natural resource problems.

This model could be applied to addressing CBM problems. Stakeholders can meet together to fashion plans to produce ac-

curate baselines for water quality and quantity, review compliance with testing and monitoring requirements, develop water management plans to ensure beneficial use, negotiate best management practices that minimize adverse impacts, ensure surface owners are involved in decisions affecting their lands, integrate CBM with other water management and ecosystem planning, and aggregate experience and lessons and communicate those with those in other CBM basins.

1 National Energy Policy Development Group, National Energy Policy: Reliable, Affordable, and Environmentally Sound Energy for America's Future 1:7 (May 2001).

2 Matthew R. Silverman, Coalbed Methane in the Rocky Mountain Region: Yesterday, Today, and Tomorrow, in Coalbed Methane Development in the Intermountain West 125, at 125 (Natural Resources Law Center, University of Colorado School of Law CD-ROM, July 2002, hereinafter NRLC CD-ROM).

3 Walter B. Ayers, Jr., Coalbed gas systems, resources, and production, and a review of contrasting cases from the San Juan and Powder River Basins, 86 AAPG Bulletin 1855 (Nov. 2002).

4 See Gary C. Bryner, Coalbed Methane Development: The Costs and Benefits of an Emerging Energy Resource 43 Nat. Res. J. 519 (Spring 2003).

5 C.A. Rice and T.T. Bartos, Nature and Characteristics of Water Co-Produced with Coalbed Methane with emphasis on the Powder River Basin (presentation at the U.S. Geological Survey Coalbed Methane Field Conference, May 9-10, 2001).

6 Peggy Williams, "Western Coalbed Methane," Oil & Gas Investor 34 (Nov. 2001).

7 Hal Clifford, Drilling method pumps up floods of conflict, The Christian Science Monitor (January 3, 2002) <http://csmonitor.com/2002/0103/p3s1-usgn.html>, last visited January 4, 2002.

8 Jill Morrison, CBM Development, Ranching, and Agriculture, NRLC CD-ROM.

9 The discussion in this section is based on Kate Zimmerman, Federal, State, and Local Regulatory Framework for Permitting of CBM Development, NRLC CD-ROM.

10 33 U.S.C. § 1313(c)(2)(A); 40 C.F.R. § 131.11(a)(1).

11 40 C.F.R. § 131.11(a)(1).

12 33 U.S.C. § 1313(d)(1)(C).

13 42 U.S.C. § 300hh-8.

14 42 U.S.C. § 300(h)(b)(2).

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PRODUCED WATERS WORKSHOP

Lemonade Stands are Good for the Local Economy:

Produced waters are an additional water supply for the West!

*Pat O'Toole, Rancher
Savery, Wyoming*

For the last few years the Family Farm Alliance, which represents farmers in 13 western states, has been trying to analyze options for coping with drought and water shortages.

The need for water storage

My family's ranch is on the Colorado/Wyoming border on the Western Slope. If you've been a farmer or rancher and lived through drought, you know it is a grinding experience; you wake up in the morning and go to bed at night thinking about drought.

I talked to a fellow in New Mexico who said the snowpack in parts of his state is 0 percent. When we hear about the possibility of 653 million barrels (42 gallons/barrel) of water being produced, I thought, "Wouldn't it be something if some of that water would help the Elephant Butte Irrigation District alleviate cutbacks this year?" The New Mexico delegation is looking at some way to hold their farmers together through this drought period so their livelihood doesn't disappear.

In this New West, facing drought-induced reality is the mission of the Family Farm Alliance. The popular perspective of water storage in the past few years has been that storage is a bad thing and we need to tear down dams. The drought has shown us that this perspective is not realistic, and in fact, if we want to move forward, we need storage. Analysis currently underway in Colorado indicates that, over the next 20 years, 2.7 million people are expected to move into the Eastern Slope of Colorado and the Eastern Slope doesn't have the water for this type of expansion.

Instead, that water is going to come from agriculture. The projections are 150,000 to 450,000 acres of agricultural production in Colorado will disappear in that period of time in order to fulfill the needs of the population growth.

Wyoming as an example

In our valley at the Colorado/Wyoming border, we're anticipating a major coalbed methane development. The initial work has already started.

When we started projecting how many mcf of gas is related to how many bbls of water; and quickly came up with numbers that boggle the mind. We started asking questions of the companies and of the state of Wyoming: what is it going to mean to us? What are we going to do with this water?



What we do know is that if we do not understand how much water and how much gas are going to be there, we can't plan.

Right now there's an Environmental Impact Statement (EIS) process going on in the Atlantic Rim, a geologic feature that runs north-south, north of the Colorado border. It's high-desert country, and it's very beautiful country. It has incredible livestock capability. It has incredible wildlife capability. It has the best sage grouse habitat anywhere. In our part of the country, we value those attributes. What we're trying to figure out is: how does this massive influx of gas development, which resulted in the Powder River experience, going to affect us? The current EIS process indicates all that water is going to be reinjected. I'm telling you right now, that isn't going to happen. Not geologically, not economically; it's not going to happen. It's going to happen other ways.

New needs, new technologies

Nineteen percent of California's total energy consumption is used to transport clean water. The relative value of water has increased from about \$5 - \$7 an acre-foot – the worth to a farmer producing hay or alfalfa – to about \$1,100 - \$1,200 an acre-foot, the cost that California's coastal communities find affordable compared to the cost of transporting that water from

somewhere else. That's how the relative value of water has changed in the last decade.

If you understand water, you understand all the fascinating interplays and relationships, There are going to be debates. There are court cases going on right now regarding who owns the water. The beauty of Western America is its resounding affirmation of private property rights. That's what we believe.

An important part of the debate in the next few years is embracing the reality that there's going to be water produced, and that water can be cleaned at reasonable cost where it fits within the context of the economies of the western states. We need the water, and the drought is going to force us to do the right thing. Everybody who understands western politics, western interstate relationships, recognizes that water is a valuable commodity. When I spoke at the Ruckelshaus Institute in Wyoming, I commented that water and disposal should not be in the same sentence. Water is much too valuable a commodity. Certainly we won't use every acre-foot or every barrel of it in a beneficial way. 'Beneficial use' is a term that people in the water world use; we won't beneficially use every bit of it, but we're darn sure going to start using more than we're using today – because we have to.

The beauty of a conference like this is that it brings people with different mindsets – some speaking in barrels and some speaking in acre-feet – together in a room to allow them to start talking about how we deal with this. As Mr. Yates said, this is one of the all-time fun things because it can be a win-win. We must use the technology that's emerging in our country and worldwide.

American resourcefulness

We have the opportunity in the West to have that new water. We're going to build the storage. We're also going to use produced water in a beneficial way. Senator Domenici of New Mexico heads a produced-water subcommittee, and the subject is going to be debated in the Senate and the House. I think that's a discussion we all ought to be looking at because there might be ways to use that vehicle to enhance the technology and the demonstration capability.

One of the things that I hope will come out of this conference is a message to these agencies. We have to have some interactions between the different agencies. In Wyoming, it took us 25 years to permit a water project that we saw for the first time last fall – imagine, 25 years! I can tell you that Mr. Yates and a major oil company can't wait 25 years for permits to get the job done.

At the same time we must exercise environmental responsibility. We have grazing permits on the Colorado/Wyoming line, and when I go to some well areas where there've been pipelines, I can see the little grooves where the seeder has passed over but there's no grass, no seed because the reclamation wasn't done, or – if it was done – it wasn't done with thought.

American farmers are the greatest farmers in the history of the world. If we can't figure out a way with water and seed and using our heads to do reclamation, that's our fault. However, the beauty of BLM/Fish & Wildlife Service/EPA interaction is that if people put their heads together, they can find magic in this opportunity of produced water.

Correction

The project described in "SCADA Employed in Middle Rio Grande Valley to Help Deliver Water Efficiently", which appeared on page 10 in the April 2006 issue of Colorado Water, is funded in part by the Middle Rio Grande Endangered Species Act Collaborative Program and the New Mexico State Interstate Stream Commission. The Middle Rio Grande Conservancy District Office in Albuquerque and its Division field offices provided their full support in planning and implementation of the project. The project is described in more detail by the FY 2004 Project Report to the New Mexico Interstate Stream Commission, March 2006, prepared by Dr. Ramchand Oad, with assistance from researchers at Colorado State University and in collaboration with S.S. Papadopoulos & Associates, Inc. The support of these people and organizations is gratefully acknowledged.

PRODUCED WATERS WORKSHOP

How Do We Squeeze Lemons and What Do We Do with the Peels?

Can technology transform produced waters into new supplies, at a competitive cost and without environmental damage or added liability?

*Lynn Takaichi, Kennedy/Jenks Consultants
San Francisco, California*

Can technology transform produced water into new supplies, at a competitive cost and without environmental damage or added liability? Clearly there are individual projects that have successfully met these criteria. I think the real question at hand is: can we make produced water reclamation live up to its full potential? One project that can serve as an interesting case study is the Santa Clarita Water Agency (CLWA).

The CLWA has a service area of approximately 195 square miles, located predominately in northwest Los Angeles County, and a small uninhabited area of eastern Ventura County. Currently, the service population is approximately 240,000 people.

Current water demands are approximately 90,000 acre-feet per year, of which 50,000 acre-feet is imported. New housing units are 2,500 per year, which translates to about 2,200 acre-feet per year of new demand. It is also the home to one of the largest subdivisions in Los Angeles County called Newhall Ranch, which has planned for 21,000 housing units, and it's just beginning.

Because of this growth rate, the agency has been very active in seeking out new water supplies. Over the last 10 to 15 years it has executed water transfers totaling some 65,000 acre-feet per year. It's also implementing a recycled water program, which is going to total some 17,000 acre-feet per year. Figure 1 shows the location of the water agency and the extensive number of water projects in California.

History of Produced Water Reuse at CLWA

Produced water reuse at CLWA began in the early 1990s, and declined in the late 1990s with a decline in oil prices and reduced production at the oilfields. In the early 2000s, with an increase in oil prices, produced water again became available.

In 2003, we updated our recycled water master plan to incorporate produced water as a potential water source. In 2004 we initiated an Environmental Impact Report – the California equivalent of an Environmental Impact Statement—which should be completed this fall.

Project Funding

The research project is interesting in its scope, results and the interaction between the petroleum industry and the water industry. Funding for the project comes from agencies and organizations interested in petroleum development, electricity production, water resource development, and water quality.



Figure 1. Santa Clarita Water Agency and Other Water Projects Statewide In California



Figure 2. Location of Oil Fields in CLWA Service Area

Project Benefits

The objectives of the project were multiple:

- Improve thermal recovery efficiencies
- Lower the produced water handling costs.
- Reduce the potential for reservoir damage from the reinjection process
- Recover more oil, using reclaimed produced water to increase the amount of extracted oil
- Develop a new water resource

Produced Water Flow Estimates

Santa Clarita is not unique. We made estimates of the amount of produced water in some of the adjacent areas. In Los Angeles County, we identified approximately 64 million gallons per day of produced water. The coastal area, which is predominantly Ventura and Santa Barbara Counties, sees 27 million gallons per day; and Kern County, which is a very active oil producing area, 129 million gallons per day. Clearly not all of this is recoverable, some because of the quality, some because it's reinjected for subsidence and mitigation.

There is substantial potential here for clients like mine, suburban water agencies, which are seeking water from every source they possibly can, and are willing to pay.

Concern for water quality

We were concerned about certain primary water quality parameters during the treatment process. Here is an example of produced water that was, actually, reasonably good:

TDS	~5500 mg/L
Temperature	150 to 175° F
Boron	~17 mg/L
Silica	255 mg/L
Hardness	~1100 mg/L
Ammonia	~9 mg/L
Total Organic Carbon	120 mg/L

It had a total dissolved solids (TDS) level of approximately 5,000 – 6,000 mg/L. Because the oil reservoir is steam flooded, the temperature of produced water is high, 150 to 175° F. Boron is very high, making the farmers cringe. Silica also was high, and that restricts the industrial reuse potential. There is moderate hardness – potable ground waters in the area typically have hardness of about 500, so this is not too bad. Ammonia is high, which affects corrosion rates, among other things. As a water purveyor, we were especially interested in the total organic carbon, or TOC. For potable water sources, we're typically looking at 2 to 10 mg/L, not 120 mg/L, so that really causes some concern.

Irrigation Water

In the project we actually looked at a variety of endpoints. Approximately 44,000 barrels per day were available. The process includes lime softening that removes the hardness and silica; cooling to reduce the temperature, filtration, a high-pH reverse osmosis system, and, finally, disinfection. Through the process, we lose quite a bit of

the water to residuals, so the output is estimated to be 32,000 barrels per day.

Water Quality Results

These are the actual water qualities determined in the pilot study; they differ from the historical numbers:

Parameter	Initial (mg/L)	Final (mg/L)
TDS	~6000	145
Temperature	150 to 175° F	90
Boron	~16	1-2
Ammonia	9.3	2-11
Silica	~10	not detectable
Hardness	1-5	not detectable
TOC	120	2

Water quality with respect to TDS, at least for Southern California, is excellent. Our state water project water has a TDS usually of about 300. Ground waters can be anywhere from 500 to 1,000. Temperature has been reduced, boron removed. Ammonia is still high, but we think we can address that through some alternative cooling mechanisms. Silica was removed, hardness was removed, TOC is down to 2 mg/L. The technology is clearly there to meet our objectives.

Total Project Costs

Based on this particular project, we estimate the plant would have a capital cost of about \$10.6 million. The treated produced water would cost about \$0.16 per barrel. These figures reflect use as recycled water and do not reflect the potable or industrial reuse options that we looked at.

Technical Conclusions

- We clearly can meet the water quality objectives. The technology is there to do that – it’s improved quite a bit since the time this research was done.
- The cost for treatment is comparable – slightly higher than the disposal cost that the oil field is currently experiencing.
- The cost of the water is more expensive than imported water but only slightly higher than local recycled water supply. Right now, when we go out to seek additional state water project entitlements – predominately from agricultural areas – we can acquire and confirm that water supply at over \$500 an acre-foot. The recycled water that we’re developing tends to be about \$1,000 an acre-foot when we include the long term development of the program. The earlier phases are more expensive than that.
- Just as important, this supply could avoid some of the environmental issues associated with our other supplies. We get our state water from a very fragile area called the Sacramento San Joaquin Delta, fraught with environmental issues. We’re not clear that we can get any more additional water supplies; whether from agriculture, but certainly from the project as a whole.

So, why has it taken us so long?

We’ve gone more than a decade now trying to discuss with the oil field operator a produced water reclamation plan. We’ve shown through research that the technology is available. The costs seem to be in line; and yet, the project still languishes.

This analysis is based on my limited experience in California, with this project and others I’ve been involved with. I’ve broken down the causes for delay into three basic reasons:

Cause	Water	Petroleum
Priority	<ul style="list-style-type: none"> •Relatively Small Supply •Competing Issues • Other contamination issues •Supply and Demand •Local Focus 	<ul style="list-style-type: none"> •Oil Price Fluctuations •Competing Issues •National Focus
Expectations	<ul style="list-style-type: none"> •Not Familiar With Produced Water •Long Time Frame •Consistent long-term supply •Long development time •Perception of Value – water quality issues •Risk Adverse 	<ul style="list-style-type: none"> •Not Familiar With Water Supplies •Short Time Fame •Investment driven •Perception of Value – water shortage •Willing to Take Risk
Communication	<ul style="list-style-type: none"> •Little Outreach to Petroleum •Prior Relationship Based on Contamination Issues •Primary Federal Agencies BOR & ACOE •Primary State Agency: Health 	<ul style="list-style-type: none"> •Little Outreach to Water •Prior Relationship Based on Contamination Issues •Primary Federal Agency: DOE •Primary State Agency: Resources

What Should Be Done?

Clearly, research is going to help. Senator Domenici’s Bill 1860, is a real good start. It funds some of the technology; it will research things that exist in this particular area. We need to expand our horizons about what areas are considered research. In my observation, problems are as much transactional as they are technology. We need to improve the social sciences and how we can better and more quickly come to

agreements about the issues at hand. The social sciences have a lot to contribute here.

Secondly, I would suggest that we start to develop state-by-state implementation plans. Senate Bill 1860 calls for some research roadmaps, but that's different than having implementation road maps. To me, it's unconscionable that every project has to start from scratch and not learn the lessons from those that preceded it. These kinds of implementation road maps can be used to educate other projects in other, smaller, communities that don't necessarily have the resources to start the project from scratch.

Thirdly, I think we need a set of demonstration projects that are visible and accessible. I would suggest that the DOE and De-

partment of Interior (DOI) get together to both develop, fund, and acquire different technologies to get a series of demonstration projects that we can bring both the water industry and the petroleum industry to view.

Lastly, we need some leadership. Right now, we in the West turn to the DOI, for the most part, for water leadership. Petroleum industry turns to the DOE. Water agencies aren't used to going to the DOE, and I'm sure the petroleum and oil industry is not accustomed to going to the BOR. We need a point of contact. The federal agencies ought to try to get together to, at least, provide the initial reissuing. The only other alternative is for the two industries to get together – a process that could be very slow to develop from where we are now.

PRODUCED WATERS WORKSHOP

The Industry Grows a lot of Lemons

Produced waters are a cost to be minimized!

*Frank Yates, Yates Petroleum Company
Artesia, New Mexico*

Yates Petroleum Corporation has been looking for treatment alternatives for several years in an effort to find economically competitive alternatives to down hole disposal. Several factors must be taken into account in order to effectively pursue these potential options, including: Economics; available technologies; new technologies; legal, regulatory and environmental concerns; and internal company and industry politics have had an influence on progress made in this arena.

Economics

Down hole disposal has been the long-time acceptable method of dealing with waste water associated with oil and natural gas production. Reinjection of produced water is expensive and can represent 50 percent of the direct operating costs of many oil and gas wells.

There are three components to reinjection costs that must be quantified: capital expenditures, direct operating costs, and gathering costs.

- Initial capital expenditures are those associated with drilling a disposal well, or more commonly, converting an existing dry hole to a disposal well, which can be considerably less expensive.

Costs vary considerably across the country. In Southeast New Mexico, a 7,000-foot Delaware dry hole can be converted to a disposal well for about \$600,000. It may be possible to inject as much as 6,000 bbls of water per day (1 bbl = 42 gal) into a well like this. This scenario calculates to \$100 / bbl / day of capacity, a ratio used for comparative economics.

Conversely, in Wyoming, the subsurface strata available for injection are very low in porosity and permeability. It can cost \$4M to drill a disposal well that will only take 4,000 bbls / day. Now you're up to \$1,000 bbl / day of capacity.

- Direct operating costs for a disposal well include costs for electricity for pump operations, filters, and chemical treatments for well bore protection. These costs can add up to between \$0.03 and \$0.07 / bbl for some areas, more in others.

- The third component of cost is gathering, or getting the produced water from the production facility to the disposal facility. Gathering is accomplished either by pipeline or by trucking, depending on the daily volumes of water to be transported. These costs can range from a few cents per barrel – when moving larger volumes through pipelines – to several dollars per barrel to truck smaller volumes of water that do not economically warrant laying gathering lines.

All of these components need to be considered when analyzing a company's produced water disposal costs. Once capital costs are amortized, and gathering considered, total disposal costs can vary widely – from about \$0.12 / bbl in SE New Mexico to more than \$5.00 / bbl in the Green River or Wind River Basins in Wyoming.

Water volumes can vary widely between regions and can have an impact on economics of disposal options. The New Mexico Oil Conservation Division (NMOCD) reports that produced water is estimated to be 653 million barrels in 2005. This includes water from East Indian Basin where one well can produce 3,000 bbls / day of water, but only costs about \$0.17 / bbl for disposal. This low disposal cost is a result of the tremendous investment in disposal infrastructure made by operators to accommodate the larger volumes of water produced per well in this region.

MYCO Industries, Inc. operates five wells east of Carlsbad, NM that produce a total of about 120bbl/day of water. With no disposal gathering infrastructure available, disposal costs for these wells run \$2.70/bbl. This price is a combination of hourly trucking rates to haul produced water to a commercial site and a disposal fee of \$0.50/barrel to actually dispose of the water. Also worth considering is the fact that the cost of converting a dry hole is not going to change just because there is less water available for disposal.

Technological and Logistical Hurdles

Wyoming and New Mexico produce similar quantities of water, but volumes vary widely between regions. For example, produced water volume from coal bed methane (CBM) production in the Powder River Basin (PRB) is about 1.5 million barrels per day from about 15,000 wells, or an average of 100 bbls/day/well. The gas production from the area is about 900 mmcf/d. These figures indicate that, for each mcf of gas produced, there is also 1 2/3 bbl of water produced. Conversely, in the Green River Basin (GRB) in Southwest Wyoming, there is an average of only about one-tenth of a bbl of water produced per mcf of gas. The high volume of water produced in the PRB – more than 16 times the volume produced in the GRB – has raised

many controversial questions about producing gas from the PRB.

Produced water quality will present technological hurdles. Produced water quality varies as widely as quantity from area to area and has a tremendous impact on treatment options available. Table 1 presents a brief summary of typical produced waters encountered in the oil field, illustrating the challenge related to treatment.

Treatment Technologies

Five years ago, Yates Petroleum knew nothing about water treatment technologies. After considerable time and money, we've moved along that learning curve. There is still a lot to learn and a way to go before we are treating meaningful volumes of water, but we believe that we are at the forefront of New Mexico producers who see the value to the state, our industry, and our company in pursuing produced water treatment options.

Four different types of technical solutions have evolved in the oil and gas produced water treatment arena: membranes, evaporative technologies, ion exchange, and thermal compression.

- Thermal compression requires expensive pressure vessels, and the operator must still dispose of a concentrate stream. It does not appear to be as economic as other technologies.
- It appears the key to any membrane technology will be pre-treatment. Conventional reverse osmosis (RO) membranes are easily fouled by bacteria, hydrocarbons, heavy metals, and other suspended solids such as calcium sulfates.
- Ion exchange treatment techniques have become the application of choice in the Powder River Basin where water qualities are fairly good with the exception of elevated sodium levels.

Evaporative technologies have evolved from using simple misters dependent on ambient conditions to more sophisticated systems that recover much of the latent heat of vaporization.

All units mg/L	Pecos River	Disposal Well	Well 1	Well 2	Well 3	Well 4	Well 5
States	NM	NM	NM	WY	WY	NM	NM
Bicarbonates	127	705	488	3,318	1,680	39	464
Hardness (CaCO ₃)	n/a	n/a	11,000	n/a	n/a	88,000	15,000
Arsenic	0.082	0.078	n/a	n/a	0.036	n/a	n/a
Calcium	620	582	3,600	404	70	30,000	5,200
Chlorides	2,020	3,100	48,000	n/a	9,360	182,000	80,000
Sodium	1,064	2,010	27,261	444	6,250	78,398	45,591
Sulfates	2,040	1,160	1,800	212	4	600	400
TDS	6,350	8,070	81,629	5,977	15,700	294,167	132,135

Regulatory and Legal Considerations

The question has been raised several times, “Who owns treated produced water? Who has jurisdiction over treated produced water?”

In January of 2004, an engineering, legal, and logistical study was prepared for the Lea and Carlsbad Soil and Water Conservation Districts in New Mexico. The study’s purpose was to evaluate the feasibility of treating and using produced water in that region. Luebben Johnson & Young LLP in Albuquerque did the legal research and observed that “wastewater from oil and gas production is generally treated as part of the real property’s mineral estate, which is originally owned by the landowner, conveyed to the producer in the oil and gas lease, and transferable by the producer as personal property.”

While there are no specific laws in New Mexico or other states directly dealing with the “appropriation” of wastewater found in conjunction with oil and natural gas (with the exception of shallow coal bed methane water), there are indications in statutory, administrative, and appellate law that produced water is not publicly owned water, but part of the privately owned mineral estate conveyed to the oil and gas operator.

New Mexico law is quite clear with regard to the Oil Conservation Division’s jurisdiction over produced water.

OCD has the responsibility to hold producers accountable for the proper disposition of their wastes, which include produced water. In addition, the New Mexico legislature recognized the operator’s ownership when it passed a tax credit bill of \$1,000 per acre foot to operators who could deliver clean produced water to the Interstate Stream Commission at the Pecos River in SE New Mexico.

The economic treatment of produced water is right around the corner from being widely utilized throughout the oil field. It will be a win-win for the oil and natural gas industry and the environment, especially in the arid West. In order for this to happen, companies must overcome the current paradigm – the single-minded thinking – that any produced water requires a disposal well. Further, companies must do a better job of quantifying their disposal costs: they must not assume the cost of owning and operating a disposal well is zero merely because the company has sunk capital into a well.

The companies that overcome these hurdles will be the companies that will develop new oil and natural gas reserves in areas previously considered not economically feasible because the wells made too much water. This is actually a win-win-win scenario because it allows our country to produce more of our own domestic hydrocarbon resources.

31st Colorado Water Workshop Wednesday-Friday, July 26-28 Gunnison, CO

The Developed Resource

Keynote: Patricia Limerick on “The Increasingly Finite West”

Questions we will consider:

Is there truly no more water to develop?

Discussion moderated by Justice Greg Hobbs

Implications and consequences

Water as property, public good, commodity, commons, ecosystem base?

Do we need to tend to shifting relationships between energy and water?

Is augmentation water for the Colorado River Basin a realistic goal?

Are the “1177 processes” helping to address allocation/reallocation issues?

Within basins? Between basins?

For more information or to register, go to www.western.edu/water
or contact George Sibley at water@western.edu.

FACULTY PROFILE

Ranil Wickramasinghe

Ranil Wickramasinghe is an associate professor in the department of Chemical and Biological Engineering at Colorado State University. He was named a 2004 CSU Monfort professor. He obtained his bachelor's and master's degrees from the University of Melbourne. His Ph.D. is from the University of Minnesota. All his degrees are in Chemical Engineering. After working for 5 years in industry Ranil Wickramasinghe joined CSU in 1998.

Ranil Wickramasinghe's research focuses on membrane based separations in a number of different fields. He has researched the use of coagulation followed by microfiltration for arsenic removal from ground waters in the USA and Bangladesh. He has also been involved in the development of a pilot plant in China for cyanide removal from ground water. The 1000 L facility uses gas filled polymeric membranes to recover cyanide, via a process known as osmotic distillation, from wastewaters from pesticide manufacturing facilities.

Currently Dr Wickramasinghe is developing 'smart' fouling resistant nanofiltration and reverse osmosis membranes in collaboration with Clemson University. Fouling resistant polymer brushes are grown from the surface of nanofiltration and reverse osmosis membranes. In addition to their fouling resistance, these polymer brushes are responsive to environmental stimuli such as pH, ionic strength or temperature. Changing, for example, the pH of the solutions leads to collapse of the brushes and release of adsorbed foulants.



Web Site Provides Information on Water Energy Technology Team

The Water and Energy Technology Team (WETT) at Lawrence Berkeley National Laboratory has released an improved Web site describing its mission and current projects, and introducing its members.

The Team's mission includes better understanding of the fundamental science, applied technology, and economics of the water/energy nexus, and developing technologies to optimize the use of both water and energy.

The Team's projects address energy-water matters as they relate to climate change, wastewater, water quality, energy and water efficiency, and industrial processes.

Please visit <http://water-energy.lbl.gov/> and explore the fundamental science, technology potential and economics of the water- energy nexus.

For more information, contact:
Camilla Dunham-Whitehead
cdwhitehead@lbl.gov
207.282.357

Did you already return your
Colorado Water
reader survey from page 35 of the
April issue?

Thanks for your help!

If you haven't returned the survey,
please help us plan for the future,
and send us your feedback now!

Survey form available at
www.cwrri.colostate.edu

Interaction of Coalbed Methane Produced Waters and Soils in the Powder River Basin, Wyoming

*John D. Stednick, Watershed Science Program, CSU
William E. Sanford, Department of Geosciences, CSU*

The Powder River Basin (PRB) of northeastern Wyoming and southeastern Montana has been undergoing major development of coalbed methane (CBM) extraction over the last decade. To extract the methane, water is pumped from the coal beds to reduce the hydrostatic pressure which allows desorption of the biogenic methane from the coal. In the PRB, unlike in other CBM-producing areas of the western United States, the re-injection of the produced waters is not a viable option given the multiple producers and multiple producing zones. A common method of disposal of CBM waters in the PRB is to discharge them into stream channels. As the water moves downstream, it infiltrates into and interacts with near-channel soils, dissolving the naturally occurring salts and altering the water chemistry.

Ranchers and water managers in the PRB would like to use the produced waters for irrigation, livestock watering and, potentially, domestic use. Major concerns are related to the salinity and the sodium adsorption ratio (SAR) of these waters. Previous studies in the PRB have characterized the waters as having high dissolved solids (250 - 200 mg/L), high specific conductance (450 - 3000 $\mu\text{S}/\text{cm}$) and high SAR (6 - 32).

Our study objectives were to chemically characterize CBM production waters and to monitor the changes

in specific conductance and SAR as the water interacts with the near-channel soils as it flows downstream. To achieve our objectives, we chose 3 study sites in the PRB



Flow from a discharge well into a holding pond from which the water feeds

that represent a range of time-on-line from new to 4 years of operation. At each site we characterized the chemistry of the CBM water at the discharge point, characterized the chemical and hydrological properties of the near-channel soils, monitored changes in SAR and specific conductance (SC) as the water moved down stream, and monitored changes in SC and SAR in the shallow groundwater near the stream channels.

The three study sites provided us an opportunity to examine how a formerly intermittent drainage responds to becoming a perennial stream and remain one for several years. Our results show that with the onset of discharge of the produced waters into the channel, some of the water will seep



Channel flow at the study site, which was on-line for two years.

from the channel into the surrounding soils. The infiltrating water will dissolve the salts in the soil and a saturated zone and associated water table will form. We observed increases in SC as much as 2 orders of magnitude in soil water. As long as the hydraulic gradient is directed from the stream to the soil, water will continue to infiltrate.

After a period of discharge, equilibrium was reached where water in the channel will exchange

with now saline groundwater, which has increased SC and SAR as a result of dissolving the naturally occurring salts in the soil, resulting in an increase in the SC and SAR of the in-stream water as it flows downstream. As is common in the PRB, the volume of produced waters decreases with time, causing the discharge in the channel to decrease. Associated with the decreased discharge is a lowering of the water depth in the channel which causes a reversal of hydraulic gradient. When this situation occurs, there is less mixing of discharge water with groundwater and the SC and SAR in-stream increases further.

During our investigation, we noted that significant salt crusts had formed on the near-channel soils for the study site that had been in operation for 4 years. For the site with two years of operation, there was only minor salt crust. For the site that came on-line during our study, we observed that salt crusts formed in several locations once the near-channel soils became saturated.

Our findings show that changes in water quality can happen on a relatively short time frame as the discharge water interacts with the salts in the soil. During the first couple of years as the discharge of produced waters stays relatively constant, the major impact is the large increase of SC and SAR in the saturated near-channel soils with a minor increase in these parameters as the discharge water moves downstream. As the discharge of produced waters decreases, there is a large increase in SC and SAR values as the water moves downstream due to the reversed hydraulic gradient. Another major impact is that once discharge ceases, the water in the once saturated near-channel soils will evaporate, leaving behind a significant amount of salt crust on the surface of the soils.

Alternatives for CBM water disposal include re-injection, mixing with other salts to decrease SAR, or evaporation. However, with the presence of salts in the soils coupled with the arid climate, these alternatives may be for naught.

Please feel free to contact us with any questions.

Acknowledgments

Funding for this study and thesis support for Andy Neuhart was provided by USEPA under contract CP-98864201-0, Denver, CO.

Colorado Foundation for Water Education Hires New Director

DENVER – The Colorado Foundation for Water Education is pleased to announce that it has named Don Glaser as its new Executive Director for the statewide non-advocacy water organization.

Glaser comes to the Foundation from the Douglas Land Conservancy, where he also served as Executive Director. He has also been employed as a senior manager for the National Fish and Wildlife Foundation, and as a private consultant. In the mid-1990s, he was appointed executive director of the Western Water Policy Review Advisory Commission. The commission was charged with reviewing the status of western water resources, and addressing potential changes to federal policy.

Glaser will begin work with the Foundation June 1. He will work in transition with the existing Executive Director, Karla Brown, who will resign on June 19.

The Colorado Foundation for Water Education was created in 2002 to promote better understanding of water resources through education and information. It publishes *Headwaters* magazine, guides tours around the state, and offers leadership trainings, conferences, and publications on topics such as water law, water quality, and conservation. The Foundation is the only non-advocacy water education organization in state.

For more information call (303)377-4433 or visit the foundation web site at www.cfwe.org.

Annual Meeting of International Soil and Water Conservation Society

July 22-26, 2006
Keystone, Colorado

For more information or to register, go to
http://www.swcs.org/en/swcs_international_conferences/

The Water Resources Archive for Lawyers

Patricia J. Rettig, Head Archivist

Water Resources Archive, Colorado State University Libraries

Water lawyers exist in abundance in Colorado, for good reason. With so many contentious water issues arising in the state, teams of knowledgeable people are needed to investigate and work out the legal kinks. As they go about their work, serving clients with varying legal situations, water lawyers are often required to delve into history and gain an historical perspective. With a range of clients disputing any possible water-related topic in the state, water lawyers need broad and efficient access to a number of historical resources.

Many—if not all—of the collections in the Water Resources Archive at Colorado State University (CSU) could be of use for legal research on water topics. This article will detail a selection of these collections and how they could benefit water lawyers. Only three of many potential subject areas will be covered—engineering, ditch companies, and legal collections—but they will serve as examples of resources that could be useful to lawyers.

Engineering Collections

As experts on the movement of water, civil engineers are essential for providing factual data and information about water projects.

Papers of Daryl B. Simons (collection dates: 1901-1991) Daryl B. Simons (1918-2005) was an internationally recognized expert in the fields of hydraulics, hydrology, geomorphology, river mechanics, sediment transport and hydraulic modeling, and his collection documents his work in these areas. Even while professor of civil engineering at CSU, Simons worked as an independent consultant around the world. Because of his knowledge and expertise, he was called to be an expert witness several times for different cases. Depositions he gave exist in his materials and serve as explanations of engineering concepts for non-engineers. Accompanying his testimony are additional case-related documents such as exhibit items, other depositions and background information.

Papers of James L. Ogilvie (collection dates: 1944-1992) James L. Ogilvie (1911-1995) had a long career with the United States Bureau of Reclamation in the field of irriga-

tion and water management. He worked on the Colorado-Big Thompson project and was the Project Manager for the Fryingpan-Arkansas Project in southeast Colorado. Interestingly, Ogilvie kept daily desk diaries, which now serve as a guide to his activities on these key Colorado water projects, giving a unique insider's perspective. Added to these are correspondence, reports, maps and photographs, rounding out the documentation of Ogilvie's work.



Dave Bailey and Patricia Rettig

Groundwater Data Collection

(collection dates: 1897-1980) Materials in this collection relate to the groundwater studies CSU researchers conducted primarily in eastern Colorado (the South Platte basin, High Plains and Arkansas Valley) as well as the San Luis Valley in southern Colorado. Subjects of particular focus are artificial recharge, observation wells and irrigation pumping,

all hot topics in the state today. Though the one-of-a-kind data in this collection is stored on paper rather than in computers, it still gives a factual picture of what was occurring with groundwater from the 1930s through the 1970s.

Ditch companies

Materials of Colorado ditch companies can be hard to come by in publicly accessible repositories, and yet ditch companies have been key to water development in the state.

Records of the Godfrey Ditch Company (collection dates: 1870-1996) Established in 1870 as the Section No. 3 Ditch Company drawing from the South Platte River in LaSalle, the organization was re-incorporated as the Godfrey Ditch Company in 1910. The newest collection donated to the Water Resources Archive, the records consist most significantly of minute books that are continuous from 1870 through 1986. (The last two decades remain with the company.) It is rare to find organizations in the state that are more than 130 years old and that have complete records documenting their business.

Records of the Iliff and Platte Valley Ditch Company

(collection dates: 1884-1997) This collection contains the financial and business records of the company which was established in 1884 and irrigated land in Logan County, Colo-

rado. The collection includes several ledger books with meeting minutes, stockholder information, cancelled stock certificates, cancelled checks and payment information, and tax and insurance records.

Legal

Though legal documentation exists in many types of collections, some materials are more concentrated in that area.

Larimer County District Court Map Collection (collection dates: 1884-1953) This collection contains maps of irrigation-related structures used as exhibits to establish water rights and settle water disputes in district courts. The maps provide information regarding water adjudication and water litigation in the first half of the twentieth century, mainly in Larimer County but also in Weld County. The information on some of the more comprehensive maps offers details about the physical description, capacity and water source of large canals, ditches, reservoirs and wells.

Papers of Delph E. Carpenter and Family (collection dates: 1827-1992) The “Father of Interstate River Compacts,” Delph E. Carpenter (1877-1951) served the state of Colorado as a lawyer, state senator and river commissioner. He wrote, negotiated and promoted the Colorado River Compact (1922), among others, following his service as lead counsel in the Wyoming vs. Colorado suit (1911-1922). The collection extensively documents interstate river compact issues as well as various water cases Carpenter was involved in. Testimony he took for one case included statements from “old-timers” recounting their observation of flows in the South Platte River. Correspondence from Carpenter’s early days as a Greeley lawyer also exists, as do materials his son Judge Donald Carpenter (of district court and water court in Greeley) saved that related to his work.

Research tips

Finding documentation of certain topics, places, people or cases can be challenging. Know that certain facts might be found in unexpected places. For example, climate data for the late nineteenth century can be found in a farmer’s diary—a person who observed the weather and made a note of it daily. Also, non-typical document types can be found in archives, things one might not think to look at, such as meeting minutes, correspondence, data, maps, photographs, legislation, drafts, scrapbooks, films and audiotapes.

Two starting points are recommended for discovering details of the holdings of the Water Resources Archive. One is the Archive’s website [<http://lib.colostate.edu/archives/water/>], where there are lists of collections available as well as a search engine that looks across all the online documentation the Archive provides (and which is frequently added to!). The other starting point is contacting the archivist (970-491-1939 or Patricia.Rettig@colostate.edu) and picking her brain. She can suggest appropriate sources both within and outside of the Water Resources Archive.

Dot Carpenter: The Woman Behind the Man:

Best known for identifying the compact clause in the U.S. Constitution as a means to settle water disputes throughout the West, Delph Carpenter’s contributions to the water community hold undisputed significance, especially in today’s water-scarce climate. With careful examination of his papers, now housed at Colorado State University Libraries’ Water Resources Archive, the important contributions of his wife, Dot Carpenter, have risen to the surface and are explored in a new online exhibit “Dot Carpenter: The Woman Behind the Man” (<http://lib.colostate.edu/archives/water/dot/>).

After having served as the lead counsel for the lengthy Supreme Court case of Wyoming vs. Colorado (1911-1922), Carpenter became the leading proponent of the interstate compact as a means to settle water disputes out of court. Instrumental in negotiating the Colorado River Compact (1922), Carpenter traveled extensively for his work, often accompanied and considerably aided by his wife, Dot.

The virtual exhibit explores Dot’s significant contributions to her husband’s career through her loving support of his work, her service in taking dictation when he could no longer write, and her care of

Carpenter in his many years of declining health. The Water Resources Archive invites you to visit our Web site to explore photographs, digital images of documents and items that tell the story of the important legacy of Dot Carpenter: The Woman Behind the Man.



Stream Depletion Model Developed by IDS Group Adopted by State Engineer

The Integrated Decision System Alluvial Water Accounting System (IDS AWAS), developed by a CSU research team lead by Luis Garcia, has been adopted by the State Engineers office. On May 6, 2006, Hal D. Simpson, the State Engineer issued Procedures Memorandum 2006-1 to all Division of Water Resources Staff announcing *“In an effort to modernize the software used to model stream depletion caused by well pumping, the Division of Water Resources has selected the IDS AWAS software as the standard software to be used by all.”* Furthermore, the memorandum stated, *“Evaluators and Engineering staff must use the IDS AWAS Stream Depletion Model, and the Records staff must direct customers to use this software in conjunction with our data”*

The IDS Alluvial Water Accounting System (IDS AWAS) developed by the Integrated Decision Support Group (IDS) at Colorado State University (www.ids.colostate.edu) is a tool that responds to the need for augmentation plans to accurately account for groundwater withdrawals and depletions. The science behind conjunctive management of ground and surface water has received renewed interest in recent years as court approved augmentation plans must be in place to insure that well pumping does not injure senior water rights. IDS AWAS helps water managers meet the challenges posed by new court decrees and legislation related to the South Platte by providing them with an accurate accounting tool.

IDS AWAS provides users with the option of calculating river depletions using The Analytical Stream Depletion method developed in 1987 by Dewayne R. Schroeder. This method uses analytical equations described by Glover (Glover 1977) and others. The model allows users to calculate depletions using daily or monthly time steps. The user may evaluate a number of different boundary conditions (alluvial, infinite, no flow and effective SDF). IDS AWAS can create model input in two ways: 1) each well can have a list of pumping records consisting of a pumping rate and duration (original

mode), or 2) input records consisting of net consumptive use or recharge in a daily or monthly time step can be used. Year type can be set to calendar, irrigation, or USGS. Data can be projected into the future or past based on historical data, and the effect of turning off the well by specifying an end date beyond the period of record can be simulated. This software can be downloaded from: <http://www.ids.colostate.edu/projects/idsawas>.

IDS AWAS is one component in a suite of tools called the South Platte Mapping and Analysis Program that was initiated with funding from the Colorado Water Resources Research Institute (CWRRI) in 1995. Since that time, the user-centered tools have garnered support and funding from numerous other sources including several water users organizations, the state engineers office, Colorado Cooperative Extension Service, and the Colorado Agricultural Experiment.

The South Platte Mapping and Analysis Program (SPMAP) tools are developed by the Integrated Decision Support (IDS) Group at Colorado State University (www.ids.colostate.edu) with the active participation of area water users and staff from the Division One State Engineer’s Office. The primary function of these tools is to accurately determine the timing and amounts of tributary groundwater withdrawals used for irrigated agriculture and resulting river depletions in a region where ground and surface water are conjunctively used. The tools have confirmed their worth by easing disputes during Colorado’s recent unprecedented drought.

IDS AWAS and the other SPMAP tools were developed in a collaborative manner which involved water user groups, the state engineer’s office and university researchers. The SPMAP project is an excellent example of how a number of diverse stake holders can contribute to the development and use of common computer tools which can benefit all.

USGS 104g National Competitive Research Grants Announced

Eight proposals were selected for funding by the National Institutes for Water Resources (NIWR) and U.S. Geological Survey National Competitive Grants Program for fiscal year 2006. NIWR received 61 proposals requesting a total of \$8.5 million. Less than \$1 million was available in this competition.

Abstracts of the funded proposals, which are listed below, are available at http://water.usgs.gov/wrri/06grants/national/national_index.html.

- Evaluating Alternatives for Watershed-Scale Design of BMPs by John W. Nicklow, Southern Illinois University at Carbondale, Illinois Water Resources Center, University of Illinois, \$90,948 (2 years)
- Application of Wireless and Sensor Technologies for Urban Water Quality Management by William A. Arnold, Miki Hondzo, Raymond Hozalski, and Paige Novak, University of Minnesota with Paul Capel, USGS Minnesota Water Science Center, Water Resources Center, University of Minnesota, \$149,176 (2 years)
- Validation, Calibration, and Improvement of Remote Sensing ET Algorithms in Mountainous Regions by Jan Hendrickx and Jan Kleissl, New Mexico Institute of Mining and Technology with David Stannard, Branch of Regional Research, Water Resources Discipline, Central Region, U.S. Geological Survey, and Alan Flint, USGS California Water Science Center, Water Resources Research Institute, New Mexico State University, \$74,795 (2 years)
- Collaborative Research on In Situ Denitrification and Glyphosate Transformation in Ground Water: NAWQA Eastern Iowa Basins Study Unit by Scott Korom, University of North Dakota with Paul Capel, USGS Minnesota Water Science Center, North Dakota Water Resources Research Institute, North Dakota State University, \$91,988 (3 years)
- An Econometric Investigation of Urban Water Demand in the U.S. by Ronald C. Griffin, The Texas A&M University, Texas Water Resources Institute, The Texas A&M University, \$103,683 (2 years)
- Microtopography Effects on Vegetative and Biogeochemical Patterns in Created Wetlands: A Comparative Study to Provide Guidance for Wetland Creation and Restoration by Changwoo Ahn, George Mason University with Gregory Noe, Branch of Regional Research, Water Resources Discipline, Eastern Region, U.S. Geological Survey, Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, \$58,115 (2 years)
- West-Wide Drought Forecasting System: A Scientific Foundation for NIDIS by Anne Steinemann, Dennis Lettenmaier, and Andrew Wood, University of Washington with Michael Dettinger, Branch of Regional Research, Water Resources Discipline, Western Region, U.S. Geological Survey, and Randall Hanson, USGS California Water Science Center, State of Washington Water Research Center, Washington State University, \$250,000 (3 years)
- Identifying High-Infiltration and Groundwater Recharge Areas, Stephen J. Ventura and John M. Norman, The University of Wisconsin - Madison with Randall Hunt, USGS Wisconsin Water Science Center, Water Resources Institute, The University of Wisconsin - Madison, \$90,952 (2 years)

Doug Kemper Now Executive Director of Colorado Water Congress

Doug Kemper is now the Executive Director of the Colorado Water Congress. He served on the Board of Directors from 1990 through 2003 and was elected CWC President (1994) and Treasurer (1996-2003). He holds degrees in Water Resources Engineering from University of Colorado (Masters) and Vanderbilt University (Bachelors) and is a registered Professional Engineer.

Prior to joining the Water Congress, Doug spent 20 years as the Water Resources Manager with Aurora Water. He was responsible for the planning, development,



and operation of the city's raw water supply system. His activities included water policy and legislative analysis, acquisition of new water supplies, system modeling, and development of intergovernmental agreements.

Doug began his water resources experience by working for four years as an engineer with Rocky Mountain Consultants (now Deere & Ault). His primary duties were analysis of agricultural water use, water supply modeling, dam safety risk assessments, and water quality remediation studies.

Nonpoint Source Forum 2006 More than Brochures -- Real Change

**One Workshop, Choice of Days
September 6 or 7, 2006
PPA Event Center, Denver, CO**

Most people know that to protect the environment they should recycle more, water their lawns less, get out of the car and take a multitude of other steps to reduce their ecological footprint. This is the starting point.

However, research indicates that each form of sustainable behavior has its own set of barriers and benefits. Our workshop presenter, **Doug McKenzie-Mohr**, has been working to incorporate scientific knowledge of behavior change into the design and delivery and evaluation of community programs.

A professor of environmental psychology at St. Thomas University, New Brunswick, McKenzie assisted in the development of Canada's public education efforts on climate change, served as a member of the Canadian National Round Table on the Environment and Economy, and presented science-based community programs around the world.

The workshop covers four key areas:

- ▶ How to identify the barriers to a desired behavior, such as reducing lawn watering or pesticide use,
- ▶ How to use behavior change "tools" to design more effective programs,
- ▶ How (and why) to pilot test a program, and
- ▶ How to evaluate the impact of a program once it has been implemented.

For more information and registration, go to <http://www.npscolorado.com/>

RESEARCH AWARDS

Colorado State University, Fort Collins, Colorado
Awards for March 2006 to May 2006

Loftis, Jim C--1372--DOI-NPS-National Park Service--Clean Water Act Impairments and Use Designations for National Park System Water Resources--**\$98,339.00**

Ippolito, James--1170--Metro Wastewater Reclamation District--Urad Molybdenum Mine Tailing Revitalization Sustainability Using Biosolids--**\$133,877.00**

Redente, Edward F--1472--Metro Wastewater Reclamation District--Urad Molybdenum Mine Tailing Revitalization Sustainability Using Biosolids--**\$66,021.00**

Wohl, Ellen E--1482--NSF - National Science Foundation--Testing the Existence of a Threshold Discharge in Bedrock Channels--**\$67,348.00**

Wickramasinghe, Sumith Ranil--1370--NSF - National Science Foundation--New Generation Tailored Adsorptive Membranes --**\$98,865.00**

Ramirez, Jorge A--1372--NSF-EHR-Education & Human Resources--Reu Site: Research Experiences for Undergraduates: Program in Water Research at Colorado State University--**\$74,876.00**

Fausch, Kurt D--1474--Wyoming Game & Fish Department--Effects of Cattle Grazing on Riparian Vegetation and Trout Populations--**\$20,000.00**

Ramirez, Jorge A--1372--NSF-EHR-Education & Human Resources--Reu Site: Research Experiences for Undergraduates: Program in Water Research at Colorado State University--**\$30,331.00**

Thornton, Christopher I--1372--Urban Drainage & Flood Control District--Hydraulic Model Study Grate and Curb Inlets for Storm Drainage--**\$187,592.00**

Cooper, David Jonathan--1472--DOI-NPS-National Park Service--Wetland Protocol Development --**\$77,860.00**

Manfredo, Michael J--1480--Western Assoc. of Fish & Wildlife Agency--Advancing Human Dimensions Expertise Among State & Province Fish & Wildlife Agencies--**\$287,247.00**

Thornton, Christopher I--1372--PJR Consulting, Inc.--Hydraulic Model Study, Baglihar Hydropower Development, Sediment Excluding Intake Hydraulic Model--**\$5,276.00**

Niemann, Jeffrey D--1372--DOD-ARMY-ARO-Army Research Office--Scaling Properties & Spatial Interpolation of Soil Moisture--**\$100,000.00**

Winkelman, Dana--1484--Colorado Division of Wildlife--Pike/Trout Interactions in Colorado Reservoirs (Exhibit D(1))--**\$8,000.00**

Winkelman, Dana--1484--Colorado Division of Wildlife--Water Pollution & Native Plains Fishes: The Effect of 17-B Estradiol on the Reproductive Behaviors of fish--**\$35,000.00**

Butler, Ronald W--1877--NSF - National Science Foundation--AMC-SS: Saddlepoint and Bootstrap Methods in Stochastic Systems and Related Fields--**\$45,707.00**

Cotton, William R--1375--DOC-NOAA-Natl Oceanic & Atmospheric Admn--Sensitivity of the North American Monsoon to Soil Moisture, & Vegetation--**\$70,000.00**

Gates, Timothy K--1372--DOI-Bureau of Reclamation--Identification, Public Awareness, & Solution of Waterlogging & Salinity in the Arkansas River Valley--**\$40,000.00**

Yang, Chih Ted--1372--DOD-ARMY-Corps of Engineers--Lewis & Clark Reservoir Sedimentation Study --**\$182,005.00**

Waskom, Reagan M and James Pritchett--1033--DOI-USGS-Geological Survey--Colorado's Evolving Irrigated Agriculture: Economic Accounting Impact Analysis--**\$16,000.00**

Garcia, Luis--1372--DOI-Bureau of Reclamation--Arkansas River Valley S&T Research Work --**\$13,631.00**

Garcia, Luis--1372--DOI-Bureau of Reclamation--Subsurface Drainage Research --**\$14,053.00**

Sale, Thomas C--1372--Suncor Energy (U.S.A.) Inc.--Proposal for Environmental Research Collaboration --**\$88,387.00**

Carlson, Kenneth H--1372--CH2M Hill--Aquifer Recharge and Recovery (ARR) Testing --**\$102,600.00**

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 cwrr@colostate.edu.

Managing Drought and Water Scarcity in Vulnerable Environments Creating a Roadmap for Change in the United States

**18 - 20 September 2006
Longmont, Colorado**



Drought-related impacts can be expected to increase in intensity in the twenty-first century as human population increases and land uses change.

This conference will evaluate current drought-related problems, anticipate future issues, and generate the basis of a Roadmap for Change -- a concise, impartial document which will contain recommendations for public policy, research, and funding needs.

**Due to the participatory nature of this meeting, registration will be limited to 250.
Register for the Meeting (online registration closes 14 September 2006).
<http://www.geosociety.org/meetings/06drought/registration.htm>**

Who should attend:

Climatologists: modelers, etc.
Communications specialists
Ecologists
Economists
Educators
Experts in natural resource law/policy
Forestry / fire scientists and managers
Geographers
Hydrologists and hydrogeologists
Journalists
Planners and developers
Policy specialists
Psychologists
Sociologists
Soil, crop, and agronomy scientists
State / local / national government officials
Tree ring experts (dendrochronologists)
Tribal government representatives
Water and natural resources managers/engineers
Water users associations

Presented by:

Geological Society of America
American Meteorological Society
American Water Resources Association
American Water Works Association
Colorado State University
Denver Museum of Nature and Science
Desert Research Institute
Ecological Society of America
Groundwater Foundation
National Center for Atmospheric Research
National Drought Mitigation Center
National Ground Water Association
National Oceanic and Atmospheric Administration
(National Climatic Data Center)
National Water Research Institute
National Institutes for Water Resources
Natural Hazards Center (CU-Boulder)
Society for Range Management
Soil Science Society of America
U.S. Army Corps of Engineers U.S. Geological
Survey -Water Resources Division
Western Rural Development Center
U.S. Geological Survey - Water Resources Division
Western Rural Development Center

CALENDAR

Jul. 18-20	2006 UCOWR Annual Conference: Increasing Freshwater Supplies. Santa Fe, NM. For more information, go to http://www.ucowr.siu.edu/ .
Jul. 22-26	Annual Meeting of International Soil and Water Conservation Society. Keystone, CO. For more information go to: http://www.swcs.org/en/swcs_international_conferences/2006_internationalconference/
Jul. 24-27	StormCon '06. Denver, CO. For more information, go to http://www.stormcon.com/sc.html .
Jul. 26-28	31th Colorado Water Workshop: The Developed Resource. Western State College of Colorado, Gunnison, CO. For more information contact George Sibley at 970-943-2055 or gsibley@western.edu or go to http://www.western.edu/water/
Aug. 16-18	River and Floodplain Modeling Using HEC-RAS v3.1.3, CU-Denver. For more information go to www.cudenver.edu/engineer/cont .
Aug. 24-25	Colorado Water Congress 2006 Summer Convention. Breckenridge, CO. For more information go to http://www.cowatercongress.org/meeting_notices.htm .
Sep. 6 or 7	Nonpoint Source Forum 2006: More than Brochures—Real Change. Denver, CO. For more information and registration, go to http://www.npscolorado.com
Sep. 10-14	Dam Safety '06. Boston. For more information, go to www.damsafety.org or call 859-257-5140.
Sep. 18-20	Wetlands Restoration Dialogue, Fort Lauderdale, FL. For more information go to http://www.awra.org/meetings/
Sep. 18-20	Managing Drought and Water Scarcity in Vulnerable Environments: Creating a Roadmap for Change in the United States. Longmont, CO. Geological Society of America. For more information, see http://www.geosociety.org/meetings/06drought/registration.htm
Sep. 25	The Law of Ecosystem Restoration: National Policy Implications of the Clark Fork River Basin Natural Resource Damage INRD) Program, Missoula, MT. For more information to go http://www.umt.edu/publicland/Conference.htm
Sep. 26-28	3rd International Symposium on Integrated Water Resources Management. Ruhr-University, Bochum, Germany. International Commission on Water Resources Systems. For more information go to http://conventus.de/water/
Oct. 25-28	Ground Water and Surface Water Under Stress: Competition, Interaction, Solutions. Boise, Idaho. For more information go to www.uscid.org/
Nov. 1	Deadline for paper submissions to 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/
Nov. 2-3	Advanced Topics in Floodplain Management. CU/Denver. For more information go to www.cudenver.edu/engineer/cont .
Nov. 6-9	American Water Resources Association 2006 Annual Conference. Baltimore, MD. For more information go to www.awra.org/meetings/Baltimore2006/ .
2007	2007
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 49th Annual Convention. Denver, CO. For more information go to: www.cowatercongress.org , or phone 303/837-0812, or email macravey@cowatercongress.org .
Jun. 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/

Calendar, usually found here, is on page 27, just inside.

If you have already mailed or faxed us your responses to our Reader Survey which was on page 35 of the April issue of *Colorado Water*, **we thank you for your time and your help as we plan for the future.**

If you haven't sent us your responses, there is still time to have your say about topics, features, and formatting of the newsletter. Please complete the survey, now available from our webpage, www.cwrri.colostate.edu, and send it back to us by mail or by fax.

Colorado State University
Colorado Water Resources Research Institute
Colorado State University
Fort Collins, CO 80523

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