COLORADO WATER

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Purgatoire river corridor shown before tamarisk removal (left) and after tamarisk removal (below). Removing non-native invasive species is one aspect of river restoration. (See article on page 12).

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WATER ITEMS AND ISSUES . . .

COLORADO WATER

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EDITORIAL

River Restoration

by Robert C. Ward
Director of Colorado Water Resources Research Institute

In the June 2005 issue of *Colorado Water*, there was an article (page 14) about the $1 billion spent annually on river restoration in the United States. The article very briefly summarized several higher education efforts to develop a stronger scientific foundation for river restoration efforts. The article also indicated that an upcoming issue of *Colorado Water* would be devoted to river restoration. This is it!

To refresh your memory, on April 29, 2005, the National River Restoration Science Synthesis Project estimated that $1 billion is annually spent on river restoration in the U.S. The Synthesis Project also noted the difficulty in gaining an accurate picture of river restoration due to lack of documentation, as well as the difficulty in agreeing on criteria for judging a successful river or stream restoration effort, particularly with respect to judging ecological success.

As this 'industry' continues to grow, CWRRI invited several higher education researchers, who work in river restoration related topics, to share with us their experiences and insights. In particular, we asked the researchers to briefly describe their work and suggest new thoughts and ideas about how Colorado can restore its rivers within a broader context of resolving water conflicts (*a la* the water roundtables created by HB 1177). Hopefully, the discussions contained in this issue will assist water roundtable discussions that move into the realm of river restoration.

The first paper , by Ellen Wohl and several colleagues, presents a philosophical overview that traces the recent (2-3 decades) history of restoration, explains the differences between restoration and rehabilitation, and explores the differing intents behind individual restoration projects. John Loomis then addresses the economics of river restoration. John's paper comes from his keynote address at the annual Universities Council on Water Resources in Portland, Maine, in July.

The Colorado State Forest Service, in an article by Ryan Boggs, John Heideman, and Shelly Van Landingham, describes a partnership effort to restore the Purgatoire River through a large scale effort to remove tamarisk. LeRoy Poff describes his research to measure the impacts of dewatering on ecosystem health and discusses how to mitigate some of the impacts – key information we need to insure that human water supply needs are met in a manner that places as light as possible 'footprint' on Colorado's aquatic environment. Chris Myrick's research is examining ways to enhance fish movement in streams that are impacted by human uses.

As Colorado continues to seek ways to meet the water needs of its growing population, the research described in this issue of *Colorado Water* suggests ways we can also work to protect Colorado's aquatic environment at the same time.

Message of Farewell from Robert Ward

After writing 84 editorials for *Colorado Water* over the past 14 years, it is time to write my last editorial and say 'farewell'. I will be retiring after 35 very enjoyable years as a faculty member at Colorado State University.

As director of CWRRI for the past 14 years, I have attempted to connect Colorado's higher education 'water' expertise with the research and education needs of Colorado's water managers and users. The limited resources available to CWRRI to establish and nurture such connections places considerable value upon the voluntary contributions from both groups of people. If CWRRI has been able to contribute to enhanced connections, it is because so many people were willing to write a newsletter article for *Colorado Water*, speak at a CWRRI sponsored conference, present a seminar on campus, contribute matching funds to a CWRRI research project, make a special effort to attend a meeting discussing university/water community connections, and answer my phone calls and questions regarding basic facts about Colorado's water management system. And do all this for no financial return! I cannot thank enough the many, many people both on and off campus who have helped CWRRI make constructive connections between theory and practice.

Robert takes the plunge.

CWRRI operates with only one full time person who must edit the newsletter, handle all research project budget and personnel tracking, submit all legislatively required reports, and staff CWRRI's office. The two ladies who have held this position during my tenure at CWRRI, Shirley Miller until 2004 and Gloria Blumanhourst since then, deserve considerable credit for CWRRI accomplishments. Their commitment to the mission of CWRRI, and willingness to go the extra mile, are very much appreciated.

Reagan Waskom will take on the position of Interim CWRRI director on January 1, 2006. Reagan brings a wealth of experience and connections to the position and I encourage all of you to support Reagan as he continues to strengthen the bridges between the Colorado's academic community and its water management community.

As a member of the College of Engineering faculty since 1970 and having taught a number of engineers working in the field of water resources today, I have another big thank you to make – to the taxpayers of Colorado who provided the funds and the opportunity for me to teach their sons and daughters. I greatly enjoyed teaching the entire spectrum of engineering students (from freshmen to graduate) and watching them transformed, through their own hard work and that of my faculty colleagues, into professional engineers. It is extremely satisfying to attend water meetings across the state of Colorado today and visit with former students who are now into very productive phases of their careers as water managers. When I began to encounter some of the former students who have retired, it dawned on me that it was time for me to consider retirement!

While I am retiring from the university, I intend to remain active in Colorado's water community as a private citizen. The subject is too fascinating to me to do otherwise. I will continue to actively support CSU's Water Archive and the Poudre Heritage Alliance as both strive to preserve, protect, and promote Colorado's rich water history. I intend to continue consulting and conducting research into the design of water quality monitoring systems – my area of personal research.

Robert, Brenda, Justin, Ryan and Stephanie (1989)

I look forward to more time with my family, time to exercise, time to enjoy more of Colorado's outdoors, and time to travel. Until our paths cross, best wishes with your endeavors to employ the latest in scientific and policy findings to improve the management of Colorado's most precious natural resource - water.

Can We Really Restore Rivers?

by Ellen Wohl, Brian Bledsoe, David Merritt, and LeRoy Poff
Colorado State University and Colorado River Water Conservation District

(Editor's note: This article is adapted from *River restoration* by Ellen Wohl, Paul L. Angermeier, Brian Bledsoe, G. Mathias Kondolf, Larry MacDonnell, David M. Merritt, Margaret A. Palmer, N. LeRoy Poff, and David Tarboton, *Water Resources Research*, v. 41.)

What is river restoration?

People have manipulated rivers for thousands of years. Egyptians dammed rivers as early as 2800 B.C. The Japanese diverted the Tone River more than 60 miles eastward to avoid the city of Tokyo in 1590 AD, and the Spaniards channelized the Rio Guadalquivir, reducing its length by 40%, in 1750 AD. Increasing population densities worldwide have been associated with increasing alteration of rivers throughout history. At any point in time and space, these alterations reflect societal expectations of river processes and form. Viewed in this context, contemporary river restoration and rehabilitation activities reflect the latest trend in societal expectations for natural, ecologically healthy rivers.

Various perceptions of what is meant by 'restoration' reflect the wide disparities in stakeholder interests, scientific knowledge, scales of interest, and system constraints encountered in practice. In the parlance of river management, 'restoration' describes activities ranging from "quick fixes" involving bank stabilization, fencing, or engineering fish habitat at the reach scale, to river-basin-scale manipulations of ecosystem processes and biota over decades. Because both technical and social constraints often preclude 'full' restoration of river ecosystem structure and function, 'rehabilitation' is sometimes distinguished from restoration.

A key distinction between river restoration and other management actions is the intent to reestablish "natural" rates of certain ecological, chemical, and physical processes and/or to replace damaged or missing biotic elements. That is, restoration is often fundamentally about enhancing ecological integrity [Angermeier, 1997; Baron et al., 2002]. We define ecological integrity as the ability to self-sustain desirable ecological entities (population, community, ecosystem) and processes (e.g. nutrient dynamics, sediment transport). Goals of individual restoration projects typically reflect this general theme but details vary widely because the particular ecological entities and processes of interest differ greatly among projects and environmental settings. In many urban rivers, for example, the potential for ecological improvement is limited, and the principal benefits from a restoration project are social, such as building a sense of community by involving citizens as well as scientists and managers.

River restoration in the United States

Continuing degradation of river ecosystems and loss of aquatic biodiversity are widespread. River restoration is now accepted by government agencies and various stakeholders as an essential complement to conservation and natural resource management. The number of river restoration projects in the U.S. has increased exponentially in the last decade, and expenditures on small and mid-size projects alone (e.g., excluding projects like the Kissimmee or the Colorado) average > $1 billion a year [Bernhardt et al., 2005]. From a study of > 38,000 restoration projects, Bernhardt et al. [2005] found that the most commonly stated goals for river restoration in the U.S. are to i) enhance water quality, ii) manage riparian zones, iii) improve in-stream habitat, iv) fish passage, and v) bank stabilization. However, despite legal mandates, massive expenditures, and the burgeoning industry of aquatic and riparian restoration, river ecosystems continue to deteriorate as a result of human influences [Karr and Chu, 1999]. Furthermore, many restoration activities have failed [Williams et al., 1997]. Recent reviews of river restoration projects across the country suggest some reasons for these failures [Bernhardt et al., 2005; Wohl et al., 2005].

First, many projects designed to restore rivers are currently being conducted with minimal scientific context. Specifically, many projects lack (i) the inclusion of a solid conceptual model of river ecosystems; (ii) a clearly articulated understanding of ecosystem processes; (iii) recognition of the multiple, interacting temporal and spatial scales of river response; and (iv) long-term monitoring of success or failure in meeting project objectives following completion [Pedroli et al., 2002; Bernhardt et al., 2005]. These problems suggest that the scientific practice of river restoration requires an understanding of natural systems at or beyond our current knowledge, and presents a significant challenge to river scientists.

Second, most restoration projects focus on a single, isolated reach of river, yet many scientists advocate the watershed as the most appropriate spatial unit to use for most river restoration [National Research Council, 1999]. Restoration undertaken within a watershed context reflects the importance of key processes and linkages beyond the channel reach, such as upstream/downstream connectivity, and hillslope, floodplain, and hyporheic/groundwater connectivity [Sear, 1994; Angermeier, 1997; Frissell, 1997; Poff et al., 1997; Stanford and Ward, 1992; Graf, 2001; Palmer et al., 2005]. The importance of these linkages is without question; water, sediment, organic matter, nutrients and chemicals move from uplands, through tributaries, and across floodplains at varying rates and concentrations. Migratory fish move upstream and downstream during different stages in their lifecycles. These obvious examples of the inextricable linkages within watersheds are too often ignored in river restoration. To date, restoration has largely been done on a piece-meal basis, with little to no monitoring to assess performance, and little integration with other projects. This reflects the lack of process-based approaches in current practice as well as the fact that comprehensive restoration strategies that reestablish watershed-scale connections and processes are more difficult to implement because of sociopolitical and financial constraints.

Third, restoration is too often focused on creating a desired form that is then artificially constrained. Because natural variability is an inherent feature of all river systems, restoration of an acceptable range of variability of process is more likely to succeed than restoration aimed at a fixed endpoint that precludes variability. Restoration of process is also more likely to address the causes of river ecosystem degradation, whereas restoration toward a fixed endpoint addresses only symptoms. The widespread clearing of the exotic riparian shrub tamarisk from western rivers has been supported by the public, politicians, and managers because tamarisk is perceived to be the cause of the problem rather than one of the many symptoms of altered rivers. Tamarisk removal has been sold as a means of restoring diversity of native communities and salvaging water through decreasing evapotranspiration, yet no scientific study has been able to quantify the yield on these investments.

To persist as healthy ecosystems, rivers must be able to adjust to and absorb change at the time scales over which change occurs. An ideal ecologically successful restoration creates hydrological, geomorphological, and ecological conditions that allow the targeted river to be self-sustainable in its new context [Palmer et al., 2005]. One of the implications of this understanding of river dynamics is that monitoring and evaluation of conditions before and after restoration must recognize the variability inherent even in “stable” rivers. Restoration that focuses on process rather than form will more effectively address most restoration goals. Process is more crucial than form in goals such as a) improving water quality by changing infiltration-runoff paths and b) stabilizing banks and increasing pool volume by allowing riparian vegetation to remain along river banks. Restoration projects that attempt to create a static or fixed form, such as meanders with riprapped banks, commonly fail [Kondolf et al., 2003]. Rivers possess physical integrity, an aspect of ecological integrity, when their processes and forms maintain active connections with each other in the present hydrologic regime [Graf, 2001].

Advancing the science and practice

Rivers are highly valued by the public; everyone interacts with and pays attention to rivers [Tunstall et al., 2000]. As the practice of river restoration continues to grow, the need to develop a sound scientific basis is obvious, as evidenced by the number of working groups and policy initiatives devoted to this topic within the federal government (e.g. USGS interagency River Science Network), non-governmental organizations (e.g. The Nature Conservancy, American Rivers, local watershed groups), and academia (e.g. the National River Restoration Science Synthesis project [Palmer et al., 2003] and the National Center for Earth-Surface Dynamics).

Achieving restoration goals will be limited by a variety of scientific and non-scientific factors [Angermeier, 1997; Hennessy, 1998]. Scientific limitations include unavailable information on critical ecosystem conditions or processes, and inadequate synthesis of available information during model development. Non-scientific limitations include infeasibility of certain desired restorative actions (e.g., eradication of exotic species, reintroduction of extinct native species), and philosophical differences among stakeholders and disagreements over who should bear the social and economic costs of restoration. Resolving resource-management issues across entire river basins and resolving conflicting interests among stakeholders requires degrees of coordination and cooperation rarely achieved in human society [Naiman, 1992]. However, as the public increasingly recognizes the link between ecological integrity and ecosystem goods or services such as clean water or productive fisheries, shifts in values may induce people to rethink assumptions about what is sociopolitically acceptable in restoration scenarios. For example, should reduced flood flows downstream from a dam constrain restoration efforts, or should restoration include greater flood-flow releases from the dam? Many factors assumed to be constraints twenty years ago are being re-examined as opportunities to restore rivers today. Rather than a dichotomy between pro-development and pro-environment, many scientists and practitioners are realizing that there is a middle ground in which some functions can be restored without great cost to water users.

River restoration can also be advanced by treating restoration projects as experiments that can teach us about ecosystem operation. Most restoration projects have been implemented without the study design, baseline data, and post-project appraisal needed to learn from them [Downs and Kondolf, 2002; Bernhardt et al., 2005]. Much of the published literature, which forms the basis of our ecological understanding, describes research conducted at space-time scales much smaller than those appropriate for restoration. Furthermore, many restorative actions are applied at scales too small to produce the intended effects on biotic populations and assemblages [Pretty et al., 2003]. A major limitation in advancing scientific knowledge to guide predictive restoration is the lack of opportunities to conduct large-scale experiments, where whole system responses can be evaluated at scales that match management actions. For example, restoration of flow regimes below existing water control structures presents tremendous opportunities to learn about system-specific responses that can guide future restoration actions [Poff et al., 2003]. Experimental flood releases such as those on the Colorado River in Grand Canyon [Collier et al., 1997] provide opportunities to pose and test hypotheses regarding the ecosystem effects of these floods. Despite the lack of standard experimental features such as randomization of controls and treatments, or replication, the flood releases create quasi-experiments that provide important knowledge about river response to restoration efforts [Block et al., 2001].

Viewing restoration projects as experiments affords a framework for engaging scientific involvement early in the process and strengthens the rationale for monitoring the results of the restoration action. Adaptive management coupled with effective monitoring facilitates learning from experience [Walters, 1997; Rogers, 2003], and has been repeatedly identified as a critical and missing component of existing river management programs such as that on the Platte River [National Research Council, 2005]. We currently have far too few experiments at appropriate scales that are conducted adaptively and thus we have not yet developed scientific guidelines for how best to restore adaptively or over what timescale adaptive management should be applied.

In summary, recent overviews of the state of river restoration in the U.S. have highlighted existing problems and suggested directions for improvement. We suggest that river restoration can be most effectively advanced with increasing emphasis on (i) implementing restoration within a clearly articulated scientific conceptual framework and a watershed context, (ii) restoring process rather than form, and (iii) monitoring and learning from ongoing restoration efforts. It is not unreasonable for society to expect a return on their investment in river restoration.

References Cited

Angermeier, P.L (1997), Conceptual roles of biological integrity and diversity, in Watershed restoration: principles and practices, edited by J.E. Williams, C.A. Wood and M.P. Dombeck, pp. 49-65, American Fisheries Society, Bethesda, MD.

Baron, J.S., N.L. Poff, P.L. Angermeier, C.N. Dahm, P.H. Gleick, N.G. Hairston, R.B. Jackson, C.A. Johnston, B.G. Richter, and A.D. Steinman (2002), Meeting ecological and societal needs for freshwater, Ecological Applications, 12, 1247-1260.

Bernhardt, E.S., M.A. Palmer, J.D. Allan, and the National River Restoration Science Synthesis Working Group (2005), Restoration of U.S. rivers: a national synthesis, Science, 308.

Block, W.M., A.B. Franklin, J.P. Ward, J.L. Ganey, J.L. and G.C. White (2001), Design and implementation of monitoring studies to evaluate the success of ecological restoration on wildlife, Restoration Ecology, 9, 293-303.

Collier, M.P., R.H. Webb, and E.D. Andrews (1997), Experimental flooding in Grand Canyon, Scientific American, 276, 66-73.

Downs, P.W., and G.M. Kondolf (2002), Post-project appraisal in adaptive management of river channel restoration, Environmental Management, 29, 477-496.

Frissell, C. A. (1997), Ecological principles, in Watershed restoration: principles and practices, edited by J.E. Williams, C.A. Wood, and M.P. Dombeck, American Fisheries Society, Bethesda, Maryland.

Graf, W.L. (2001), Damage control: restoring the physical integrity of America's rivers, Annals of the Association of American Geographers, 91, 1-27.

Hennessey, T.M. (1998), Ecosystem management: the governance approach, in Ecosystem management, a social science perspective, edited by D.L. Soden, B.L. Karr, J.R. and E.W. Chu (1999), Restoring Life in Running Waters - Better Biological Monitoring, Island Press, Covelo, CA

Kondolf, G.M., D.R. Montgomery, H. Piégay, H. and L. Schmitt (2003), Geomorphic classification of rivers and streams, in Tools in fluvial geomorphology, edited by G.M. Kondolf and H. Piégay, pp.171-204, John Wiley and Sons, Chichester, England.

Naiman, R.J., editor (1992), Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York.

National Research Council (1999), New strategies for America's watersheds, 311 pp. National Academy Press, Washington, D.C.

National Research Council (2005), Endangered and threatened species of the Platte River, 299 pp. National Academies Press, Washington, D.C.

Palmer, M.A., E. Bernhardt, J.D. Allan, and the National River Restoration Science Synthesis Working Group (2005), Standards for ecologically successful river restoration, Journal of Applied Ecology, 42, 208-217.

Pedroli, B., G. de Blust, K. van Looy and S. van Rooij (2002), Setting targets in strategies for river restoration, Landscape Ecology, 17 (Suppl 1), 5-18.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg (1997), The natural flow regime, BioScience, 47, 769-784.

Poff, N.L., J.D. Allan, M.A. Palmer, D.D. Hart, B.D. Richter, A.H. Arthington, J.L. Meyer, J.A. Stanford, and K.H. Rogers (2003), River flows and water wars? Emerging science for environmental decision-making, Frontiers in Ecology and the Environment, 1, 298-306.

Pretty, J.L., S.S.C. Harrison, D.J. Shepherd, C. Smith, A.G. Hildrew, and R.D. Hey (2003), River rehabilitation and fish populations: assessing the benefits of instream structures, Journal of Applied Ecology, 40, 251-265.

Rogers, K. (2003), Adopting a heterogeneity paradigm: Implications for biodiversity management in protected areas, in The Kruger experience: Ecology and management of savanna heterogeneity, edited by J. du Toit, K. Rogers and H. Biggs, pp. 41-58, Island Press, Washington, DC.

Sear, D.A. (1994), River restoration and geomorphology, Aquatic Conservation: Marine and Freshwater Ecosystems, 4, 169-177.

Stanford, J.A. and J.V. Ward (1992), Management of aquatic resources in large catchments: recognizing interactions between ecosystem connectivity and environmental disturbance, in Watershed management: balancing sustainability and environmental change, edited by R.J. Naiman, pp. 91-124, Springer-Verlag, New York.

Tunstall, S.M., E.C. Penning-Rowsell, S.M. Tapsell, and S.E Eden (2000), River restoration: public attitudes and expectations, Journal of the Chartered Institution of Water and Environmental Management, 14, 363-370.

Walters C. (1997), Challenges in adaptive management of riparian and coastal systems, Conservation Ecology, 1:1 http://www.consecol.org/vol1/iss2/art1, last viewed 12 February 2003.

Williams, J.E., C.A. Wood, and M.P. Dombeck (1997), Understanding watershed-scale restoration, in Watershed restoration: principles and practices, edited by J.E. Williams, C.A. Wood, and M.P. Dombeck, pp.1-16, American Fisheries Society, Bethesda, MD.

Economic Values of River Restoration

by John Loomis
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Restoration of rivers and related riparian areas is now a billion dollar a year business, with at least $15 billion spent since 1990 (Bernhardt, et al., 2005). This restoration is taking place coast to coast, from the Everglades to the Elwha River in Washington. Restoration brings hope and optimism that we can begin to achieve some balance in our use of water resources. With restoration we can optimize the many values that rivers and lakes provide rather than solely maximizing the water supply that we can wring from them.

Restoration may not always be perceived as a "win-win" for each party involved. This perception may be due to changes in the hydrograph often needed to re-establish channel structure or native species. However, restoration can also be viewed as the mitigation for past and proposed water developments. In this sense, river restoration may remove hurdles for expanding existing water projects and allow new water projects to proceed conditional on river restoration. As such, river restoration should be viewed as an integral component of moving from a fractious water competition (e.g., urban vs agriculture or environment vs development) to a more cooperative view of water resources. In the long run this broader view of water resources is likely to result in "win-win" situations for the "water haves" and "water have nots".

However, as river restoration grows into a billion dollar a year effort, some will no doubt ask whether the benefits of these efforts are worth the costs. This paper will present examples of the types of economic benefits that river restoration provides society. The paper will show that besides recreation opportunities and increased residential property values that non-use or passive use values of river restoration are critical to include when dealing with restoration of riverine habitat for threatened and endangered (T&E) species.

Total Economic Values

The Total Economic Value associated with restoration is made up of the obvious use value as well as the not so obvious passive use values. The use values of river restoration include a wide variety of ecosystem services such as recreation, fish habitat, water quality, stormwater management and aesthetics. However, restoration also provides widespread benefits to people who obtain satisfaction or utility from knowing that native species exist in their natural habitat (i.e., existence value) or from knowing that restoration today provides native species and their natural habitats to future generations (i.e. a bequest value).

These existence and bequest values have been termed passive use values since they were upheld by the U.S. Court of Appeals for use in natural resource damage assessment. The U.S. Court of Appeals noted "Option and existence values may represent "passive" use, but they nonetheless reflect utility derived by humans from a resource and thus, prima facie, ought to be included in a damage assessment." (US Court of Appeals, 1989: 67). In response to this court ruling, Dept. of Interior agencies include use and passive use values in their natural resource damage assessment (Ward and Duffield, 1992; USDOI, 1994). It seems that if passive use values are appropriate for the government to collect on behalf of the public when damages occur to natural resources then passive use values are appropriate to include when estimating the benefits of river restoration as well.

Technique: Use Values

To estimate use values of river restoration economists often rely upon actual market behavior to detect how visitors or homeowners value restoration of lakes and rivers. Visitors reveal their greater demand and benefits for improved water resources by the increased number of trips they take to restored lakes and rivers as compared to degraded ones. The Travel Cost Method (Loomis and Walsh, 1997) can be used to estimate the demand curve for restored rivers and allow calculation of the visitor's additional net willingness to pay to visit these restored rivers as compared to degraded ones. For rivers running through residential areas, house price differentials reflect what homeowners will pay for living by a restored or natural stream as compared to a degraded one. This statistical analysis of house price differentials is called the Hedonic Property Method.

Technique: Passive Use Values

Existence and bequest values are public goods and as such their values are not fully reflected in markets or in the behavior of most individuals. Thus economists have developed constructed or simulated markets to allow people to state what they would pay to know that a restored river exists with native fish. This stated preference or contingent valuation method (CVM) starts by providing households with a comparison of existing river conditions and improved river conditions, and then asking whether they would pay a given increase in cost, that varies across households. This varying costs and the response to it, allow for tracing out a demand like relationship for restoration (i.e., the higher the cost, the fewer people would pay).

While reliance on what people say they would pay has been controversial (see Portney, 1994), the method has shown to be reliable in test-retest studies (Loomis, 1989; Reiling, et al., 1990, Carson, et al. 1997). Past comparisons with actual cash have sometimes show that CVM derived values may overstate true WTP. However, a blue ribbon panel appointed by the National Oceanic and Atmospheric Administration that was chaired by two Nobel Laureates concluded that carefully constructed CVM studies are believed to yield reliable enough estimates of existence or passive use value to be a useful starting point for judicial and administrative deliberations (Arrow, et al., 1993).

The hedonic property method has been frequently employed to estimate the value of river restoration to nearby residents. One of the first applications was by Streiner and Loomis (1995) that showed that houses in northern California along streams that were restored sold for 11%-12% more than houses along unrestored streams. Research in Arizona by Colby and Wishart (2002) and Colby, et al. (2005) suggest that riparian areas have a significant positive influence on property values. Netusil (2005) found that publicly owned streams had a positive and significant influence on property values in Oregon.

Restoration of free-flowing rivers and recovery of native species often has existence values that are received by households all across the entire nation (Loomis, 2000). Previous studies have shown that existence values make up at least half the benefits of improving water resources (Fisher and Raucher, 1984; Sanders, et al., 1990). As such it is important to include these passive use or non use benefits when calculating the benefits of restoration. The empirical importance of doing so is illustrated with a case study.

Elwha River Case Study

Removing two dams from the Elwha River near Olympic National Park in Washington, is an expensive proposition with costs of nearly $250 million. It will take decades before significant increases in harvestable fish return to support appreciable commercial and recreational fishing. But the restoration of the river and return of the natural migration of the salmon is expected to occur within the first decade. In order to estimate the existence or passive use values associated with the dam removal and river/salmon restoration a CVM survey was conducted of Washington households to ask them whether they would pay for dam removal and salmon recovery. The economic question was framed as a voter referendum question asking whether they would vote in favor of dam removal and salmon restoration at a specific increase in cost. This cost ($X) varied from $3 to $190 per household across the sample.

The survey response rate was 68% for Washington residents, and their average WTP was $73 (with a 90% confidence interval of $60-$99). This translates into about $94 million in passive use values to Washington households each year. Including these passive use value results in positive net benefits (benefits in excess of cost) for dam removal.

As the case study illustrates, calculating the total economic values of restoration including passive use values is necessary so as to not understate the benefits of river restoration. The passive use or non use values often make up a majority of the benefits, and their omission can often lead to the impression that the restoration is uneconomic. As this case study indicates, inclusion of passive use values demonstrated that restoration was economic efficient, with benefits exceeding costs. While economics should not be the sole determinant of whether to restore an area or not, as restoration projects expand in frequency and scale, some prioritization of restoration projects becomes inevitable. In sorting through restoration projects competing for scarce funding, having information about the use and passive use values of the restoration project can aid decision makers in selecting among those restoration projects which provide the greatest benefits to society as a whole.

References

Arrow, K., R. Solow, P. Portney, E. Leamer, R. Radner and H. Schuman. 1993. Report of the NOAA Panel on Contingent Valuation. Federal Register 58(10):4602-4614.

Bernhardt, E. and 12 others. 2005. Synthesizing U.S. River Restoration Efforts. Science Vol 308: 636-637. April 29, 2005.

Carson, R., M. Hanemann, R. Kopp, J. Krosnick, B. Mitchell, S. Presseor, P. Ruud, V.K. Smith, M. Conaway, and K. Martin. Temporal Reliability of Estimates from Contingent Valuation. Land Economics 73(2): 151-163.

Colby, B. and S. Wishart. 2002. Quantifying the Influence of Desert Riparian Areas on Residential Property Values. The Appraisal Journal 70 (3): 304-308.

Colby, B., R. Bark and D. Osgood. 2005. Valuing Restoration of Water Dependent Urban Amenities. Proceedings of the UCWOR/NIWR Annual Conference. Portland Maine.

Fisher, A. and R. Raucher. 1984. Intrinsic Benefits of Improved Water Quality: Conceptual and Empirical Perspectives. In V.K. Smith, ed. Advances in Applied Micro-Economics. JAI Press Inc, Greenwich, CT.

Loomis, John. 1989. Test Re-test Reliability of the Contingent Valuation Method: A Comparison of General Population and Visitor Responses. American Journal of Agricultural Economics, Volume 71(1): 76-84.

Loomis, J. 1996. Measuring the Economic Benefits of Removing Dams and Restoring the Elwha River: Results of a Contingent Valuation Survey. Water Resources Research 32(2): 441-447.

Loomis, John. 2000. Vertically Summing Public Good Demand Curves. Land Economics 76(2): 312-321.

Loomis, J. and R. Walsh. 1997. Recreation Economic Decisions, 2nd Edition. Venture Publishing, State College, PA.

Netusil, N.R. 2005. Does Ownership Matter? Examining the Relationship Between Property Values and Privately and Publicly Owned Open Spaces, Streams and Wetlands. Reed College, Department of Economics, Working Paper.

Portney, P. 1994. The Contingent Valuation Debate: Why Economists Should Care. Journal of Economic Perspectives 8(4): 3-18.

Reiling, S., K. Boyle, M. Phillips, and M. Anderson. 1990. Temporal Reliability of Contingent Values. Land Economics 66(2): 128-134.

Sanders, L., R. Walsh, and J. Loomis. 1990. Toward Empirical Estimation of the Total Value of Protecting Rivers. Water Resources Research 26(7): 1345-1358.

Streiner, C.F. and J. Loomis. 1995. Estimating the Benefits of Urban Stream Restoration Using the Hedonic Price Method. Rivers 5 (4): 267-78.

United States District Court of Appeals for the District of Columbia Circuit. 1989. State of Ohio vs US. Department of Interior, et al. Cases # 86-1529 and # 86-1575. July 14, 1989.

U.S. Department of Interior (USDOI). 1994. Natural Resource Damage Assessments; Final Rule. 43 CFR Part 11. Federal Register 59(58): 14262-14288.

Ward, Kevin and John Duffield. 1992. Natural Resource Damages: Law and Economics. John Wiley and Sons. New York, NY.

Tackling Tamarisk on the Purgatoire to Improve the Watershed

by Ryan Boggs, The Nature Conservancy
John Heideman, Tamarisk Coalition
Shelly Van Landingham, Colorado State Forest Service

The lower Purgatoire River watershed spans more than 200 miles, including the river and tributary feeder streams. The main stem of the Purgatoire flows east from the 14,069-foot Culebra peak high in the Sangre de Cristo mountains to Trinidad, Colorado, and then northeast to Las Animas, Colorado, where it converges with the Arkansas River.

This watershed is home to one of the most intact native fisheries in the Central Shortgrass Prairie east of the Rocky Mountains. The river's tributaries have also created lush side canyons that sustain several rare plant species. And a diverse prairie mosaic of shale outcroppings, piñon-juniper woodlands, and extensive prairie uplands with native grasses and shrubs is found above the canyons.

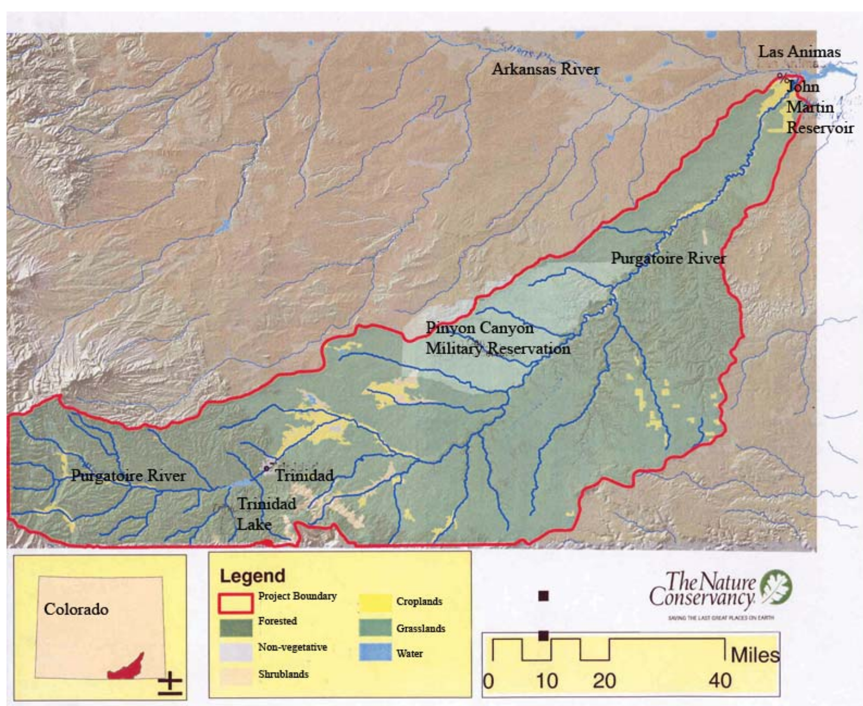
Due to the decades-long invasion of aggressive, non-native woody plants including tamarisk, Russian olive, and Siberian elm, the Purgatoire's globally rare riparian plant communities are being threatened. These plant pests, particularly tamarisk, also increase the fire risk to communities and watersheds because the plants ignite easily and when they burn, they cause fire to spread rapidly and create intense heat. In addition, they compromise healthy riparian forests, and negatively impact livestock production and the economic sustainability of communities that rely on a strong agricultural base.

Tamarisk is not unique to the Purgatoire. This invasive species, which was imported from the Middle East in the early 1900s for erosion control and its ornamental qualities, has choked rivers throughout the southwestern United States. It has also transformed many of Colorado's Eastern Plains riparian areas from healthy, viable habitat with diverse plant communities that support 90 percent of the area's wildlife into crowded monocultural forests with little biodiversity.

Tamarisk, which is also known as salt cedar, has a voracious appetite for water. Every year, tamarisk in the Arkansas River drainage in Colorado uses enough water to supply all of Pueblo's domestic water for that year. It also degrades ecosystems in other ways. For example, it increases the salinity of the surface soil, which renders it unsuitable for use by other plants; it widens flood plains, clogging stream channels and increasing sediment deposits; and it diminishes human enjoyment of and interaction with the river and surrounding environment.

The unique distribution of tamarisk in the Purgatoire River Watershed, which ranges from light infestations above the Trinidad Reservoir to heavier, denser stands downriver, makes the area ideal for large-scale control. And improving the Purgatoire Watershed through large-scale control is exactly what the Tackling Tamarisk on the Purgatoire Project—or TTP—is all about.

TTP is a collaborative effort between public agencies, non-profit organizations, and private landowners who work, live, and play in the Purgatoire River Watershed. They have been working together during the



past year to develop and implement a comprehensive plan to control woody invasive species. The Nature Conservancy, Purgatoire River Water Conservancy District, Colorado State Forest Service, Tamarisk Coalition, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, Spanish Peaks-Purgatiore River Conservation District, , Southeast Colorado Water Conservancy District, U.S. Forest Service, U.S. Department of Defense, local governments, and private landowners are leading the way—and the list of cooperators continues to grow.

Recognizing the enormity and importance of the effort they were about to undertake, project team members developed a charter and work plan to help them stay on track and monitor progress. In March 2005, they drafted a work plan and established five teams to implement specific goals and objectives. Following is a summary of the goals of each team:

See before and after photos on front page.

- Science Team–ensure that actions reflect the knowledge of experts by providing access to research and expert advice; capture and demonstrate the effects of restoration activities on multiple scales.
- Planning Team–develop a strategic watershed-scale plan based on the best available science and include views and needs of all interested stakeholders.
- Fundraising Team–fully fund the TTP Project by creating a comprehensive database of funding sources and developing and implementing a fundraising strategy.
- Education and Outreach Team–heighten awareness of the tamarisk issue to stakeholders; ensure effective, accurate, and precise communication about the project.
- Implementation Team–identify and implement projects that transform the watershed plan into effective, on-the-ground restoration.

With the organizational structure in place, the TTP Project team is focusing first on the development of a comprehensive map that pinpoints invasive woody tree populations. The map will help identify areas in which strategic treatment mitigates the establishment and spread of these undesirable species. The mapping effort is being funded by grants from the Colorado Water Conservation Board, Purgatoire River Water Conservancy District and The Nature Conservancy. Other grant applications have also been submitted for additional funding. After the mapping has been completed, scattered individual trees encountered on the upper reaches of the watershed, which provide a downstream seed source, will be removed. The team also will establish demonstration sites for educational purposes.

Future phases of the TTP Project involve the removal of target trees, completing work downstream from the remainder of the watershed, and monitoring and re-treatment as needed. A variety of control methods will be applied, depending on the location and density of tamarisk. Such methods include stump cut, foliar herbicide treatment and mechanical removal with later applications of herbicide as either a basal bark spray or foliar treatment to the regrowth. The team is also recruiting volunteers to help with eradication efforts.

To complement the work being done on the ground and foster support for the project, the team will continue to host public forums, distribute information about how to effectively control these invasive species, and work with local media to help keep the public informed about progress and events. The project has already received significant local media coverage. Newspapers in Trinidad published two front page articles about the project and Trinidad State Junior College taped a 30-minute interview that was broadcast on Trinidad cable television.

Recognizing that private landowners are instrumental to the success of the project, the team is also working with landowners to provide them with the information they need to make informed decisions about how best to control tamarisk on their land.

The TTP Project team is currently planning activities for spring 2006, which includes additional mapping that incorporates data from the National Institute for Invasive Species Science, identification of a demonstration site, and the application of eradication treatments at the top of the watershed. Meanwhile, interest continues to grow as new cooperators are added to the list of involved organizations. They all recognize that this is a long-term effort—and that the Purgatoire River Watershed and its native fisheries, rare riparian plant species, agriculturally based communities, and recreational users—depend on their success.

For more information about the Tackling Tamarisk on the Purgatoire Project, contact Shelly Van Landingham, Colorado State Forest Service, at (719)384-9097.

Flow Restoration:
Using Science to Anticipate Ecosystem Needs of Colorado's Mountain Streams

by Julia M. McCarthy, Christine M. Albano, David M. Pepin, and N. LeRoy Poff
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Water remains a scarce resource in Colorado and throughout the arid West. The U.S. Bureau of Reclamation (2003) projects continuing conflicts, with potential water shortages along the Colorado Front Range by 2025. One common approach to providing water to the Front Range (and elsewhere) is via streamflow diversion. Indeed, in Colorado there are approximately 109,000 active points of diversion on streams (CDSS 2000). Many of these diversions occur on small streams on the Western Slope of the Rockies, where water is transported by tunnels to the Front Range population centers. This movement of water provides a valuable resource, but at what cost to the aquatic ecosystems that are deprived of their native flows? The question of ecological damage caused by extensive streamflow diversion is one that has received very little attention, but one that we expect to become increasingly important in the future. Many scientific studies show that the ecological integrity (or health) of streams and rivers declines when too much water is removed from the channel (Poff et al. 1997, Richter et al. 1997), but what is "too much"? While there is a growing scientific literature on how streamflow alterations below larger dams impair stream and riparian ecosystems, this question has not been resolved for diversions on mountain headwater streams.

South Fork Ranch Creek in the Fraser River basin upstream (left) and downstream (right) of the diversion structure. *Photo Credit: Julia McCarthy*

Management and policy decisions on restoring river flows should be guided by the best available science. By providing clear definitions of ecosystem needs, scientists can aid in the policy-making process and help to balance the sometimes competing demands of ecosystems and stakeholders (Poff et al. 2003). Accordingly, the research conducted by our group at CSU focuses on quantifying the ecological effects of stream diversions. Specifically, we are investigating how aquatic ecosystems respond to differences in operational mode of diversion structures, the magnitude of diversion, and the location on the landscape. Additionally, we are trying to better define the flow needs for these ecosystems. We envision that our results will further improve diversion management by helping managers and stakeholders operate diversions in a way that maintains and restores the system's ecological integrity.

Mode of Diversion Operation

The Fraser River is at the headwaters of the Colorado River where it drains the western slope of the Arapaho National Forest's continental divide. The City of Denver diverts water from streams in the Fraser basin under the continental divide through the Moffat tunnel and into Gross Reservoir on South Boulder Creek. Diversion dams in the basin are operated to either take all the water from a stream or to allow some "bypass" or "fish flow" around the structure. Dams that dewater streams leave downstream sections virtually dry, with flowing-water riffle habitats becoming absent for up to a kilometer downstream. In some cases, however, the stream below a dewatering diversion structure receives groundwater flows due to local geologic conditions. In such cases, flowing habitats can return relatively quickly downstream, but at reduced levels compared to upstream of the diversion. Finally, some diversion structures are designed to bypass a near-baseflow volume of water (minimum flow) at all times. During the low flow period, reaches downstream of bypass structures appear very similar to upstream control (undiverted) reaches.

We have measured the ecological effects of these three modes of operation by examining the diversity of aquatic insects (water quality indicators) and production by stream algae in downstream versus upstream reaches on several streams. Interestingly, aquatic insect indices are significantly impacted by the complete dewatering mode, and much less so by the groundwater-return or bypass-flow operations. Many of the aquatic insects that are lost below the diversion structures require flowing water, which is largely absent. The proliferation of stream algae in the dewatered reaches is also significantly higher than in upstream, naturally flowing reaches, probably due to the reduced water velocities that cannot scour away these small "plants." However, this effect was not seen in reaches with groundwater-return or bypass-flow operational modes. We did not quantify indices of fish health in these streams, but we observed reduced abundances of fish in dewatered reaches and groundwater-return reaches, where stream depths were relatively shallow compared to bypass reaches.

At this time, we can say that for the transbasin diversions in the Fraser basin, groundwater connectivity and bypass flows ameliorate some of the effects of water removal, as diverted reaches within these operation categories did not diverge significantly from naturally-flowing reaches with respect to some measures of ecological integrity. The implications of this for restoration and management are that restoring or maintaining connectivity of surface or groundwater flows may contribute to maintenance of high ecological integrity in these systems.

Threshold of impact

A few previous studies in the Fraser Basin conducted by our group and others have indicated that when streams are diverted by less than about 50%, changes in aquatic insect communities are virtually undetectable, whereas in more severely diverted reaches, significant changes in habitat and community health are observed (Rader and Belish, 1999, Pepin and Poff, 2001). Based on these observations, another component of our research is to examine how aquatic communities respond across a more continuous gradient of baseflow diversion magnitudes, from minimal to near complete. To increase the generality of our results, we are investigating diversion effects by examining this response over multiple drainage basins in the Arapahoe-Roosevelt, Medicine Bow, and Routt National Forests. With this approach we hope to discover whether there is a threshold of diversion magnitude beyond which the biological community becomes severely impaired. The identification of any

Sampling Middle Fork Ranch Creek in the Fraser River basin upstream (top) and downstream (bottom) of the diversion structure. *Photo credit: Julia McCarthy 2005* biological response thresholds to streamflow diversion would aid greatly in determining what proportion of natural flow is needed downstream of diversions to maintain ecological integrity during baseflow periods.

Downstream recovery gradients

As the above studies illustrate, negative impacts of diversion on the integrity of aquatic habitat and biological communities can be ameliorated by re-entry of water to diverted reaches. In addition to groundwater, water is restored to diverted reaches from inflowing tributaries, which are likely to contribute to rapid recovery of aquatic habitat and communities. In recognition of this, a third component in our research program aims to quantify how quickly downstream diverted reaches may recover as a function of differing degrees of groundwater and tributary inputs. We are examining this question at a broad scale, sampling diverted streams from multiple basins across northern Colorado, all with varying degrees of flow diversion and recovery. With this approach, and with the aid of a geographic information system (GIS), we plan to design a multi-basin model to predict the number of stream miles impaired by diversion dams. This landscape-scale perspective on the biological impairment caused by diversion dams is important for furthering management and restoration efforts, as it provides scientific information at a scale relevant to river managers and policy makers.

Implications for restoration and management

Maintaining some flow below diversion dams is necessary to sustain a viable aquatic community. Our initial, and preliminary, data suggest that maintenance and/or restoration of stream ecosystem integrity may be achieved by providing a relatively small volume of water to pass through diversion structures. Based on our ongoing research, we expect to gain a better understanding of how the "landscape setting" influences the magnitude of diversion impact – for example, diversions in proximity to groundwater recharge areas or having downstream tributaries could potentially be managed differently than those having a slower recovery of flow.

Further, determining a threshold of impact in subalpine and montane streams can advance restoration efforts, especially for water users with permits on multiple structures in one area. For example, our research could eventually suggest that collecting small amounts of water from multiple streams would have fewer impacts upon stream biota than collecting large amounts of water from just a few streams. In the cases of large water diversion projects, where structures on several streams are already in place, incorporation of this knowledge into water management could enable th same amount of water to be collected, with fewer ecological impacts.

With growing populations on the Front Range, there is increasing interest to divert more water for human consumption. An opposing tension, however, may be the value that our modern society places on managing resources for ecosystem health. Good science is needed to determine how much alteration ecosystems can withstand and still remain "healthy." Our preliminary research on the impacts of diversion location, operation and magnitude can help shape management and policy decisions about our shared water resources. Furthering the conversation with water users, managers and policy makers on our research and restoration initiatives can improve the future of water management for all water users, human and aquatic.

References

CDSS. 2000. Hydrobase Database, Colorado Water Conservation Board.

Pepin, D.M. and N.L. Poff. 2001. Flow regime analysis of 7 Colorado trout streams. Report prepared for Trout Unlimited.

Poff N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks and J.C. Stromberg. 1997. The Natural Flow Regime: A paradigm for river conservation and Restoration. Bioscience 47(11). 769-784.

Poff, N.L., J.D. Allan, M.A. Palmer, D.D. Hart, B.D. Richter, A.H. Arthington, K.H. Rogers, J.L. Meyer and J.A. Stanford. 2003. River Flows and water wars: emerging science for environmental decision making. Frontiers in Ecology and Environment 1: 298-306.

Rader, R.B. and T.A. Belish. 1999. Influence of mild to severe flow alterations on invertebrates in three mountain streams. Regulated Rivers: Research and Management 15: 353-363.

Richter, B.D., Braun, D.P., Mendelson, M.A. and L.L. Master. 1997. Threats to imperiled freshwater fauna. Conservation Biology 11: 1081-1093.

USBR. 2003. Water 2025: Preventing crises and conflict in the West. U.S. Bureau of Reclamation.

Applying Fish Swimming Research to River Restoration Efforts

by Christopher A. Myrick
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Rivers throughout the United States have been modified to improve navigation or access, to produce hydroelectric power, to serve as conduits for water deliveries, or to control flooding or erosion. These changes, while undoubtedly beneficial, have often had unintended negative effects on the aquatic ecosystems found in those rivers. One of the most common effects is the loss of ecological connectivity that results from the installation of diversion dams, weirs, culverts, and various flood control structures in a river channel. These structures can impede the movement of fishes, particularly in the upstream direction, and when they form a barrier to upstream migrations, then the system's ecological connectivity has been severed, placing fish populations and aquatic communities at risk (Moyle et al. 1995; Schlosser and Angermeier 1995). In the most severe cases, the presence of an impassable impoundment or structure can lead to the local extirpation of one or more of the native fishes (Helfrich et al. 1999; Winston et al. 1991).

Fishery biologists and other resource managers have long been aware of these problems, and in the case of high-value fisheries, such as the salmon in Pacific coast rivers, have expended considerable effort designing and installing fish passage structures (fishways) to allow fish to successfully negotiate the instream obstacles (see Clay, 1995, for a comprehensive review). One class of these structures, the pool-and-weir fishways, take advantage of the tendency of salmon and trout to jump over obstacles during their upstream migration, and allow the fish to negotiate an ascending series, or ladder, of pools by jumping over the weirs. Other designs that do not require jumping were also developed, and these include Denil-type fishways, vertical slot fishways, and rock-ramp or nature-like fishways. These fishway classes rely on the manipulation of hydraulics to provide fish with water velocities that they can manage, and areas where they can rest between bouts of upstream movement. Unfortunately, a similar level of effort has yet to be made on the vast majority of the inland rivers, or for the majority of non-salmonid fish species that are not similar in performance to trout or salmon, such as minnows, darters, and suckers.

Many of the small-bodied fishes endemic to inland rivers are fairly strong swimmers, but they may not rely on their jumping ability to surmount obstacles, as is the case for large-bodied salmon and trout. Ongoing studies in the Fish Physiological Ecology Laboratory at Colorado State University using an innovative type of artificial waterfall (Kondratieff and Myrick 2005) have shed some light on the question of whether some of these small-bodied fishes will attempt to jump over a vertical obstacle. Theses studies have demonstrated that while small-bodied fishes, such as brassy minnows (*Hybognathus hankinsoni*) and fathead minnows (*Pimephales promelas*), will try to jump over a vertical obstacle representing a low weir. However, their small size (commonly less than 6" long) means that even if they can jump three times their own body length, a relatively short vertical obstacle (e.g., a two-foot high weir), can still represent an impassable barrier. The studies have also shown that other small-bodied fishes, like the Arkansas darter (*Etheostoma cragini*), cannot negotiate a vertical weir, even one that is only one body-length high. Because of these performance limitations, the use of classic pool-and-weir fish passage structures is not recommended for most inland rivers systems. Doing so would impose an artificial selective pressure on the local fish community, and, from an engineering standpoint, it would be probably be impractical to incorporate the number of small weir-steps needed to allow successful upstream passage of a fish that can only jump four or five inches high at a time. Fortunately, the extensive research on salmon and trout passage structures resulted in alternative designs that do not require the fish to jump (see above). Regardless of the type of fishway being considered, how does one adapt a structure developed for large, strong-swimming salmon and trout to successfully allow passage of these smaller, non-jumping fish species?

There are a number of biological factors that should be considered when designing a fish passage structure. First, one needs to know what fish species are present in the river and what their size range is. Where possible, additional information on the fishes' life history is valuable because it may identify critical times or seasons when migrations or mass movements occur. Once the fishes of interest are identified, data on their swimming performance is needed. The most useful information on swimming performance takes the form of species-specific swimming velocity *vs*. endurance curves that show how long fish of a known size can maintain a range of different swimming velocities (Katopodis 1994; Peake et al. 1997). These curves can be used by engineers to determine whether a fish, swimming at speed *Y*, will be able to cover a known distance (such as the length of a culvert) through which the water velocity is known, before it fatigues and is swept back downstream. In order to generate such a curve, a fish physiologist needs to measure the swimming performance of the species of interest at a wide range of speeds, from the fish equivalent of a slow walk to the equivalent of a sprint. Additionally, because of the well-documented effects of temperature and fish size on swimming performance (Myrick and Cech 2000), the studies should also be repeated for the range of water temperatures the fish are likely to encounter and for a realistic range of sizes. Studies of this nature are not technologically difficult, and can be performed in a standard fish physiology laboratory using a variety of swimming flumes. These studies are time-consuming, because of the number of variables that have to be tested, but they represent the best method of developing performance curves that are easily understood by fishery biologists and engineers alike.

Once suitable performance curves are available, fishery biologists and engineers should work together to develop a fishway design that affords maximum upstream access to the fishes of concern while meeting the constraints imposed by the site-specific topography, flow requirements, the original purpose of the structure, cost, and intrinsic values such as appearance. Compromises may have to be made in most cases (e.g., recognizing that passage of fish under a certain size will be impaired, or releasing slightly higher flows to ensure that the fishway is functional), and the decision on where those should fall will not be an easy one. Resource managers, stakeholders, and society at large will have to place a value on restoring ecological connectivity and weigh the costs and benefits of such efforts, while keeping in mind that adding fish passage structures cannot along restore a river to a natural state.

References

Clay, C. H. 1995. Design of fishways and other fish facilities., 2nd edition. Lewis Publishers, Boca Raton.

Helfrich, L. A., C. Liston, S. Hiebert, M. Albers, and K. Frazer. 1999. Influence of low-head diversion dams on fish passage, community composition, and abundance in the Yellowstone River, Montana. Rivers 7(1):21-32.

Katopodis, C. 1994. Analysis of ichthyomechanical data for fish passage or exclusion system design. Pages 318-323 in D. D. MacKinlay, editor High Performance Fish. Fish Physiology Association, Vancouver, BC.

Kondratieff, M. C., and C. A. Myrick. 2005. Two adjustable waterfalls for evaluating fish jumping performance. Transactions of the American Fisheries Society 134(2):503–508.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish species of special concern in California. Department of Wildlife & Fisheries Biology, University of California, Davis, Report # 2128IF, Davis, California.

Myrick, C. A., and J. J. Cech. 2000. Swimming performances of four California stream fishes: temperature effects. Environmental Biology of Fishes 58(3):289-295.

Peake, S., F. W. H. Beamish, R. S. McKinley, D. A. Scruton, and C. Katopodis. 1997. Relating swimming performance of lake sturgeon, Acipenser fulvescens, to fishway design. Canadian Journal of Fisheries and Aquatic Sciences 54:1361 - 1366.

Schlosser, I. J., and P. L. Angermeier. 1995. Spatial variation in demographic processes of lotic fishes: Conceptual models, empirical evidence, and implications for conservation. Pages 392-401 in J. L. Nielsen, editor. Evolution and the aquatic ecosystem: defining unique units in population conservation, volume 17. American Fisheries Society, Bethesda, MD, USA.

Winston, M. R., C. M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society 120(1):98-105.

Online Collection Facilitates Water Resources Research

By Patricia J. Rettig
Head Archivist, Water Resources Archive, Colorado State University Libraries

Libraries and archives often hear researchers saying they want—and even expect—materials to be online, easily accessed with a keyword and the click of a mouse. Though the immense volume of unique archival materials will never entirely be put on the Internet, archives do utilize this modern medium for increased access. The Colorado State University Water Resources Archive has recently become part of this effort with its Colorado's Waters Digital Archive [http://lib.colostate.edu/archives/cowaters/].

Still in its beginning stages, the Colorado's Waters Digital Archive (CWDA) debuts with fourteen reports on Colorado water projects. All fourteen come from the Water Resources Archive's Ival V. Goslin Water Resources Collection, which documents the Colorado Water Resources and Power Development Authority's activities during the 1980s. Goslin was the executive director of the Authority from 1982 to 1985.

From 1983 to 1990, the Authority conducted, at the request of local sponsors, several feasibility studies to find potential projects to finance. The engineering reports and basic data from the Authority-funded water planning studies constitute the Goslin Collection. Specific water project examinations now found in the Digital Archive include ones involving: Cherry Creek, Clear Creek, the Fraser River, the San Luis Valley, the Saint Vrain Basin, the Colorado River, the Upper Gunnison-Uncompahgre Basin and the Cache la Poudre River.

The reports are presented both as digital images of each page (nearly 3,000 of them) as well as searchable full text. A search on any word will show results of where that word appears on any page in all of the reports. This facilitates research not only through the searchability of previously print-only documents, but also brings all of these reports to computer desktops around the world.

While additional documents from the Water Resources Archive will be scanned and made available in the same manner over time, these particular reports were chosen for their relevancy to current topics being investigated in the state. The reports provide the data and information on projects once intended to be built in Colorado, but which never were constructed. As agencies around the state look for new water supply solutions, knowing what wasn't built and why can be very informative. Additionally, more historical information available facilitates more informed dialog by decision makers in the state, such as the interbasin roundtable participants.

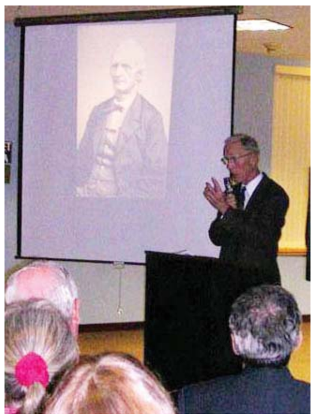
The CWDA is part of the Western Waters Digital Library [http://www.westernwaters.org/], a collaborative effort of the Greater Western Library Alliance that was funded by the Institute of Museum and Library Services. In addition to Colorado, libraries from five other states have contributed materials about water in the west, focusing on the Platte, Rio Grande, Colorado and Columbia river basins.

As stated earlier, not all materials in archives and libraries will find their way to the Internet. One solution these repositories are providing, though, is online lists of materials in their holdings. The Water Resources Archive does this through finding aids for each collection, which have been searchable online for nearly two years now, with new finding aids being added frequently [see http://lib.colostate.edu/archives/water/]. The CSU Libraries is also providing a new online list of water-related publications in its Colorado Agriculture Bibliography [http://lib.colostate.edu/research/agbib/], which specifically includes a section on irrigation and water.

To help libraries and archives in the daunting task of determining what to digitize for online access next, it is helpful to know what would be of benefit to today's students, researchers and water professionals. If you have ideas or suggestions along these lines, or have questions about the Water Resources Archive—physically or virtually—please contact Patty Rettig at 970-491-1939 or Patricia.Rettig@colostate.edu.

Celebration of Carpenter Papers a Success

The Colorado State University Water Resources Archive celebrated the opening of the Delph Carpenter Papers with a large, diverse audience in Morgan Library on November 18th. Numerous water resources professionals from campus and around the state attended, as did several archivists, many Carpenter family members, and quite a few people generally interested in history. Approximately 80 people joined in the celebration, enjoying the hors d'oeuvres, presentations and exhibits.



(Counter clockwise from top) Patty Rettig speaks with Colorado River Commission displayed on screen. Daniel carpenter (Delph's grandfather) rovides backdrop for Dan Tyler's presentation. Robert Ward chats with Greg Silkensen (Northern Colorado Water Conservancy District). M.J. Carpenter and Doris Carpenter enjoy the festivities.

Delph Carpenter served as lead counsel in the *Wyoming vs. Colorado* case and later wrote and negotiated several of Colorado's river compacts. His correspondence, professional papers, personal materials and those of his family were donated to the Water Resources Archive in May 2004. It took nearly a year and a half of work to make them available for research use.

The celebratory evening's presentations commenced with Dean of Libraries Catherine Murray-Rust speaking about the importance of archives, followed by Archives and Special Collections Coordinator Janet Bishop addressing the strengths and benefits of the Water Resources Archive in particular. Bishop then introduced the first of two speakers, CSU history professor emeritus Dan Tyler.

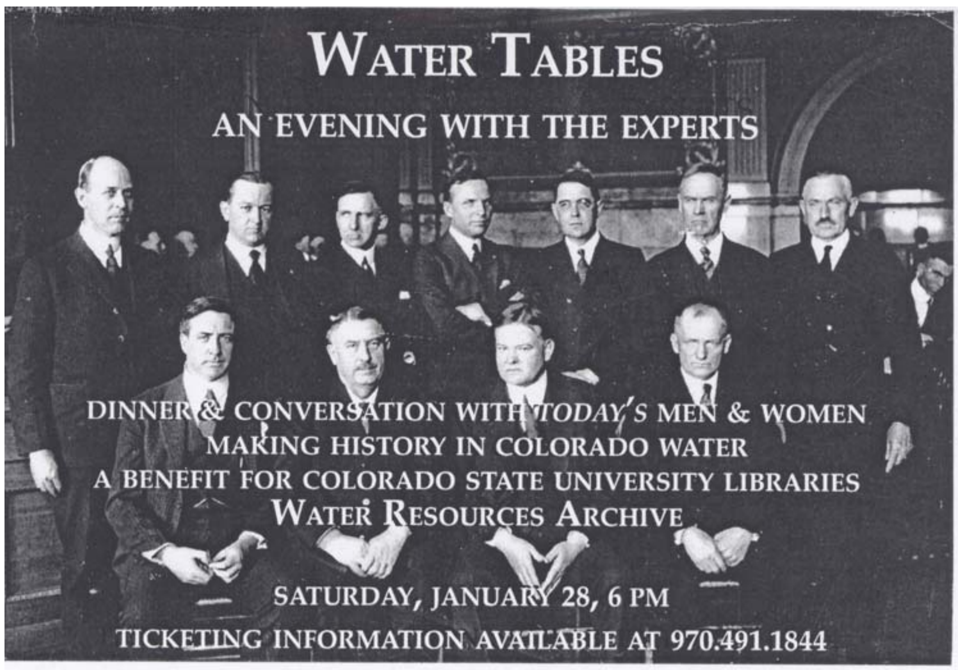
Dr. Tyler wrote the biography *Silver Fox of the Rockies: Delphus E. Carpenter and Western Water Compacts* using the Carpenter Papers as well as other resources. He spoke about Carpenter and the lessons that can be learned today from Carpenter's negotiation of the Colorado River Compact. Tyler then described his upcoming book, *Love in an Envelope*, which relies on Delph's parents' courtship letters to tell a long-distance love story. Leroy Carpenter courted Martha Bennett from Greeley for over a year before going back to Iowa in 1872 to marry her. Their letters cover many topics, including what makes a marriage work, women's rights and irrigation ditches.

The second speaker was Patty Rettig, the archivist who prepared the Carpenter Papers for use by the public. Rettig briefly described and showed slides of what was in the collection and then detailed the work required to make the collection usable. She demonstrated the condition of the materials upon arrival, and showed the equipment purchased to facilitate the mold cleaning process.She described the cleaning procedure as well as the sorting process needed to organize the materials, which ultimately came to be housed in 127 boxes, three flat files and nine tubes. Rettig concluded with some examples of unexpected items in the collection, including a letter written by "a youthful bovine bachelor."

Following the presentations, the audience had a chance to pick up a copy of the *Guide to the Papers of Delph E. Carpenter and Family* and purchase *Silver Fox of the Rockies*. A small exhibit on "Carpenter and the Compacts" was on display in the presentation space, and original materials from the collection were on view in the Archives. The exhibit there was entitled "Dot Carpenter: The Woman Behind the Man" and was accompanied by various materials for guests to examine more closely, including a 155-year-old photograph and original newspaper coverage of compact negotiations.

One of the highlights of the evening was the presence of so many Carpenter family members, including one who came all the way from Connecticut to join in the celebration and two who had known Delph at the end of his life.

The Carpenter collection is now open for all to use. Details can be found on the Water Resources Archive website [http://lib.colostate.edu/archives/water/], or a paper copy of the finding aid can be requested by contacting Patty Rettig at 970-491-1939 or Patricia.Rettig@colostate.edu.



"Colorado River Commission, 1922." Originally printed in the *Denver Post*. From the papers of Delph E. Carpenter and Family. Courtesy of Water Resources Archive, Archives & Special Collections.

Water Resources Research Competitive Grant Proposals
Due February 10, 2006

The Request for Proposals for the FY 2006 National Competitive Grants Program authorized by section 104G of the Water Resources Research Act of 1984 has been released. The RFP may be obtained either by going to https://niwr.org/ and clicking on "View the RFP" under "National Competitive Grants Program" or by going directly to https://niwr.org/competitive_grants/2006RFP104G. The research priorities for FY 2006 differ only slightly from those of last year.

The closing date for proposals to be filed on the web site by principal investigators is 5:00 PM, Eastern Standard Time, February 10, 2006. Submittal of the proposal must be coordinated with Colorado Water Resources Research Institute and Colorado State University Office of Sponsored Programs. Once you have completed entry of the on-line portion of the proposal, contact CWRRI at (970) 491-6308 to coordinate the approval and final submittal.

Nobel Prizes and Irrigation Ditches: Some Thoughts about Thomas Schelling, Social Conflict, and Water Organizations

by David M. Freeman
Professor Emeritas, Department of Sociology, Colorado State University

On October 10, the Royal Swedish Academy of Sciences announced its decision to award the Nobel Prize in Economic Sciences jointly to Thomas C. Schelling and Robert J. Aumann. Dr. Schelling, after having taught 20 years at Harvard University's John F. Kennedy School of Government, now is on the faculty of the School of Public Policy at the University of Maryland, College Park. Professor Aumann serves at the Center for Rationality, Hebrew University, Jerusalem, Israel.

Tom Schelling is a game theorist who worked within the context of the deep international polarization of the cold war years. His *Strategy of Conflict* (1960) and *Arms and Influence* (1966) became classics that were received as much more than economic studies. They were analyses of underlying processes that had application in the several social sciences and would inform scholars in sociology, political science, and anthropology for decades to come. Many economists have treated persons as individual decision-makers seeking preference satisfaction without reference to their position in social organizational networks. People have been viewed by them as being free to trade away the things they do not want to get the things they do without consideration of family ties, organizational rules, or other network constraints. Dr. Schelling, an economist by training, began with the sociologists' premise–i.e., people's choices are fundamentally conditioned by their position in networks of social organizational interaction. Schelling saw that a single individual can seldom determine what will happen in a given choice situation. Rather, individual people engage in interaction in ways that modify each other's prospects–i.e., what one does, or is expected to do, conditions the actions of another. The essence of game theory is the systematic study of strategic interaction. Alternatively stated, game theory is about how competing players can attempt to get what they want in a conflict situation via some degree and kind of cooperation constrained by the shape of the network in which they find themselves. It is posited that lessons can be applied in all kinds of social interactional settings whether in arms races or among rival water users.

In real-world situations finding ways to rationally obtain objectives can be difficult in any single conflict game framework; it is fundamental that cooperation will be easier to obtain and sustain when the players must face each other in future multiple encounters–i.e., when they know that they cannot escape each other in the future. Robert Aumann, mathematician, earned his share of the prize because he: a) employed mathematical tools to concisely draw out specific hypotheses; and b) provided ways to study repeated strategic interactions among rational players over many game encounters.

Why are sociologists, political scientists, and anthropologists indebted to these prize winners? What possible application could all this have to the real world of water organization, conflict, and cooperation? Basically, what game theorists of several varieties have repeatedly demonstrated is that what is perfectly rational for each individual player seeking to maximize personal goal achievement will, under specified conditions, be perfectly disastrous for the community of players. Game theory has logically established that–-under specified conditions frequently found in the real world–-individual rationality will not lead to collective rationality.

Let us look at a simple example. Two individually rational farmers ponder the possibility of building an improved watercourse for channeling irrigation water to their adjacent fields. The total cost of the improvement is, shall we say, $600. However, the benefits to farmer A equal only $400 while those to farmer B amount to $500. From the standpoint of their collective joint benefit, the improvement should be made–they collectively would enjoy $900 of benefits, well in excess of the $600 cost. However, if each farmer only looks at his or her privately captured benefits neither will build the improvement. Each farmer individually does better not contributing to the common good while hoping that the other–in an economically irrational but altruistic move–will build the improvement and thereby allow the non-contributing member in this game to enjoy benefits of increased water supply and control. Because each calculates in the same rational but selfish manner, neither invests and both find a equilibrium with each other that is much worse off as compared to what they could gain together by cooperative action. They are simultaneously rational in an individual sense, but are irrational in a collective sense.

Obviously, throughout history people have found themselves in such situations and for thousands of years people in virtually all cultures have surmounted the problem of individual rationality by getting organized. Now this is the stuff of sociology. If farmers A and B can devise means of holding each other accountable for making a "fair share" contribution, if they can each insure that the other will not defect from agreed upon cooperative action–in other words if they get organized in a viable way–they can work cooperatively to improve their situation. The game theory tradition to which Professors Schelling and Aumann have made their important contributions has allowed social scientists to pose two questions of great interest: 1) what are the attributes of self-sustaining social organizations that can empower individually rational actors to transcend their individual rationalities and thereby improve the conditions under which they live and work; and 2) how can individually rational players be mobilized to construct such empowering organizations? These two questions are central to analysis of water management problems because water capture and delivery generally involves conflict among human purposes and requires getting organized to undertake cooperative action that self-seeking behavior in marketplaces cannot provide.

For the better part of 38 years this author has, along with colleagues in CSU sociology–working in interdisciplinary collaboration with engineers, economists, agronomists, and other natural resources disciplines including law–been studying the two big questions in the context of local organizations for managing water domestically and internationally. Our strategy has been to study local organizations in specific locales (e.g., Pakistan, India, Sri Lanka, Nepal, Philippines, Western United States and most especially Colorado) by finding examples of failed organizational efforts and by comparing them to long enduring successful organizations in the same agro-climatic zones, same cropping patterns, same language and culture patterns. The task has been to tease out crucial variables that explain the differences in performance (Freeman and Lowdermilk, 1985, 1991; Freeman, Bhandarkar, Shinn, Wilkins-Wells, 1989 and Wilkins Wells, 1989)

We compare our findings to the work of others who have been probing the same questions (e.g., Ostrom, 1990; Bromley, 1992). For example, CSU sociologist Dr. John Wilkins-Wells has been studying the organizational needs (a variation on question 1) of a diverse array of mutual companies and irrigation districts in several western states. As this is written, the author is now studying the second question–how individually rational actors are mobilized to cooperate to re-regulate the waters of the Platte River basin for purposes of recovering endangered and threatened species under the Endangered Species Act (Freeman, 2003 and Freeman, forthcoming)

Neither Schelling nor Aumann ever did fieldwork. However, those of us in the social science community who have followed the literature of game theory, and whose thinking about the meaning of our fieldwork has profited from their insights, salute them. They have provided foundations upon which much theory of social organization, conflict, and cooperation in the world of water management has been, and will continue to be, constructed.

Literature Cited:

Bromley, Daniel (ed.). *Making the Commons Work: Theory, Practice, and Policy*. (Institute of Contemporary Studies Press, 1992).

Freeman, David M., and Max K. Lowdermilk. "Middle Level Organizations As Links Between Farms and Central Irrigation Systems." in *Putting People First: Sociological Variables in Rural Development*. Edited by Michael Cernea (Published for the World Bank, Oxford University Press, 1986, 1991. 113-144.

Freeman, David M. (with Vrinda Bhandarkar, Edwin Shinn, John Wilkins-Wells, Pat Wilkins Wells). *Local Organizations For Social Development: Concepts and Cases of Irrigation Organization. (Westview, 1989)*.

Freeman, David M. "Organizing for Endangered and Threatened Species Habitat in the Platte River Basin." Special Report 12. Colorado Water Resources Research Institute, Colorado State University, Fort Collins. September, 2003. This interim report is precursor to what is yet an untitled book manuscript that will examine, in detail, how individually rational water users in Colorado, Wyoming, and Nebraska came to transcend their individual rationalities and to collectively mitigate conflicts and construct a Platte River Basin Habitat Recovery Program in collaboration with the U.S. Department of Interior.

Ostrom, Elinor. Governing the Commons: The Evolution of Institutions for Collective Action. (Cambridge, 1990).

MEETINGS

Ag Water Interests Convene the First Colorado Agricultural Water Summit

The Colorado Agricultural Water Summit was held on November 4, 2005 at the Adams County Fairgrounds in Brighton, Colorado. The Summit was a one-day facilitated process designed to engage Colorado Ag water leaders in identifying and addressing key water issues facing the industry. The goal of the Summit was to initiate a process for unifying and strengthening Ag's voice in water management and policy.

(Above) Mike Mitchell of Mitchell Farms in the San Luis Valley (left) and Jim Reasoner of Central Colorado Water Conservancy District (right) listen as Bob Sakata of Sakata Farms reports the results of the group discussion.

(Below) Frank Jaeger of Parker Water and Sanitation, David Robbins of Hill and Robbins, Representative Kathleen Curry, and Representative Diane Hoppe field questions from the audience.

Key Colorado agricultural organizations nominated and sent 120 delegates to the Summit to represent diverse perspectives and industry sectors. These organizations included: Colorado Association of Conservation Districts, Colorado Cattleman's Association, Colorado Corn Growers, Colorado Farm Bureau, Colorado Grain and Feed Association, Colorado Green Industry, Colorado Livestock Association, Colorado Wheat Growers Association, Rocky Mountain Farmers Union, Western Dairy Association, Colorado Department of Agriculture, and Colorado State University. The Summit was facilitated by MaryLou Smith of Aqua Engineering, with assistance from a team of Colorado State University (CSU) Cooperative Extension faculty.

The Summit delegates heard from several speakers during the day including Rick Brown of the Colorado Water Conservation Board, Ag Commissioner Don Ament, Division of Natural Resources Director Russ George, Frank Jaeger of Parker Water, David Robbins of Hill and Robbins, Rep. Kathleen Curry and Rep Diane Hoppe. These speakers discussed the stresses on Ag water supplies and the need for Ag to look for creative solutions to help maintain viable systems for those who wish to continue farming and ranching.

A series of questions were posed to the delegates for discussion in breakout groups and during the general sessions. The questions were designed to help the delegates think through the challenges and opportunities that Ag might face in uniting around water issues. These included:

- What are the interests Colorado Agriculture wants to preserve in any water negotiations or transactions?
- What interests unite us and which ones divide us when it comes to water?
- How can Colorado Agriculture unite to promote our interests in regards to water?
- What solutions can we come up with to reconcile the differences which divide us from each other and from other users of Colorado's water?
- What strategies or options can we organize ourselves around?

While many diverse opinions were expressed by the delegates over the course of the day, some common themes and difficult challenges emerged. The delegates identified significant barriers that tend to splinter the agricultural community: East slope versus West Slope, ground water versus surface water appropriators, senior versus junior water rights, water shortages, and proximity to urban water markets. One delegate remarked that water was the single most divisive issue facing Colorado agriculture. Additionally, some paradoxes were identified that challenge the Ag community. Chief among these is the individual right to sell water rights to the highest bidder, versus the general interest in thriving rural communities and a healthy agricultural economy. A second paradox is a rock-solid belief in the doctrine of prior appropriation, in contrast with the clear need for more flexibility in the way water is administered in Colorado.

Delegates discuss options in breakout sessions (above).

MaryLou Smith of Aquaengineering with panel of delegates report on options identified by groups.

Many common interests were identified that serve to unite agriculture. Among these is the general interest in helping farmers and ranchers remain profitable, with adequate water supplies and supporting infrastructure. Unreliable water supplies will eventually erode the markets for Colorado Ag products that have been developed as a result of much community effort. Intermittent water will not preserve the ditch infrastructures and operating practices, nor will labor be reliably present if the field work is uncertain. In general, the delegates stated that a strong agricultural economy serves Colorado well by providing food security, jobs, rural communities, open space, wildlife habitat, a sense of our heritage, and a buffer to the environmental and social impacts of population growth.

The delegates discussed many ideas for strengthening Ag's position in water management and policy. In general, it was agreed that greater communication and cooperation both within Ag and with the larger water community is needed to find solutions that are in the best interest of Colorado. More storage, more flexibility, more options for Ag producers, more cooperation from federal agencies, more education and more research are all needed to help us develop cooperative solutions to Colorado's water needs, while sustaining a healthy Ag industry in the state.

At the end of the Ag Water Summit, delegates focused their attention on future steps for the Ag community as it attempts to unite and strengthen its ability to negotiate for a better future. They discussed the need for a new state-wide Ag water organization, versus the potential benefits of working more closely with the Colorado Water Congress. In the end, a decision was made to have the participating Ag organizations work with the Ag Council to form an interim think-tank to further explore the options and strategies that the Ag groups should cooperatively pursue. The interim group will report back to the community at large at the upcoming Ag Outlook Forum on February 23, 2006 in Denver. For more information, contact Reagan Waskom at (970) 491-2947 or reagan.waskom@colostate.edu.

RESEARCH

Colorado State University, Fort Collins, Colorado
Awards for October 2005 to November 2005

Pielke,Roger A--Atmos Sci--NASA - Natl Aeronautics & Space Admin.--*Integrated Regional Climate Study with a Focus on Land-Use-Land-Cover Change & Associated Changes in Hydrological* --**$200,000.00**

Pielke,Roger A--Atmos Sci--NASA - Natl Aeronautics & Space Admin.--*Sensitivity of the Arctic Climate System to Changes in Shrub Stature & Distribution*--**$24,000.00**

Douglas,Marlis R—Fish and Wildlife Bio--Turner Enterprises, Inc.--*Introgression in Rio Grande Cutthroat Trout* --**$16,886.00**

Swift,Curtis E--Cooperative Extension--Colorado River Water Conservation Dist.--*The Mesa County Irrigation Audit Program* --**$6,972.00**

Ward,Robert C and **Luis Garcia**--CWRRI--Various "Non-Profit" Sponsors--*Developing a Decision Support System for the South Platte Basin*--**$10,000.00**

Thornton,Christopher I--Civ Eng--PJR Consulting, Inc.--*Hydraulic Model Study, Baglihar Hydropower velopment, Sediment Excluding Intake Hydraulic Model*--**$61,897.00**

Demott,Paul J--Atmos Sci--University of Nebraska--*Investigation of Hygroscopicity and Cloud- and Ice-Nucelating Activities of Combustion Aerosols*--**$107,170.00**

Khosla,Rajiv--Soil Crop Sci--USDA-NRCS-Natural Resources Consvtn Srv--*Innovative Precision Manure Management Strategies Using Site-Specific Management Zones for Enhancing Water Quality.*--**$74,978.00**

Hansen,Neil--Soil Crop Sci--USDA-NRCS-Natural Resources Consvtn Srv--*Sustainable Cropping Systems for Transition from Full Irrigation to Limited Irrigation and Dryland*--**$74,381.00**

Dillon,Merlin A—Cooperative Extension--USDA-NRCS-Natural Resources Consvtn Srv--*The San Louis Valley Drip Irrigation Initiative* --**$75,000.00**

Breidt,F Jay--Statistics-Oregon State University--*Applying Design-Based Model Assisted Survey Methodology to Aquatic Resources*--**$151,426.00**

Conant,Richard T--Nat Res Eco Lab--University of Colorado--*DMUU: Science Policy Assessment & Research on Climate (SPARC) for Decision-Making Under Uncertainty*--**$8,000.00**

Cotton,William R--Atmos Sci--NSF - National Science Foundation--*Collaborative Research: Inhibition of Snowfall by Pollution Aerosols*--**$76,263.00**

Gates,Timothy K--Civ Eng--Lower Arkansas River Valley Water Conservancy Dist.--*Monitoring and Modeling Toward Optimal Management of the Lower Arkansas River*--**$25,000.00**

Schneekloth,Joel--Cooperative Extension--USDA-NRCS-Natural Resources Consvtn Srv--*Limited Irrigation and Crop Rotation Demonstration in the Republican Basin*--**$59,986.00**

Poff,N LeRoy--Biology--USDA-USFS-Forest Research--*Aquatic Ecosystem Responses to Streamflow Diversion*--**$23,300.00**

Ramirez,Jorge A--Civ Eng--DOD-ARMY-ARO-Army Research Office--*Instrumentation to Investigate the Hydrologic Response of an Ephemeral Desert Wash*--**$56,517.00**

Sanders,Thomas G--Civ Eng--DOI-NPS-National Park Service--*Preservaton, Protection, & Management of Water Aquatic Resources of Units of the National Park System*--**$124,000.00**

Ward,Robert C--CWRRI--DOI-USGS-Geological Survey--*Produced Water Workshop* --**$43,602.00**

Whitley,L Darrell--Comp Sci--Raytheon Company*--*Intelligent Agents for Severe Weather Tracking* --**$20,000.00**

Shaw,Robert B--CEMML--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*Strategic Planning GIS Support to Meet Sikes Act Require-*

ment SOW 05-12 for US Army Alaska--**$1,224,000.00**

Garcia,**Luis**--Civ Eng--USDA-ARS-Agricultural Research Service--*Apply & Enhance the Object Modeling System for Building New Models for Field, Farm, & Watershed Scales*--**$200,000.00**

Bestgen,Kevin R--Fish and Wildlife Bio--DOI-Bureau of Reclamation--*Research Framework for the Upper Colorado River Basin*--**$10,465.00**

Fausch,Kurt D--Fish and Wildlife Bio--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*Tradeoffs Between Native Fish Passage and Non-native Fish Invasions*--**$9,000.00**

Vonderhaar,Thomas H--Atmos Sci--DOC-NOAA-Natl Oceanic & Atmospheric Admn--*Environmental Applications Research Project* --**$185,672.00**

Myrick,Christopher A--Fish and Wildlife Bio--University of Washington--*Evaluation of Larval Starter Diets and Culture Conditions for 3 Subspecies of Cutthroat Trout and Gila Trout*--**$28,031.00**

Fassnacht,Steven--For Range Waters Stwrdshp--NASA - Natl Aeronautics & Space Admin.--*Quantifying Scale Relationships in Snow Redistribution: A Systems Approach*--**$24,000.00**

Shaw,Robert B--CEMML--Parsons Infrastructure & Tech Group, Inc--*Sustainable Range Program, Geographical Information Systems, Western Regional Support Center*--**$37,007.00**

Thornton,Christopher I--Civ Eng--Cottonwood Research, LLC--*Yalobusha River Data Collection and Training* --**$111,264.00**

Vonderhaar,Thomas H--Atmos Sci--DOC-NOAA-Natl Oceanic & Atmospheric Admn--*Funds for the Cooperative Institute for Research* --**$165,000.00**

Loftis,Jim C--Civ Eng--DOI-NPS-National Park Service--*Clean Water Act Impairments and Use Designations for National Park System Water Resources*--**$25,000.00**

Shaw,Robert B--CEMML--Parsons Infrastructure & Tech Group, Inc--*ITAM Program Support HQ, USARC Off-Campus*--**$123,947.00**

Wohl,Ellen E--Geosci--USDA-USFS-Forest Research--*Aquatic, Wetland and Riparian Assessments for the Rocky Mountain Region*--**$20,000.00**

Rathburn,Sara L--Geosci--USDA-USFS-Forest Research--*Analytical Framework for Assessing Effects of Stream Hydrology on Fish Habitat and Riparian Vegetation* --**$25,000.00**

Smith,Freeman M--For Range Waters Stwrdshp--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*Mapping Snow Properties: A Multi-Scale Approach* --**$9,459.00**

Thornton,Christopher I--Civ Eng--Mussetter Engineering, Inc.--*Kootenai River Hydraulic Model Study* --**$49,881.00**

Binkley,Daniel E--For Range Waters Stwrdshp--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*Biogeochemistry of Riparian Wetlands on Rocky Mountain Headwater Streams*--**$7,500.00**

Trlica,Milton J Jr--For Range Waters Stwrdshp--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*Patterns of Vegetation Recovery following Control of Invasive Plants*--**$17,034.00**

Child,R Dennis--For Range Waters Stwrdshp--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*Monitoring Rangeland Sustainable Management* --**$6,584.00**

Doherty,Paul F Jr—Fish and Wildlife Bio--DOI-USGS-Geological Survey--*Design and analysis for evaluation of human impacts on trust species of the US Fish & Wildlife Service*--**$70,000.00**

Stephens,Graeme L--Atmos Sci--DOC-NOAA-Natl Oceanic & Atmospheric Admn--*Study of the direct and indirect effects of aerosol on climate*--**$131,236.00**

Waskom,Reagan M--Civ Eng--USDA-CSREES-Coop State Rsrch Edu & Ext-*Coordinated Agricultural Water Quality Programming for the Northern Plains and Mountains Region*--**$592,000.00**

Ramirez,Jorge A--Civ Eng--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*Vulnerability of the United States Water Supply System to Shortage*--**$34,440.00**

Ramirez,Jorge A--Civ Eng--USDA-USFS-Rocky Mtn. Rsrch Station - CO--*The system-wide water quality impacts of watershed disturbance*--**$3,500.00**

Salas,Jose D--Civ Eng--DOI-Bureau of Reclamation--*Phase II: Development of Stochastic Hydrology for the Colorado River System*--**$150,772.00**

Doesken,Nolan J--Atmos Sci--DOC-NOAA-Natl Oceanic & Atmospheric Admn--*Documenting Historical Climate Network Stations in Colorado*--**$15,000.00**

Loftis,Jim C--Civ Eng--DOI-NPS-National Park Service--*Status and Trends of Impaired, Threatened, & Outstanding National/State Resource Waters in the ?*--**$452,600.00**

Wohl,Ellen E--Geosci--USDA-USFS-Forest Research--*Mapping Longitudinal Distributions of Wood Along Forest Streams*--**$21,100.00**

Kummerow,Christian D--Atmos Sci--NASA - Natl Aeronautics & Space Admin.--*The Role of Warm Rain Systems in the Tropics* --**$24,000.00**

Steltzer,Heidi--Nat Res Eco Lab--University of Alaska at Anchorage--*Collaborative Research: Coupling of Carbon and Water Cycles in a Cold, Dry Ecosystem: Integrative Physical, Chemical*--**11,547.00**

University of Colorado, Boulder, Colorado

Williams, Mark, Long Term Ecological Research: The Landscape Continuum Model: A Biogeochemical Paradigm for High Elevation Ecosystem, **$4,920,000**

Williams, Mark, NPS, Developing Screening Procedures and Sampling Protocols for Assessment of Deposition-Sensitive Surface Waters in the Rocky Mountains, **$50,000**

Williams, Mark, NPS (PI); Development of Vital Signs for the N-Status of Ecosystems in National Parks: DIN, DON, and C:N in Streams and Rivers, **$32,440**

Williams, Mark, Colorado Mountain College Isotope Tracing Analysis for Leadville Mine Drainage Tunnel, California Gulch Superfund Site and Affected Areas, **$135,152**

Colorado School of Mines, Golden, Colorado

McCray, John E.—U.S. DoD SERDP – Polymer enhanced remediation using bioremediation amendments and chemical oxidants --**$544,472.00**

McCray, John E.—Water Environment Research Foundation – Watershed-scale modeling of decentralized wastewater systems --**$280,000.00**

McCray, John E. – U.S. EPA, Scientific, technical, research, engineering, and modeling support (STREAMS) **– ~ $1.5M** (estimated)

Poeter, Eileen - Air Force Center for Environmental Excellence via Mitretek Systems - Colorado School of Mines Support to the Air Force Center for Environmental Excellence Project in Redlands, California **-- $69,720**

Poeter, Eileen and McCray, John - Exxon-Mobil Corporation - Support for Environmental Modeling Research -- **$10,000**

NOTE: All research awards from Colorado School of Mines and University of Colorado are self-reported by the principal investigator.

MEETINGS

26th Annual American Geophysical Union

Hydrology Days
March 20-March 22, 2005

Cherokee Park Room in the Lory Student Center
Colorado State University, Fort Collins, CO

Hydrology Days Award Lecture
Frontiers in Hydrologic Sciences:
Complexity and Organization in Hydrology
by Professor Rafael L. Bras of Massachusetts Institute of Technology

Borland Lecture in Hydrology
Hydromorphology: Hydrology in an Evolving World
by Professor Upman Lall of Columbia University

Borland Lecture in Hydraulics
Impulse Waves, Shore Instabilities and Tsunamis
by Professor Willi H. Hager of ETH, Zurich

Paper abstract submittal deadline: February 10, 2006

Registration fees: $100 by February 24, 2006; $150 after February 24, 2006
Free registration to students

For more information on programs, paper submittal, or to register, go to:
http://hydrologydays.colostate.edu/

The International Soil and Water Conservation Society
Annual Meeting - July 2006
Keystone, Colorado
For more information go to:
http://www.swcs.org/en/swcs_international_conferences/2006_international_conference/

Colorado State University Cooperative Extension

Ogallala Aquifer Symposium

Monday, February 20, 2006

Wray High School Auditorium - Wray, CO

Water Conservation – Creative Solutions for the Future

This symposium will enlighten you about the "Big Picture" of the Ogallala Aquifer and bring you up to date with the current water use and management practices; as well as provide food for thought on the issues concerning the future and protection of this most valuable resource.

Registration: 7:40 – 8:30 a.m.

THE OGALLALA AQUIFER

Sessions

Republican River Litigation – Update From States

- Colorado -- Scott Richrath
- Nebraska -- Dave Barfield
- Kansas -- Ann Bleed (invited

Republican Water Conservation District

- District Update – Dennis Coryell
- Program Update for Water Conservation -- Scott Richrath

Water Management Impacts

- Impacts of Management and Technology -- Dr. Luis Garcia (CSU)
- In-season impacts of residue -- Dr. Norm Klocke (KSU)
- Off-season impacts of residue – Dr. David Nielsen (ARS)

Lunch & Exhibits

Drought and the River

- Understanding the River - Jim Goeke (UNL)
- Drought – Impacts and Depth -- Dr. Nolan Doesken (CSU)

Water Management and Legislative Issues

- Water Management and Crop Selection for Limited Water -- Joel Schneekloth (CSU)
- Legislative Issues impacting Water -- Commissioner Don Ament (Colorado Dept of Ag)

Who should attend? Ag producers, elected officials, city council/mangers, electric association boards, conservation district boards, ground water management boards, people associated with water use issues and citizens of the region.

Registration Fee Includes: Lunch, Breaks & Handouts

Postmarked by February 6th – \$20/person; Late Registration Fee - \$30/person

Payable to: Golden Plains Area Extension, Akron, CO 80720

For a printable registration form and/or more information, go to www.goldenplains.colostate.edu

Commercial booths and exhibits - \$150 For more information call 970-345-2287

Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating

Cooperative Extension programs are available to all without discrimination

Colorado Water Congress

2006 Annual Convention

January 26-27, 2006

Denver, Colorado

CWRRI has organized the following sessions for the 2006 CWC Annual Convention:

Protecting, Preserving, and Promoting Colorado's Water History: Update on Water Archiving Efforts in Colorado

Panel:

Karen Rademacher, DARCA

Hal Simpson, State Engineer's Office

Rod Kuharich, Colorado Water Conservation Board

Janet Bishop, Archivist, Colorado State University's Morgan Library

Moderator: Robert Ward

Contributions to the 1177 Process from Water Research

Panel:

New USDA ARS Water Management Research Leader, Fort Collins, CO

James Pritchett, Agricultural and Resource Economics, CSU

Lyn Kathleen, Colorado Center of Public Policy, CSU

Moderator: Reagan Waskom

Additionally, there will be presentations by the presidents of two of Colorado's institutions of higher learning -- Hank Brown and Larry Edward Penley

For more information go to : http://www.cowatercongress.org/meeting_notices.htm

CALENDAR

2006	2006
Jan. 11-13	**Four States Irrigation Council 53rd Annual Meeting.** Fort Collins, CO. For more information contact vgomez@ncwcd.org.
Jan. 26-27	**Colorado Water Congress 48th Annual Convention.** Denver, CO. For more information go to: www.cowatercongress.org, or phone 303/837-0812, or email macravey@cowatercongress.org .
Feb. 16	**2005 Annual Meeting and Symposium of Big Thompson Watershed Forum.** Greeley, CO. For more information go to www.btwatershed.org.
Feb. 22-24	**Ditch and Reservoir Company Alliance 2006 Annual Convention.** Montrose, CO. For more information go to www.darca.org.
Mar. 20-24	**Applied Environmental Statistics, Colorado School of Mines, IGWMC Short Course.** (location to be announced). For information on registration deadlines, fees, or to register online, go to http://www.mines.edu/igwmc/short-course/

Apr. 14	**Colorado water Supply issues – Today and Tomorrow.** Mount Vernon Country Club, Denver, CO. For more information go to www.awar.org/state/colorado/conferences.htm.
May 4-5	**Third Annual Water Law, Science and Policy Conference.** Nebraska City, NE. For more information go to: http://snr.unl.edu/waterconference/.
May 8-10	**American Water Resources Association 2005 Spring Specialty Conference: Geographic Information Systems (GIS) and Water Resources IV.** Houston, TX. For more information go to: http://www.awra.org/meetings/Houston2006/index.html .
May 17-19	**9th Inter-Regional Conference on Environment – Water: Concepts for Watermanagement and Multifunctional Land-Uses in Lowlands.** Unesco I.H.E., International Institute for Infrastructural, Hydraulic and Environmental Engienering, Delft, The Netherlands. For more information go to http://www.wau.nl/rpv/isomul/envirowater2006.
May 19-21	**Polishing Your Ground-Water Modeling Skills**, **Colorado School of Mines IGMWC Short Course.** Golden, CO. For information on registration deadlines, fees, or to register online, go to http://www.mines.edu/igwmc/short-course/
May 19-21	**Intro to ArcGIS, Colorado School of Mines IGMWC Short Course.** Golden, CO. For information on registration deadlines, fees, or to register online, go to http://www.mines.edu/igwmc/short-course/
May 19-21	**Finite Element Groundwater Modeling using FEFLOW, Colorado School of Mines IGMWC Short Course.** International Ground Water Modeling Center, Golden, CO. For information on registration deadlines, fees, or to register online, go to http://www.mines.edu/igwmc/short-course/
May 19-21	**MODFLOW-2000: Introduction to Numerical Modeling, Colorado School of Mines IGMWC Short Course.** Golden, CO. For information on registration deadlines, fees, or to register online, go to http://www.mines.edu/igwmc/short-course/
May 19-21	**Analysis of Surface Water-Groundwater Flow Systems Using Integrated Codes, Colorado School of Mines, IGWMC Short Course.** Golden, CO. For information on registration deadlines, fees, or to register online, go to http://www.mines.edu/igwmc/short-course/

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