Colorado Water

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Highlights

In Every Issue

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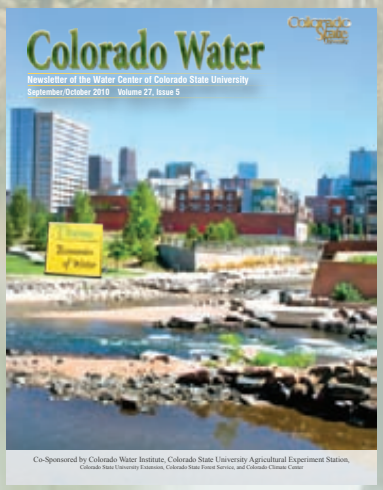

Cover page: Water from the Platte River joins with Cherry Creek in Confluence Park, Denver, alongside the industries and water consumers of downtown Denver. Photo by Lindsey A. Knebel.

This page: A farm near Berthoud, Colo., surrounds a small body of water. Photo by Lindsey A. Knebel.

COLORADO WATER is a publication of the Water Center at Colorado State University. The newsletter is devoted to enhancing communication between Colorado water users and managers and faculty at the state's research universities. This newsletter is financed in part by the U.S. Department of the Interior, Geological Survey, through the Colorado Water Institute. The contents of this publication do not necessarily reflect the views and policies of the U.S. Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the U.S. Government.

Editorial

Reagan Waskom, Director, Colorado Water Institute

Recent global financial difficulties have changed our thinking about the importance of jobs, markets, credit, and the global financial infrastructure. Note how the current political rhetoric focuses on these issues. The business and economics of water are rarely mentioned in these discussions but are no less important to the well-being of our society.

Water is cheap in the U.S. - most of us pay less than a penny a gallon for clean, safe water delivered to our taps. It is often argued that water is artificially cheap, creating inefficiencies in management, infrastructure, and markets. As Chuck Howe points out in this issue of *Colorado Water* (p. 16), our water law does not require us to maximize the economic value of water - that is left to the market to sort out. However, effective water markets are not facilitated by our legal system, as our laws discourage the private speculation inherent in most commodity markets.

Nonetheless, many entrepreneurs detect opportunity in future water scarcity. They are alert to the potential financial rewards of capturing an undervalued commodity or creating new technologies and services for providing clean water. Capital and creativity naturally flow to market opportunities. This is fortunate given the huge capital investments that will be needed to meet future water infrastructure needs and regulatory requirements.

Our current system rewards political leaders for minimizing public costs in the short term rather than asking for sacrifice to ensure that future generations have the benefit of a well-functioning infrastructure. An estimated $200 billion will be needed just to maintain the U.S. water infrastructure over the next couple of decades. Aging water infrastructure is certainly a problem, but it also creates an opportunity to rebuild a highly efficient green infrastructure. The question is who will provide these investments? At present, roughly 12 percent of U.S. residents are provided drinking water by some type of private organization, while only two percent are provided wastewater services by the private sector. The rest of us are served by public utilities. While there is resistance to privatization in the U.S., privatized water systems have become the operational norm in many parts of the world.

The rapid emergence of water investment funds is largely based on the idea that water is a scarce and undervalued commodity. While fresh water has no true substitute, those selling treatment technologies for desalination contend that there is no water shortage, just a shortage of cheap energy. One of the key long-term value drivers for investments in water is that demand is not likely to be affected by inflation, recession, interest rates or changing tastes.

It has been estimated that the U.S. domestic water and wastewater sector is a $120 billion enterprise annually and the world water market is likely to approach $500 billion. It is also interesting to note that the water industry is a significant sector of the economy in Colorado. A public/private group is currently working to establish a Water Innovation Cluster in northern Colorado that will focus on partnerships to advance water innovation and new jobs in the region, as noted in the article on page 25.

While new technology alone will not solve the world's water problems, it appears that there are many innovations and scientific breakthroughs coming that will enrich investors and help society. As water stress and scarcity become more common, water prices will inevitably rise, new markets will emerge, and water will move to higher economic uses. In Colorado, we see this trend in the move of water from agriculture to the urban sector, and a great deal of effort is underway to identify mechanisms to encourage more efficient markets. The outcome is not likely to be cheaper water, but perhaps we will find more efficient ways to share water between agriculture, the environment, and our growing cities.

Relative Costs of New Water Supply Options for Front Range Cities

Douglas S. Kenney, Michael Mazzone, and Jacob Bedingfield
Western Water Policy Program, University of Colorado's Natural Resources Law Center

Introduction

Ensuring an adequate water supply for the growing municipal population of Colorado's Front Range is an ongoing challenge. The Statewide Water Supply Initiative in 2004 (SWSI) projects that Colorado's population will grow 65 percent between 2000 and 2030, resulting in an increasing municipal and industrial (M&I) water demand of 630,000 acre-feet. The majority of this demand (507,700 acre-feet) will occur along the Front Range in the South Platte and Arkansas River Basins.

As each city charts its own course in seeking to eliminate a potential water supply gap, water utilities normally explore three general (and non-exclusive) strategies:

(1) increase water supplies through new projects (and/or the rehabilitation or expansion of existing projects);
(2) purchase and transfer water rights from the agricultural sector; and/or
(3) reduce demand through conservation and efficiency projects.

In this research project, we are reviewing the efforts of each of the three types on Colorado's Front Range, comparing the approaches based on one simple criterion: average cost per acre-foot ($/AF). In this comparison, we are not simply assuming that the best choice is always the lowest-cost option. Determining which options are "best" is a complex matter, as it entails an assessment of highly case-specific opportunities, constraints, trade-offs, and risks, all overlain by value choices. Nonetheless, $/AF provides an obvious starting point for making comparisons among broad categories of options.

In the paragraphs and tables that follow, we present our preliminary compilation of cost data, focused primarily on the upfront capital expenditures associated with the three previously mentioned categories of supply options. Over the next year (in phase two of research), we plan to supplement this data on capital expenditures with an assessment of ongoing, operating expenses, especially as they relate to energy costs. Looking forward, this figures to be an increasingly important consideration for Front Range water utilities, as the era of supply projects powered by gravity and delivering clean mountain snowmelt is quickly giving way to projects requiring extensive pumping and advanced water treatment.

Data and Methodology

Case studies and data sources varied widely for our three categories of supply options. For new projects, we selected prominent options spread across the northern, central, and southern Front Range for which detailed public documents exist. This yielded 28 different water development options associated with three main efforts: the Northern Integrated Supply Project (NISP) with 6 variations, the South Metro Water Supply Authority (SMWSA) Master Plan with 15 variations, and the Southern Delivery System (SDS) with 7 variations. For water transfers, we relied on information compiled from a privately published newsletter, the *Water Strategist*, focusing on agriculture-to-urban transfers from 1990 to 2009 of at least 100 acre-feet or 100 shares in the case of the Colorado-Big Thompson (CBT) project. This yielded 121 transactions, of which 113 involved CBT shares. Finally, for water conservation, we relied on data drawn primarily from reports by the Conservation and Efficiency Technical Roundtable (established as part of Phase 2 of the SWSI exercise in 2007), an analysis by Denver Water (*Solutions: Saving Water for the Future,* 2009), and a yet unpublished analysis of Water Conservation Implementation Plans prepared by the Great Western Institute for the Colorado Water Conservation Board (CWCB). We chose these reports because they are recent, they provide credible sources, and they include a mix of both actual and theoretical (projected) savings.

We found it challenging in many ways to compile and present data in a way that supports meaningful comparisons among the three supply options. The simplicity of our $/AF criterion hides many challenges, assumptions and ambiguities. For example, while the numerator in our $/AF metric has been standardized in 2010 dollars, it is worth considering that our dataset has options with widely variable temporal qualities. The water projects reviewed are primarily still in the planning stage; the transfers reviewed have all been consummated (often several years ago); and the conservation programs typically describe programs that are highly incremental and multi-faceted in application (e.g., ongoing appliance retrofit programs), as opposed to the big, one-time expenditures associated with bringing a new project online or completing a water rights purchase. More challenging are issues surrounding the denominator in the $/AF metric, as not every acre-foot is created equal

in terms of reliability, quality, location, and so on. Limiting our focus to the reliability criterion only partially simplified our task, as procedures for defining and measuring reliability vary across our three strategy types, and between options within each category. In this report, every effort has been made to provide data that are accurate and fair, but complete standardization of results is impractical, and comparisons should be made carefully.

Findings

New Projects

Table 1 provides a summary of firm-yields, total costs (converted to 2010 dollars), and unit costs, $/AF, for the 28 new project options grouped into four sub-categories: (1) NISP (6 options); (2) SMWSA: S. Platte (9 options); (3) SMWSA: Arkansas (6 options); and (4) SDS (7 options).

For the 28 projects reviewed, the average cost of a new acre-foot of firm yield is $20,764. This figure changes slightly (to $20,482) when calculated as a weighted average (total costs/total yields). These values are consistent with numbers commonly quoted in the water management community. However, a significant reduction in cost estimates can be achieved by taking the least-cost option in each of the four sub-groupings on the grounds that, in practice, only one option within each grouping (maximum) is likely to ever be pursued, although there are no guarantees that the least-cost options would be selected. Using that approach, average costs are reduced to $15,932, or $16,282 if using a weighted average. In this report, for purposes of comparison to the other categories of new supply options, the value $16,200 is utilized.

Table 1. Potential Costs of New Water Supply Projects Serving the Front Range.

Project: Option	Firm Yield (acre-feet/year)	Cost (2010 dollars)	Average Cost ($/AF)
NISP (Northern Integrated Supply Project)			
Average of Alternatives 3, 4.1a, 4.1b, 4.2, Proposed 1, Proposed 2	40,000	$544,038,650	$13,601
Lowest Cost Option: Proposed 1	40,000	$458,900,100	$11,473
SMWSA (South Metro Water Supply Authority Master Plan): South Platte River Options			
Average of alternatives based on Split, Single or Shared Pipelines, with diversions at Greeley, Sterling or Weldona	47,800	$942,776,967	$19,723
Lowest Cost Option: Shared-Greeley	47,800	$789,856,800	$16,524
SMWSA (South Metro Water Supply Authority Master Plan): Arkansas River Options			
Average of alternatives based on Split, Single or Shared Pipelines, with diversions at Avondale or La Junta	42,783	$1,023,041,150	$23,912
Lowest Cost Option: Shared-Avondale	47,800	$877,490,700	$18,358
SDD (Southern Delivery System)			
Average of Alternatives 1 through 7	55,257	$1,288,453,157	$23,317
Lowest Cost Option: Alternative 3	74,900	$1,301,211,600	$17,373
Averages			
Average (all 28 projects)	46,918	$960,951,557	$20,764
Weighted Average (all 28 projects) (total costs/total yields)			$20,482
Average of Lowest Cost Options (4 projects)	52,625	$856,864,800	$15,932
Weighted Average (4 projects) (total costs/total yields)			$16,282

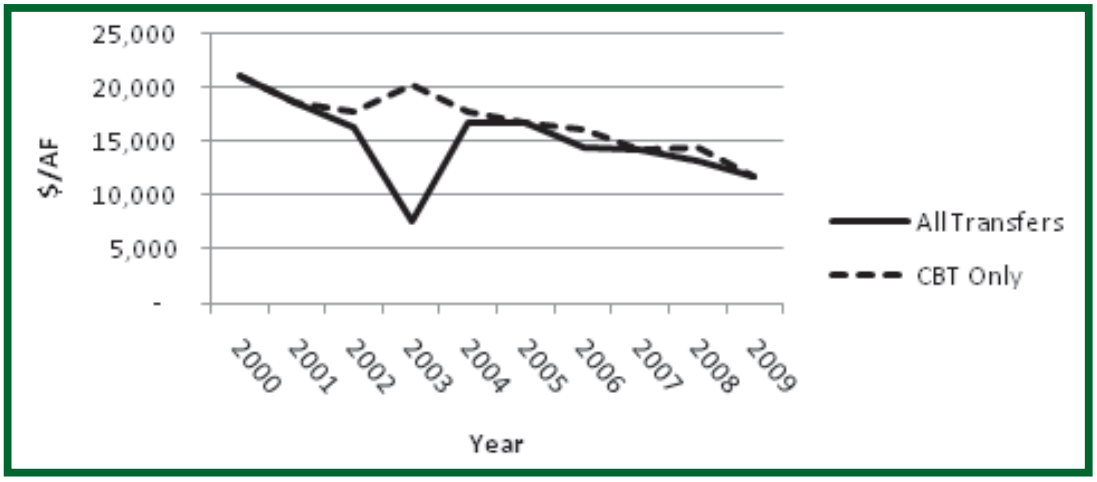

Figure 1. *Cost trends in water transfers: 2000-2009 (2010 $/AF).*

Water Transfers

Results compiled from the review of water transfers are presented in Figure 1 and Table 2. The dataset contains information from each of the past ten years (2000-2009) as well as three points in the 1990s. This was done to help illuminate trends and averages.

Prices for water transfers have shifted over time. Prices jumped sharply to start the new millennium (to over $21,000/AF in 2000), but the rest of the decade featured a steady decline. The only interruption in this steady trend was in 2003, which saw a slight jump in CBT prices, but this rebound in price was modest and short-lived and was more than offset in our dataset by an unusually inexpensive and large non-CBT transfer. The average cost per acre-foot in the past 5 years (2005-2009) is $13,996; consequently, for purposes of comparison to the other categories of new supply options, the value $14,000 is utilized.

Water Conservation

The three studies consulted for water conservation data utilized very different approaches. The SWSI study reviewed a variety of municipal water conservation strategies that could be applied statewide, estimating a potential savings by 2030 of 286,900 to 458,600 acre-feet/year at an average cost of $11,098 (once converted to 2010

Table 2. Summary of Major Front Range Water Transfers.

Year	Number of Transactions	Total Yield (acre-feet/year)	Total Price (2010 dollars)	Unit Cost ($/acre-foot)
1990	12	2,857	$8,171,047	$2,860
1994	13	1,957	$6,315,488	$3,227
1999	21	2,699	$22,345,051	$8,278
2000	11	2,146	$45,242,631	$21,080
2001	3	932	$17,289,153	$18,557
2002	8	2,141	$34,803,342	$16,259
2003	12	8,882	$68,069,282	$7,664
2004	8	1,811	$30,409,665	$16,795
2005	6	1,289	$21,556,085	$16,727
2006	7	1,188	$17,249,732	$14,515
2007	5	940	$13,423,692	$14,279
2008	12	4,022	$52,709,074	$13,106
2009	3	378	$4,466,541	$11,816
Totals and Weighted Averages (total costs/total yields)				
Total	121	31,241	$342,050,782	$10,949
Sub-Total: 2005-2009	33	7,817	$109,405,124	$13,996

Table 3. Summary of data from 22 water conservation implementation plans.			
All Programs	**Total Cost (over planning horizon)**	**Total Water Savings (in acre-feet, over planning horizon)**	**Average Cost ($/AF)**
Total	$328,648,807	63,534	$5,173
Cities and Districts: Arapahoe County Water and Wastewater Authority, Aurora, Boulder, Brighton, Castle Pines North, Castle Rock, Centennial, Colorado Springs, Denver, East Larimer County, Evans, Fort Collins Loveland Water District, Firestone, Greeley, Left Hand Water District, Longmont, Fort Lupton, Northglenn, North Table Mountain, North Weld County, Parker Water and Sanitation District, and Windsor.			

dollars). However, by focusing solely on turf replacements (at the lowest rebate level), leak reductions, toilet rebates, washer rebates (at the lowest rebate level), and conservation-oriented pricing regimes, these data suggest it may be possible to achieve roughly 300,000 acre-feet/year of these savings at costs no higher than $7,000 per acre-feet.

This number is consistent with the other two studies focused on planned and implemented Front Range conservation programs. The Denver Water study reports efforts already implemented in 2008 costing an average of $5,861 per acre-foot (in 2010 dollars), while the plans of 22 Front Range utilities covered by the data compiled by the Great Western Institute (for the CWCB) suggest a value of $5,173 per acre-foot. This is shown in Table 3. This value drops further, to $4,572 per acre-foot, if the major outliers (i.e., the 3 most and 3 least costly programs) are removed from the dataset. Given these considerations, we have chosen to use the value of $5,200 acre-feet as a fair estimate of the average cost of conservation on the Front Range.

Water supplies, like this canal that delivers Horsetooth Reservoir water to the Front Range, will need to grow to meet rising population demands.
Photo by Lindsey A. Knebel.

Summary and Conclusions

Three major themes emerge from the compilation and comparison of cost data. First, cost data are extremely difficult to find. Given the magnitude of the dollars involved, and the fact that the money spent and the obligations incurred belong to the public, we found this to be both odd and troubling. Second, the values we have compiled are deficient in many ways, as they are not produced using standardized assumptions, and in most cases they are confined to upfront capital expenditures. By using the $/AF metric across all categories, we standardized the data to the extent possible; nonetheless, the numbers presented should be considered as generalizations. And third, despite our concerns about the availability and quality of information, the data are sufficient to indicate that water obtained via conservation is, by far, the cheapest option. To review, our estimates of representative costs (in $/AF) are as follows: new projects, $16,200; water transfers, $14,000; and conservation, $5,200.

This is a highly condensed version of the full Phase 1 report. That report can be viewed online at www.waterpolicy.info or by contacting the lead author at douglas.kenney@colorado.edu. This research was supported by a grant from the Colorado Water Institute.

Examining the Economics of Water Issues in Colorado: An Equilibrium Displacement Mathematical Programming Model

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Agriculture is an important base industry in Colorado that generates more than $6 billion of farm gate receipts and contributes broadly to the state's economic activity – nearly 20 percent of Colorado's gross domestic product can be traced to agriculture or allied industries. It is also a sector in transition–new markets are developing, technological innovations are improving efficiency, laws and institutions are evolving and, importantly, agriculture is seeing increasing competition for key resources such as land and water.

In the midst of these structural changes, the Colorado State University (CSU) President's Agricultural Advisory requested that CSU use its capacity to help inform stakeholders about the opportunities and challenges inherent in the future of Colorado agriculture. One piece of the puzzle is engaging in 'what-if' analyses so that the tradeoffs of various policies and trends can be better understood. The Department of Agricultural and Resource Economics has created a state-of-the-art model to help sort out 'what-if' scenarios including alternatives involving water resources. In the following sections, we describe the Colorado Equilibrium Displacement Mathematical Programming (CEDMP) model, its representation of Colorado water resources, and how the model can be used to assist in the assessment of many of water resources issues. An example application illustrates the model's use.

Methodology

Optimizing models have a long history in economics and engineering applications. The basic purpose of these programming approaches is to maximize an objective (called an objective function) by choosing activities that take into account constraints on resources and interactions among choices. Following Harrington and Dubman (2008), the CEDMP model finds solutions that maximize net social benefits to the agricultural sector (the sum of consumer and producer surplus). This approach is among the most current in that it yields, in its base, an exact calibration with observed production and consumption levels. In addition, the method reflects farmers' risk profiles and price expectations and accounts for levels of durable capital used given values of excess capacity, capital acquisition costs, and salvage values. Our CEDMP follows the work of the USDA's Economic Research Service except that it focuses on calibrating to Colorado's economy and extending the model to other natural resource issues, especially water. The CEDMP is calibrated to represent economic conditions found in 2007.

The activities in the model proxy nearly all of the agricultural production in Colorado, including 13 crop and nine livestock commodities that are sold to local consumers or exported out of state. Imports for nine products are present and compete with local production. The nine livestock sectors are cow calf, fed beef, hogs, dairy, sheep, broilers and layers, turkeys, and horses, some of which produce multiple products, including meat, milk, and/or eggs. Demand for feed crops and forages are derived from livestock activities through their demand for rations. Crops

used at least partly for food are wheat, corn, potatoes, barley and beans. Calf imports go directly into the cattle feeding industry. Related processing industries, such as livestock feeding, dairy, and meat processing are present.

The activities described above all create costs and require the use of limited resources, which are added as constraints into the model. Currently, the relationship between inputs and outputs is fixed, with no substitution possible, so that corn production, for example, has a fixed yield of 132 bushels per acre and each acre uses a certain amount of fertilizer, other chemicals, irrigation energy (when irrigated), etc. We have divided Colorado into water basins so that farm production costs reflect accepted management practices in the region. Inputs are categorized as genetic inputs, such as seed or calves; specialized technology; mineral fertilizers (without manure applications); other chemicals; fuel and lube; electricity; irrigation energy and other irrigation costs; other variable purchased inputs; fixed cash costs; and capital replacement costs. Irrigated and dryland crop costs are derived from enterprise budgets created by Extension professionals in Colorado and the High Plains.

The main resource inputs that are limited in quantities are land and water. Cropland, pasture, range lands and land in the retirement programs are quantified and include land fallowed as part of crop rotations, including wheat-fallow. The supply of water available to agriculture is fixed, while the demand for water is exogenously determined for each crop by the State of Colorado's Consumptive Use Model (StateCU) component of the Colorado Decision Support Systems (CDSS), which is based on a modified Blaney-Criddle method. Corn, wheat, and hay production are separated by location for the South Platte and Arkansas River Basins and the rest of Colorado, and within the locations are identified by whether they are irrigated or dryland production.

Application to Colorado Water

A necessary component of the CEDMP model is to capture the economic activity associated with the water supplies, required deliveries, and end users of water by basin.

Water in Colorado is increasingly scarce, in part because it is a resource that is almost completely allocated even as demands are increasing among all users. As an example, the population in Colorado's South Platte River Basin is expected to increase by sixty-five percent (two million residents) during the next twenty years, requiring more than 400,000 acre-feet of water annually. Voluntary transfers from agriculture are one way to fulfill these demands, but this may require the fallowing of large swaths of irrigated land. Thorvaldson and Pritchett document irrigated agriculture's economic activity in Colorado watersheds (Table 1). Notable is the South Platte, which expects to fallow as many as 226,000 (22 percent) of its acres. An irrigated acre generates nearly $700 of economic activity in the basin, so potential losses are substantial in sparsely populated rural areas with few other alternatives. The economic activity estimates of Thorvaldson and Pritchett are based on an input/output model that does not consider the potential impacts to important downstream industries including feedlots, meat packing, dairies, cheese manufacturing, and ethanol production. Their analysis is best viewed at the margin, but the acreage changes described in Table 1 are quite large, so much so that the analysis may misrepresent actual impacts. Their analysis does not allow for endogenous prices and the out-of-state imports of irrigated crops that mitigate potential welfare losses. Significant improvement in policy analysis can be made with a more representative, flexible modeling effort that considers both water transfer scenarios and other water firming projects (e.g., reservoirs). The CEDMP represents one such modeling approach.

Table 1. Economic activity generated by irrigated agriculture in three Colorado river basins.[a]

Basin	Population Increase by 2030 (%)	Additional Annual Water Demand (AF)	Forecasted Fallowing of Irrigated Acres	Economic Activity for Each Irrigated Acre
Arkansas	55%	98,000	23,000 to 72,000	$428
Rio Grande	35%	43,000	60,000 to 100,000	$1,235
South Platte	65%	409,700	133,000 to 266,000	$690

[a]Population, water demand and lost irrigated acres drawn from the Colorado Water Conservation Board, Statewide Water Supply Initiative (2004). Thorvaldson and Pritchett (2006) provide economic activity estimates.

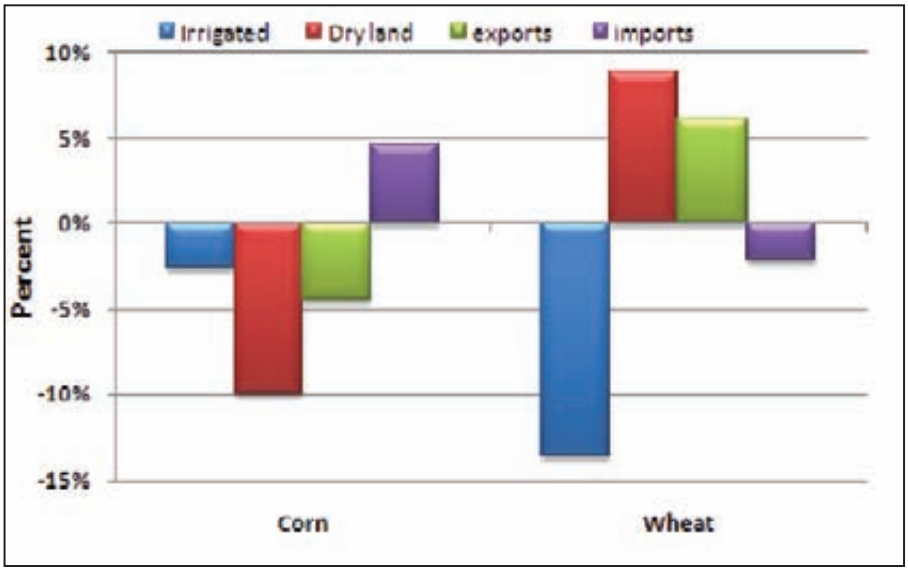


Figure 2. Production and trade impact for corn and wheat.

CEDMP Illustration

In order to illustrate the use of the CEDMP, the level of irrigated agriculture was reduced in the South Platte and Arkansas River Basins according to the midpoint of the forecasted reductions found in Table 1 (page 7). Following conventional land management practices for water transfer in Colorado, the irrigated cropland is completely fallowed, and the resulting impacts to agriculture are tabulated. Fallowing of land hurts livestock producers and leads to an overall reduction in industry output (cow calf operations, fed beef, dairy, and sheep). This is no surprise given that three-quarters of Colorado's irrigated production is used as livestock feed. Such reduction in output decreases livestock producers' profit (between -1 to -11 percent), as shown in the last column in Table 2.

Adjustment in Trade and Consumers Welfare

With access to rail lines and unit train loadout facilities, neighboring states provide some of the feed inputs that are lost with fallowing. Figure 2 describes import substitution for corn and wheat, as well as changes in dryland and irrigated acreage. Both irrigated corn and wheat acreage decrease – corn drops several percent, but dryland wheat declines by more than 13 percent. Dryland corn acreage also decreases by almost 10 percent, while dryland wheat increases by nearly the same amount. Changes are driven by a wheat price that declines by 2 percent, while corn prices are projected to increase by 1 percent. The trade response mitigates the price rise and input costs to consumers and feedlots. Decreased production in the livestock industry is driven in part by higher feed input costs. Impacts are also measured as producer surplus, in which cow calf production shows the largest decline ($15.6 million).

Table 2. Livestock Industry Response to Fallowing.

	Output		Produce Surplus	
Livestock	**Thousand CWT**	**Change (%)**	**Thousand $**	**Change (%)**
Cow Calf	**-26**	**-2.2%**	**-15,623**	**-4%**
Fed Beef	-292	-1.1%	-1,688	-2%
Hogs	**-4**	**-0.1%**	**-3,41**	**0%**
Dairy	-141	-0.5%	-4,405	-1%
Sheep	**-144**	**-5.6%**	**-8,076**	**-11%**
Broilers and Turkeys	-7	-0.2%	-165	0%

The model simulation also allows evaluation of effects on consumer surplus (the end-users welfare) within Colorado. Due to price increases in livestock originating from higher input costs, consumer surplus related to livestock products decreases by 1 percent or $24.5 million. For crops, higher prices also lead to consumer surplus declines by 0.7 percent, or $3.2 million. The price increases arise from the fact that the increased imports are only brought into the Colorado agricultural economy if higher prices in the state occur. Understanding exactly what inducements are needed to attract more feed inputs to our livestock feeding industry is an area for future research. This issue amounts to asking whether Colorado can maintain a livestock feeding industry with less local feed inputs resulting from reduced water allocations to the sector.

Ongoing Research

The previous example represents one application of the CEDMP, and it is our hope to extend its use to pertinent policy issues. Additional applications require more specificity, so we will disaggregate the South Platte basin into upper and lower sub-basins. The upper sub-basin is the most populated and will see continuing population inflows, so issues with groundwater contamination that can originate from both urban waste and livestock manure are present. The lower South Platte sub-basin and the Northern High Plains are largely agricultural, and the latter derives irrigation water from the Ogallala aquifer. The aquifer is being depleted at an unsustainable rate, and we will be able to sort out the economic impacts of these depletions using the CEDMP. In this fashion, the benefits of rotational fallowing and limited irrigation practices can be measured against a benchmark of current activities.

USGS

Recent Publications

Evaluation of Water Year 2011 Glen Canyon Dam Flow Release Scenarios on Downstream Sand Storage along the Colorado River in Arizona by S.A. Wright, and P.E. Grams http://pubs.usgs.gov/of/2010/1133/

Gas, Oil, and Water Production from Grand Valley, Parachute, Rulison, and Mamm Creek Fields in the Piceance Basin, Colorado by P.H. Nelson, and S.L. Santus http://pubs.usgs.gov/of/2010/1110/

Land Disturbance Associated with Oil and Gas Development and Effects of Development-Related Land Disturbance on Dissolved-Solids Loads in Streams in the Upper Colorado River Basin, 1991-2007, and 2025 by S.G. Buto, T.A. Kenney, and S.J. Gerner http://pubs.usgs.gov/sir/2010/5064/

Land-Use Analysis and Simulated Effects of Land-Use Change and Aggregate Mining on Groundwater Flow in the South Platte River Valley, Brighton to Fort Lupton, Colorado by L.R. Arnold, C.S. Mladinich, W.H. Langer, and J.S. Daniels http://pubs.usgs.gov/sir/2010/5019/

Nitrate Loads and Concentrations in Surface-Water Base Flow and Shallow Groundwater for Selected Basins in the United States, Water Years 1990-2006 by N.E. Spahr, N.M. Dubrovsky, J.M. Gronberg, O.L Franke, and D.M. Wolock http://pubs.er.usgs.gov/usgspubs/sir/sir20105098/

PHAST Version 2-A Program for Simulating Groundwater Flow, Solute Transport, and Multicomponent Geochemical Reactions by D.L. Parkhurst, K.L. Kipp, and S.C. Charlton http://pubs.usgs.gov/tm/06A35/

The Geologic Story of Colorado's Sangre de Cristo Range by D.A. Lindsey http://pubs.usgs.gov/circ/1349/

Wyoming Landscape Conservation Initiative Science and Management Workshop Proceedings, May 12-14, 2009, Laramie, Wyoming by V.F. Nuccio, Ed., F.D. D'Erchia, Ed., K. Parady, com., and A. Mellinger, com. http://pubs.usgs.gov/sir/2010/5067/

Quality of Source Water from Public-Supply Wells in the United States, 1993-2007 by P.L. Toccalino, J.E. Norman, and K.J. Hitt http://pubs.usgs.gov/sir/2010/5024/

Quality of Water from Public-Supply Wells in the United States, 1993-2007 Overview of Major Findings by P.L. Toccalino, and J.A. Hopple http://pubs.usgs.gov/circ/1346/

Soil Geochemical Data for the Wyoming Landscape Conservation Initiative Study Area by D.B. Smith, and K.J. Ellefssen http://pubs.usgs.gov/ds/510/

The Costs and Benefits of Preventative Management for Zebra and Quagga Mussels

Catherine Thomas, Graduate Student, Colorado State University
Christopher Goemans, Assistant Professor, Colorado State University
Craig Bond, Assistant Professor, Colorado State University

Zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*) are invasive mollusks native to an area in the Ukraine and Russia near the Black and Caspian Seas. Introduced to the Great Lakes in the late 1980s, Dreissena mussels rapidly spread throughout the Mississippi River Basin and the eastern U.S. These mussels currently cost the nation an estimated $1 billion per year, mostly in damages and control costs associated with electric power plants and water supply facilities. Western waterways were believed to be free of Dreissena mussels until 2007 when Lake Mead in Nevada became the first water body west of the 100th Meridian to have a confirmed Dreissena population.

Until recently, many scientists believed that the Colorado environment was unsuitable for mussel invasion. Nevertheless, juvenile mussels (called veligers) were identified in Colorado waters in January of 2008, with Pueblo Reservoir, Grand Lake, Jumbo Lake, Lake Granby, Shadow Mountain Reservoir, Tarryall Reservoir, and Willow Creek Reservoir all testing positive in the past two years. The presence of mussels in Colorado waters is a major concern due to potentially severe economic and ecological damage. Adult mussels attach to all types of structures and form dense mats up to one foot thick. These mats can clog water pipes and damage hydrologic infrastructure. Dreissena also affect natural ecosystems through their feeding behavior; they are filter feeders and process up to one gallon of water per mussel per day, thus drastically altering the food web and negatively affecting fisheries and biodiversity. In response to these threats, the Colorado Division of Wildlife (CDOW) has implemented a mandatory boat inspection program that requires trailered boats to be inspected before launching in Colorado waterways.

This study builds a bioeconomic simulation model to predict the intertemporal and spatial spread of mussels in a case study water delivery and storage system, the Colorado-Big Thompson (C-BT) system. The objective of this analysis is to compare the costs of implementing the CDOW boat inspection program to the benefits of the program. For this analysis, program benefits are assumed equal to the expected reduction in control costs to water conveyance systems, hydropower generation stations, and municipal water treatment facilities (see Table 1 for a complete list of program benefits).

Table 1. Benefits of preventative management for zebra and quagga mussels.

Reduced costs to infrastructure	Possible costs to infrastructure include:
	Costs to hydropower facilities, water treatment facilities, dams, and pump plants
	Costs to manually clean pipelines, tunnels and canals in the Colorado-Big Thompson system
Reduced control costs to industrial users	Industrial users that could be affected include:
	Fossil-fuel fired power plants
	Any industry using raw water as an input to production
Reduced control costs to irrigators	Affected irrigators include:
	Farmers using sub-irrigation or overhead sprinkler irrigation
	Parks and golf courses using raw water
Reduced ecological damages	Possible ecological damages include:
	Food chain depletion
	Long term negative effects to fisheries
	Severe reduction in populations of native mussels
	Noxious weed growth and associated control costs
	Algal blooms and associated control costs
Reduced human and animal health concerns	Human and animal health concerns include:
	Accumulation of organic pollutants that are passed up through the food chain
	Foul tastes in drinking water and associated costs to mitigate this in drinking water supplies

Mussels in Colorado and the West

Western water systems are very different from those found in the East. The rapid spread of mussels through the eastern system was facilitated by connected and navigable waterways. Western water systems are less connected, making overland transport by recreational boats the most important vector of spread in the region. This gives western water managers and policy makers a unique opportunity to slow or prevent invasions by implementing policies, such as the CDOW program, that reduce the probability that mussels are introduced by recreational boats.

A Colorado Department of Wildlife officer decontaminates a boat hull for zebra or quagga mussels at Granby Reservoir. Photo by Elizabeth Brown.

Very few mussel studies have focused on western water systems and the effect of preventative management programs, and only a few studies have analyzed the potential threat, including the economic impacts, of invasive mussels at a water system level. This study considers the potential spread of mussels in a connected western water system and the corresponding economic damages of an invasion. The study highlights how the spatial layout of a system, the type of infrastructure and level of control costs associated with a system, and the risk of invasion within a system affect the benefits of preventative management.

Model

The developed model simulates an invasion in the C-BT system (Figure 1) over a 50-year time horizon based on the probability of colonization for each reservoir in each year. The probability of colonization is derived based on two factors: (1) the suitability of the receiving environment, and (2) the ability of the species to reach the receiving environment. Dreissena mussels can be transported to new environments on boats or via downstream flows. The number of invaders that reach a new location via these pathways determines propagule pressure, an important predictor of invasion success. Once veligers are introduced to a new environment, their ability to persist depends on the suitability of the new environment for survival. Thus, the probability that a water body will become colonized is

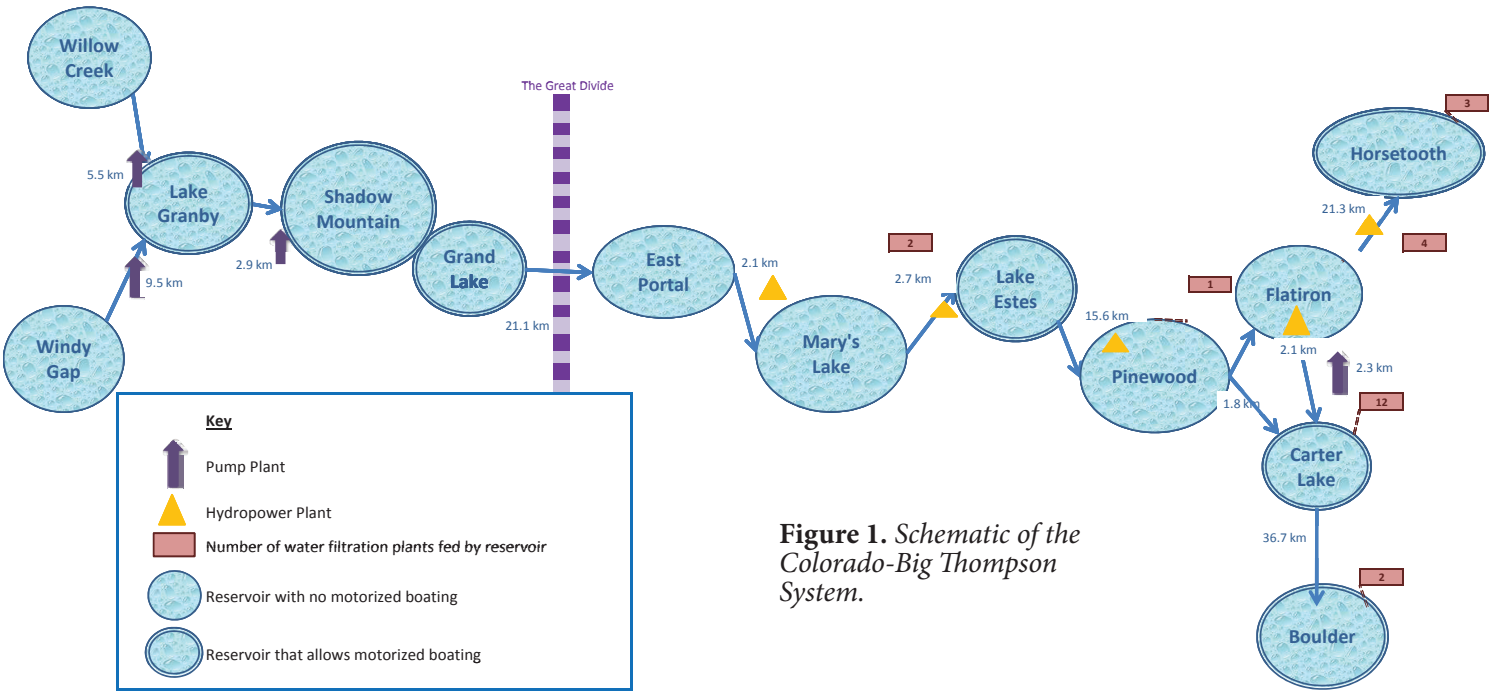


Figure 1. *Schematic of the Colorado-Big Thompson System.*

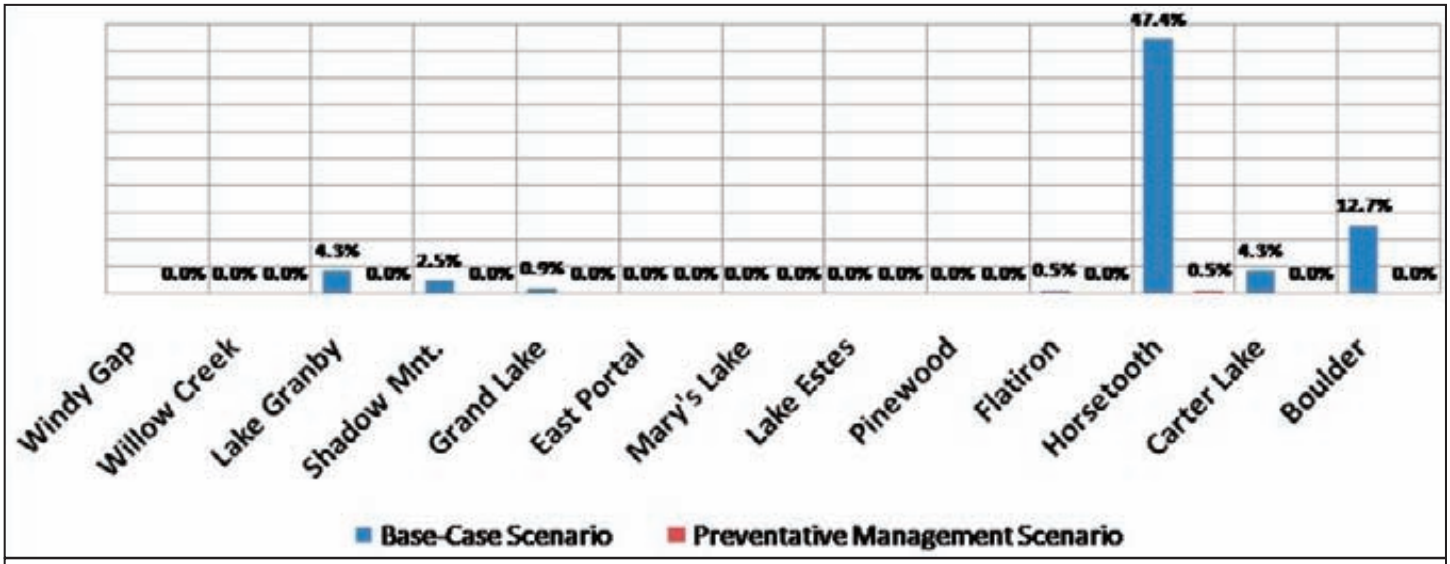


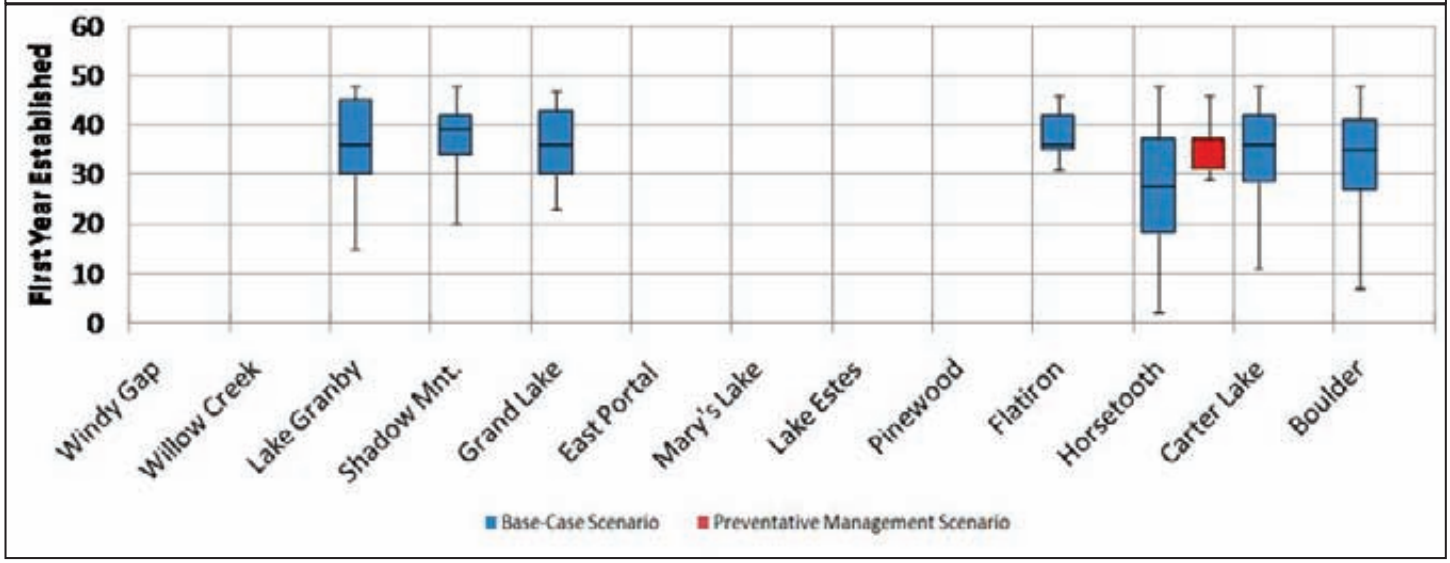
Figure 2A. Percent of runs that result in establishment. Generated using low probability of invasibility parameter values.

jointly determined by the probability that the water body is invasible (i.e., provides a suitable environment for mussels to survive and reproduce) and the probability that the water body becomes established (i.e., the probability that a sufficiently large number of propagules are introduced to the water body). Together, these probabilities determine the likelihood that a reservoir will become colonized by a given period in time.

Facilities and infrastructure below colonized reservoirs are assumed to incur mussel-related control costs. Cost schedules were developed for all of the water treatment plants, hydropower facilities, dams, and pump plants in the C-BT system and include yearly capital and variable costs associated with mussel mitigation. Other system infrastructure such as pipelines, tunnels, canals, and gauging stations are also likely to incur minor damage costs if mussels are present, but these costs are not included in the analysis. Unique control cost schedules are developed for each type of infrastructure and are based on published mussel control cost survey results and unpublished cost estimation studies. Control cost schedules only account for mussel-related costs incurred by facilities experiencing settling mussels, with facility costs assumed to be zero prior to settling. Boat inspection costs are based on budget data provided by CDOW.

The simulation model predicts spread and control costs in the system under a base case scenario if no preventative management takes place, then under an alternative scenario in which the boat inspection program is in place. The key difference between the two is the probability that reservoirs become established by propagules introduced by boats. By slowing the rate of invasion and catching and

Figure 2B. Simulated first year of establishment. Generated using low probability of invasibility parameter values.



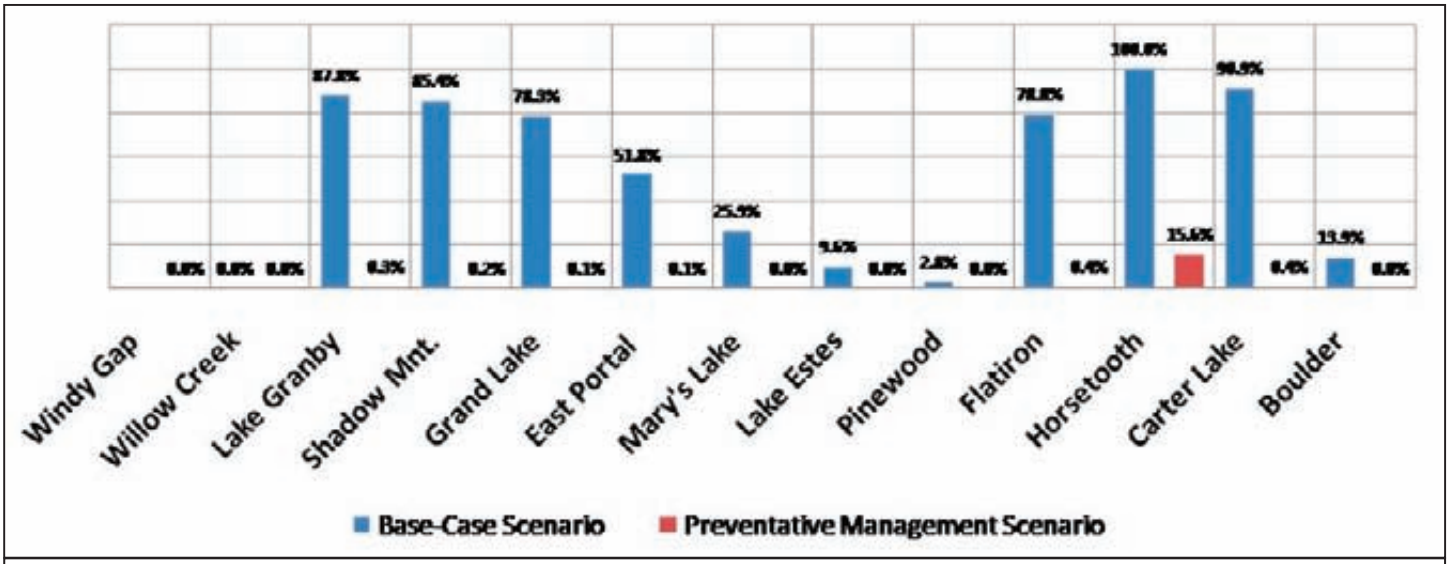


Figure 3A. Percent of runs that result in establishment. Generated using high probability of invasibility parameter values.

cleaning a large percentage of boats that are potentially carrying mussels, the boat inspection program reduces the probability of colonization.

Program benefits are measured as the difference in the net present value of expected control costs for the base case scenario and for the preventative management scenario, and program costs are measured as the net present value of the direct costs of implementing the program. Net program benefits are equal to program benefits less program costs.

The model is run 1,000 times per simulation and uses randomly-drawn numbers to determine the state of nature in each year. The resultant output characterizes the distribution of mussel establishment and net program benefits over the 1,000 runs.

Results

Establishment patterns and associated control costs are simulated using two levels for the probability of invasibility. The probability that a reservoir is invasible is a function of many variables, some known and some unknown. For the simulation of invasion in the C-BT system, parameter estimates for the probability of invasibility are assigned based on the calcium risk level for each reservoir. Calcium level is a key indicator in determining the suitability of a water body for Dreissena survival. With the exception of Boulder Reservoir, calcium levels in the C-BT reservoirs are very low, and many experts would consider these reservoirs to have very low probabilities of invasibility. Results for contrasting levels of invasibility are presented for two reasons: (1) the CDOW boat inspection program is a statewide mandate, and it could have different effects

Figure 3B. Simulated first year of establishment. Generated using high probability of invasibility parameter values.

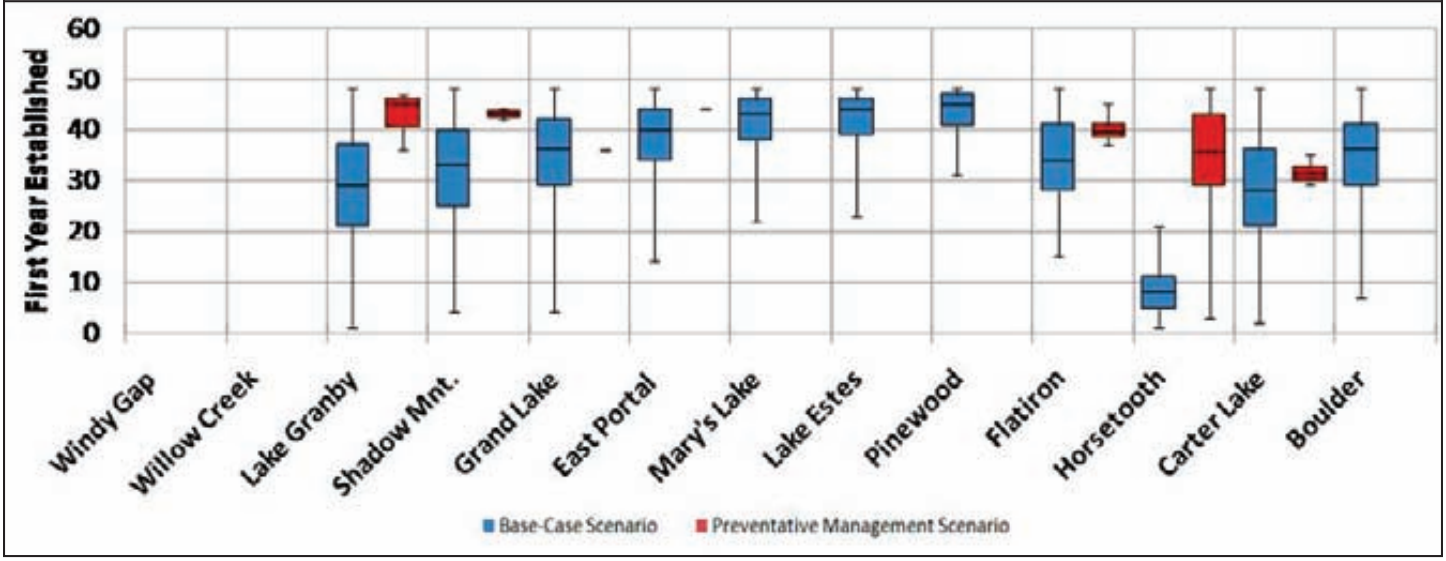


Table 2. Simulated mean costs and benefits of the CDOW boat inspection program on the reservoirs of the Colorado-Big Thompson (C-BT) system over a 50-year time horizon. Simulation results are presented based on parameter values that represent a system with low probabilities of invasibility and low mussel densities and a system with high probabilities of invasibility and high mussel densities. Net present values (NPV) are calculated using a discount rate of 2.65%.

System-wide Probability of Invasibility	Low	High
Program Cost		
NPV Direct Costs	$23,450,768	$23,450,768
Program Benefits		
Average NPV Control Costs (Base-Case Scenario)	$10,110,108	$62,384,958
Average NPV Control Costs (Preventative Management Scenario)	$34,215	$1,515,144
Average Program Benefits	$10,075,893	$60,869,815
Average Net Benefits	($13,374,875)	$37,419,047
Benefit-Cost Ratio	0.4297	2.5956

in other water bodies in the state that have higher probabilities of invasibility, and (2) the actual environmental probabilities of invasibility in the C-BT waters are extraordinarily uncertain. The identification of mussels in the low-calcium waters of Grand County reservoirs is a sign that the system may be more susceptible to invasion than expected.

Figures 2 and 3 (pages 12-13) provide simulated establishment patterns in the system under low and high probabilities of invasibility, respectively. In both cases, the simulated results suggest that the boat inspection program is very effective at reducing the probability that reservoirs in the system become established and almost entirely eliminates the possibility of invasion in the system over the 50-year horizon.

Table 2 provides the simulated net present values (NPV) of program costs and program benefits over the 50-year horizon using a discount rate of 2.65 percent. These results suggest that the benefits of reduced control costs to infrastructure are less than the costs of the boat inspection program in a system with low invasibility. In a highly invasible system, the benefits are over 2.5 times the costs of the program, and it would be reasonable to spend as much as $2.1 million per year on preventative management.

If the system has a low probability of invasibility, then the simulated gap between the NPV of the costs and benefits of the program there is about $13 million. This gap is driven by three factors: (1) the probabilities of colonization in the system are low; (2) once established, facility control costs in the system are relatively low compared to program costs; and (3) program costs are incurred every year whereas program benefits are realized 30 to 40 years in the future.

Furthermore, as measured in this analysis, benefits only include reduced control costs to infrastructure and facilities in the system. Non-market benefits such as the prevention of ecosystem disruption, reductions in ecosystem services, and diminished recreational opportunities are not included in the benefit calculation. Also omitted from program benefits are reductions in control costs to irrigators and industries using raw C-BT water. The boat inspection program is cost effective if all of the omitted program benefits exceed the cost-benefit gap.

Within the system, Horsetooth Reservoir and Boulder Reservoir have the greatest risk of establishment. Horsetooth Reservoir has nearly 50,000 boat visits each year, making its probability of establishment by boats very high. Boulder Reservoir has relatively low boat pressure, with about 1,500 boat visits each year, but has a high probability of invasibility due to high calcium levels. The majority of the control costs incurred in the system are incurred by facilities below these reservoirs. The spatial layout of the system also plays a role in the cost-benefit results. All of the hydropower facilities in the system are located between East Portal Reservoir and Flatiron Reservoir. With the exception of Lake Estes, which has a very small number of trailered boat visits each year, the reservoirs in this central stretch are closed to trailered boats. Thus, probabilities of colonization in the central reservoirs are almost entirely driven by flows. Simulation results suggest that if the probability of invasibility and the overall density of mussels in the system are low, then the probability that the central reservoirs become established by flows is close to zero, which results in zero control costs to hydropower facilities.

Conclusions

Preventative management is a valuable option for dealing with irreversible invasions that have the potential to cause severe ecological and economic damages; however, the costs of proactively slowing an invasion can be large. Results of this analysis suggest that preventative management programs designed to slow the spread of mussels over land on recreational boats are effective at preventing mussel invasions. However, the market benefits of these programs are highly dependent on the environmental suitability, the spatial layout, the type of infrastructure, and the level of control costs associated with the managed system. Lower risks of invasion and a smaller industrial presence in the West suggest that invasion and the associated control costs in western states are likely to be less severe than they were in the East, which may make the market benefits of slowing an invasion smaller than anticipated.

The results of this study identify several areas for future research. To fully address the costs and benefits of preventative management for mussels in Colorado, valuation of the non-market benefits and costs of the program and the regional economic impacts of the program are needed. In addition, a statewide analysis that captures positive spillover effects of management between systems will give a more accurate estimate of the net benefits of preventative management. Overall, the probability of invasibility and the magnitude of control costs in the system are the most important drivers in the cost-benefit analysis, and further research is needed to reduce uncertainty around these values.

The Excel-based model is available at http://dare.colostate.edu/tools/index.aspx, where users can test the effects of varying model parameter values on the establishment patterns and associated distributions of control costs.

A sign stops lake visitors from putting in their boats because of mussel contamination. Photo provided by Elizabeth Brown.

Reconciling Law and Economics in Water Administration

Charles W. Howe, Professor Emeritus of Economics, University of Colorado - Boulder

Water is developed and administered within the framework of water law. The resultant economic benefits and costs to the region or nation show an important result of applying this legal framework. While there is no legislative requirement that water law maximize economic results, economic assessments of projects, policies, and regulations are required under several federal laws and should inform adaptation of the law over time. The appropriations doctrine (AD) framework has proven adaptable over the long term, but there remain aspects of the law that generate unnecessary economic losses and/or restrain the ability of our water system to adapt to changing conditions (e.g., climate change). This article addresses two ways in which the law and economic results can be more nearly reconciled.

Our system of water law and administration, the AD, has served well over the past century to provide flexibility through the establishment of clearly-defined water rights that can be transferred among uses over time. While the AD has been called rigid and inflexible, innovations have occurred, including out-of- priority diversions and storage and related substitute water supply plans. Other innovations include implementing conditional rights, recognizing instream flows and recreational uses as beneficial, having water banks of various forms to facilitate transfers, and (belatedly) empowering the water courts to consider water quality effects when considering water transfer filings.

Nonetheless, there remain areas in the administration of the AD that result in substantial economic losses to water users and related communities. A 2008 Denver University study of the effects of the 2006 South Platte well shutdowns, occasioned by a river call by senior downstream rights, estimated that the losses to the well owners and related economic activities greatly exceeded the potential marginal gains to the calling agricultural seniors. In addition, high-value non-agricultural users (including Greeley, Boulder, Highlands Ranch and multiple irrigation ditches) had to forego valuable withdrawals, calling into question the economic results of river calls generally. These losses were the result of the historical fact that downstream senior rights were held by low marginal value users while the higher-valued upstream users held only junior rights.

One would expect that water markets would correct this situation over time by moving water rights from lower-valued to higher-valued uses – the correlation between values in use and seniority is low. Colorado has 125 years of buying and selling water rights and a more recent history of innovative leasing arrangements that include water banks, interruptible supply arrangements (for drought or other emergencies), and agricultural rotating fallow arrangements for long-term leasing without permanent sale of the water rights.

Effective water markets depend on many factors, but among them are two key conditions: (1) low transaction costs dependent, in part, on expeditious court rulings, and (2) a legal framework within which a wide range of types of transactions can be executed, i.e., sufficient scope to allow innovative, well-informed transactions to take place.

"Speculators All." Water use is dictated by a variety of consumer and economic needs. Created by Bruce Stark; provided by Charles Howe.

Transaction Costs

Transaction costs of an appropriation or transfer (measured by dollars ($)/acre-foot transferred) include filing costs and all the investigations required by the court to establish consumptive use and non-injury. These unit costs depend on the size of the transfer (economies of scale) and on the level of controversy surrounding the transfer, partly measured by the number of protests filed in connection with the appropriation or transfer filing. In addition to monetary costs, long delays in issuing rulings are frequent, ruling out quickly-needed transfers, especially in times of agricultural drought.

Water transactions can be complicated by a lack of basic data. While Colorado keeps records on every water right, the names of owners are not recorded and changes of ownership are not always recorded. Prices of sales are also not recorded, complicating the problem of "price discovery," i.e., figuring out what a reasonable offer would be. Filing an application for transfer requires only a meager description sufficient for initially notifying other water users, impelling those other water users to file protests with the court in order to learn more about potential effects of the transfer. This substantially increases costs to participants and the court.

Some level of administration is, of course, necessary for the orderly administration of water rights, but costs to the transferors and the courts should be kept to minimum since they inhibit market transactions. A Colorado Supreme Court Water Court Committee was appointed in 2008 to, according to the committee, "review the water court process; to identify possible ways…to achieve efficiencies in water court cases." While the intent was to make the court process simpler and quicker, the resulting changes in court procedures appear to some water managers to have made the process more difficult and expensive. Reducing transaction costs thus remains a challenge. Some suggestions are presented in the last section of this paper.

The Scope of Water Markets

The scope of water market transactions can refer to the geographical extent of the market or the breadth of allowable transactions. In Colorado, this scope is limited by statuary requirements of which the prohibition of "speculation" in filings may be the most inhibiting. The definition of speculation is fuzzy at best. The point is that "speculation" (reasonably defined) can play a highly beneficial role in water transfer markets.

The popular interpretation of speculation is that of market manipulators intending unfairly to make an unwarranted profit. A working definition must be inferred from the conditions imposed on water transfers by water law, the most important being that a change of use filing must name a definite transferee who has a clear "beneficial use" for the water. It is frequently acknowledged that the beneficial use doctrine itself is ill-defined and ill-enforced and has been ineffective in curbing wasteful uses of water.

The anti-speculation doctrine also overlooks the value that repackaging smaller rights for transfer to emerging markets can have. The High Plains Consortium had acquired extensive water rights and options on the Fort Lyons Canal with the intent of reserving the consumptive component for transfers to unspecified but fairly obvious Front Range communities. The water remained in productive agricultural use awaiting transfer. That "repackaging" of water is a valuable function that is overlooked in many applications of the non-speculation doctrine.

Speculators are typically parties who invest in risky situations, banking on superior information or better-informed anticipation of future conditions to profit from spot and forward sales or purchases. These transactions are necessary for a continuous, efficient market in any commodity. It seems reasonable to assume that the High Plains group had made extensive investigations into the emerging Front Range water markets and the willingness of Arkansas Valley farmers to sell parts of their water supplies. After all, they invested large sums on those grounds. By providing a ready market for rights owners who wanted

A canal runs along Highway 34 in Greeley, Colo. This water supply will be tapped by many different users.

Photo by Lindsey A. Knebel.

to sell as well as an alternative source for buyers, the Consortium probably would have beneficially served both.

The formative Arkansas Valley "Super Ditch" in Division 2 (10CW4) is an innovative proposal in which participating farmers agree to fallow part of their irrigated land by the season so that their reduced consumptive use can be leased for longer terms to other users. The project would allow water supplies to pass temporarily from agriculture to other users without permanent sale of the underlying water rights. As anticipated, many protests have been filed with the Division 2 Water Court on grounds that the filing is speculative. While many of these protests may be pro forma, the broad acceptance of the non-speculation doctrine is clear.

Uneven Application of the Non-Speculation Doctrine

It appears that the prohibition of speculation has been unevenly applied and that there are ways of getting around the prohibition. Cases cited in the Denver Post investigative series "Turning Water into Gold" in November of 2005 show that water brokers have been able to acquire water rights for unspecified future sale through temporary application to presumably beneficial uses, sometimes establishing specially formed water districts.

"Conditional water rights" that are typically granted to municipalities, while presumably having a well-defined intended use, have not been considered speculative even though some have not been perfected for 50 years and even though the probability of future need may be very low ("the substantial probability standard" of the "can and will" statute). Thus, the line between legal water right ownership and "speculation" is hard to draw. One could argue that every water right owner speculates since prices of water are broadly expected to continue increasing. The many water investment groups that have invested in ranchland clearly aren't in the business to raise cattle.

Reconciling These Water Law and Economic Conflicts

In sum, we want to work toward the reconciliation of three issues: (1) the likely inefficiency of river calls, (2) the related issue of excessive transaction costs in water filings, and (3) excessive applications of the non-speculation doctrine that rule out beneficial "repackaging" of water rights.

Regarding reduction of transaction costs, it has been widely suggested that rules of thumb for measuring consumptive use and time of use be developed on a watershed basis using the many years of data currently available. Such rules could be used to avoid the need for costly new hydrologic and agronomic studies for each filing. The Colorado Supreme Court currently allows the use of historical data only for transfers on the same ditch. Further study of the efficiency of water court procedures is warranted, aimed at the simplification of court standards and processes.

Larry MacDonnell, now a Professor of Law at the University of Wyoming, reasoned in an article published in the University of Denver Water Law Review that the well-recorded consumptive use of a water right privatizes the consumptive component, reducing the need to administer the right. For example, the High Plains Consortium restricted its change-of-use filing to the consumptive use of the rights and options acquired. In addition, more adequate record keeping of owners and prices would reduce costs, as noted earlier.

In the case of river calls, the frequency of calls should decrease over time as water markets move water to its higher-valued uses, although this has proven a slow process historically. This function of markets will be enhanced by reductions in transaction costs. The administration of priorities on an upper basin-lower basin basis has been suggested since the historically lower valued uses are usually in the lower parts of a basin while the (later developed) upper basin uses usually have higher economic values.

Regarding speculation, the design of a consistent set of definitions of speculation and beneficial use should allow for useful "repackaging" of water rights while guarding against monopolization in local watersheds, which was the early rationale for beneficial use. Currently we have a chicken and egg situation in which buyers are unlikely to sign contracts until the seller has court approval, while the seller can't get approval until the buyer signs the contract. Finally, the treatment of conditional rights should be tightened by limiting the life of such rights and stiffening due diligence requirements to free up water and reduce the hydrologic uncertainties faced by downstream water users.

Overview of the "Colorado Review: Water Management and Land Use Planning Integration"

Dr. Lyn Kathlene, Senior Research Assistant, Center for Systems Integration

Adequate supplies of fresh water will be the number one resource scarcity issue of the 21st century, both globally and here in the western United States. Water shortages in the West are the result of multiple stressors, including rapid population growth, economic conditions and employment levels, energy demands such as oil shale development, agricultural irrigation, climate change, increased hydrological variability in major watersheds, and interstate compact obligations. Land development, like water demand, is being driven largely by residential, business, and industrial growth. Arizona, California, Colorado, Idaho, Nevada, Texas and Utah – all western states – are experiencing the highest population booms in the country. Among these, Colorado is ranked as the third fastest growing state in the U.S. and is expected to double its population from 4.8 million in 2005 to a projected 8.7 – 10.3 million people in 2050. Moreover, Colorado counties are growing quickly; eight of the top 18 fastest-growing counties nationwide are in Colorado, and almost 40 percent of Colorado counties are projected to more than double in population by 2050.

To meet our consumptive and non-consumptive water needs, both demand side and supply side strategies will be needed. In 2009, the Colorado Water Conservation Board (CWCB) embarked upon a series of efforts to examine the integration of land use planning with water management. These efforts included:

Statutory and policy research of integrated planning efforts especially focused on opportunities and barriers to implementing water demand management strategies into land use planning.

A statewide survey of a broad range of stakeholder groups was conducted across the state of Colorado, including those involved in land use planning, land development, water management, water law, resource conservation, and business. A total of 345 people participated in the survey.

A Western states symposium, Water & Land Use Planning for a Sustainable Future: Scaling and Integrating, was held on September 28-30, 2009, in Denver, Colorado. The symposium, hosted by the CWCB and the Western States Water Council (an arm of the Western Governors Association), brought together 150 stakeholders from the water and land use planning communities to tackle issues related to integrated planning efforts occurring across the West and in the state of Colorado.

Colorado and other western states have integrated land use and water supply in many areas and arenas. This is especially the case with ensuring adequate water supplies for new developments. The focus of this CWCB effort, however, is on the water demand management components of land use planning and practices. Demand management will now be as important as supply management and, in fact, the two must go hand in hand. According to D.B. Brooks in an article called Water Resources Development, water demand management includes any method – technical, economic, administrative, financial or social – that addresses one or more of the following five issues:

- Reduce the quantity or quality of water required to accomplish a specific task;
- Adjust the nature of the task or the way it is undertaken so that it can be accomplished with less water or with lower quality water;
- Reduce the loss in quantity or quality of water as it flows from source through use to disposal;
- Shift the timing of the use from peak to off-peak periods;
- Increase the ability of the water system to continue to serve society during times when water is in short supply.

Land use planning helps ensure that Colorado cities like Denver, pictured above from Confluence Park, have adequate water.
Photo by Lindsey A. Knebel.

Figure 1 depicts the relationships between demand management strategies and Table 1 provides a breakdown of various demand management methods and potential water savings.

Understanding what has already been accomplished, where we might go, and how we can continue to move forward is the purpose of the newly released report, "Colorado Review: Water Management and Land Use Planning." Bringing together information gathered through research and stakeholder input, it sets the stage for communities, planners, and policymakers to move forward armed with information about policies, statutes, and strategies that exist in Colorado and the West.

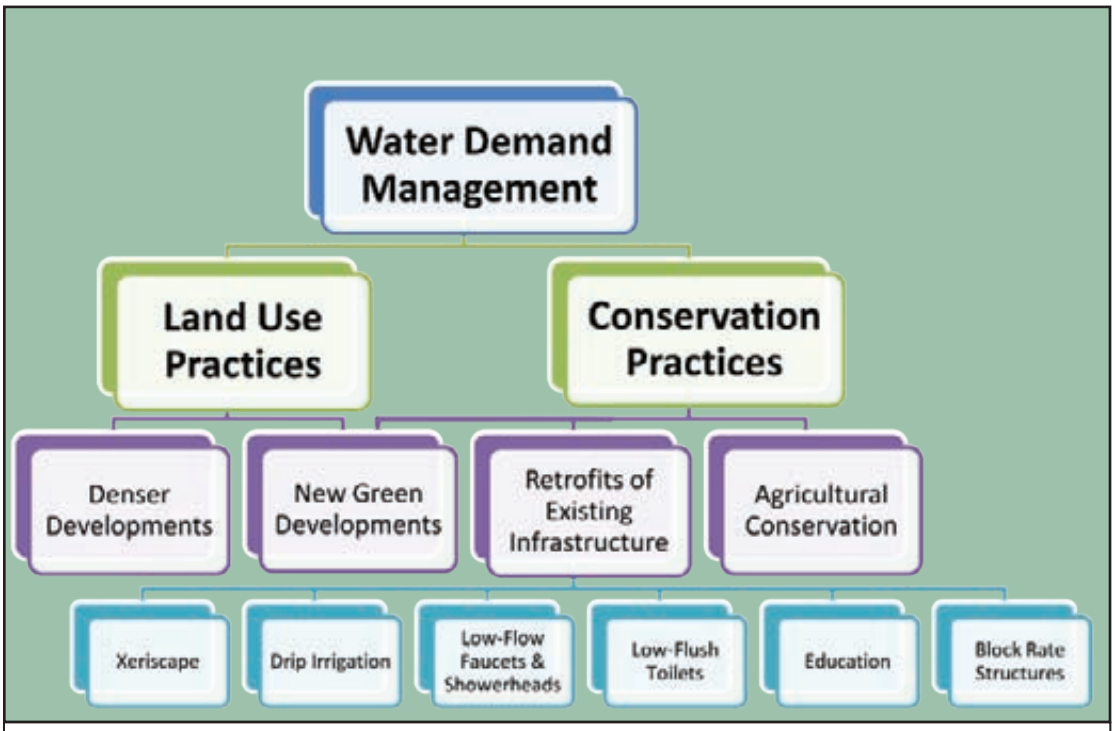


Figure 1. Water demand management practices and tools.

The report contains:

1. Review of Colorado statutes. Land use planning authority, like water planning authority, is derived from statutes, rules and regulations. Few Colorado statutes explicitly integrate land planning with water planning, although several tools are in place to encourage this and permit it to happen voluntarily. Opportunities for integrated planning are already available. For example, counties and municipalities are required to adopt a master plan for the physical development of their jurisdictions, which *may* include a water supply element. Additionally, water efficiency and conservation are encouraged through public project landscaping guidelines; and one statute, which passed in 2008, requires developers to demonstrate to local governments that they have an adequate water supply to serve their proposed development. Statutes also allow for water and land use integration to occur through intergovernmental agreements and other regional collaborations. Also, local governments may address water demand issues through local ordinances and design standards in addition to the few mandates from state statutes. Although state statutes support and permit intergovernmental cooperative agreements on water, planning, and service issues, coordination and sharing of information between local governments and water suppliers are largely voluntary. This section of the report provides an analysis of Colorado statutes related to water and land use planning, enabling statutes that grant authorities to municipalities and counties, governance structures, and quasi-governmental structures. Included is a chart with information about specific statutes and how these affect integrated planning efforts.

2. Identification of tools and strategies. States, regional councils, and local governments throughout the country are undertaking a wide variety of strategies to decrease water usage and tie water usage to land use planning decisions. The strategies range from mandatory requirements on government agencies and/or individuals and business to voluntary and public education approaches. Many of the strategies are most appropriate to land use planning focused on new development, while some others are more likely to be used with existing development (see Figure 1). Eight major strategies are covered. Each includes examples of policies that may be applicable to Colorado to support the strategy, evidence of success where research has been tracking outcomes, barriers to adoption and implementation, and relevant survey results. Strategies covered include:

Water Supply Assessments: New developments must "prove" there is enough legal and "wet" water available to serve the new residential, commercial, and/or industrial area.

Recapture and Precipitation Capture: While technically this falls more into water supply development, these two specific techniques interface with water demand management.

Rate Structures: Structured impact fees and block rates are demand management strategies that seek to change

consumer behavior through incentives, disincentives and/or education.

Comprehensive Planning Efforts: Land use master plans or water supply plans are methods by which water management and land use can be addressed in a single document.

Densification and Growth Management: These land management strategies seek to manage new growth and infill to protect natural resources and address both water quality and quantity concerns.

Regional Structures: Regional government structures bridge the two different systems in Colorado at which water planning occurs (state and region) and land use planning occurs (local – counties and municipalities) by engaging leaders in decision-making that crosses jurisdictional boundaries.

Green Programs: Green programs vary in their audiences (residential, commercial, and industrial) and strategies but have in common a goal of decreasing water usage through changing technology, external environments, and human behavior.

Education: Education is critical to building awareness and support for water wise living, promoting water smart land use planning, and subsequently, successfully carrying out the water demand management practices.

This section includes a chart with examples of strategies that have been implemented in Colorado and elsewhere at the state and local level.

3. Stakeholders' Views. An important question for Colorado state government and local stakeholders to explore together is the extent to which state government can or should participate in policymaking and implementation to further integrate water and land use planning beyond the programs already being implemented. The Colorado survey explored this issue in depth, asking respondents for their levels of support for mechanisms that have potential for a regional-level impact, as well as explicitly asking for their opinions on how the state

Table 1. Water demand strategies and potential water savings in Colorado. Adapted from Colorado Water Conservation Board (2007, November). Colorado Department of Natural Resources.

General Approach	Examples	Estimated Implementation Level by 2030	Projected Long-Term Water Savings (acre feet/year) by 2030
Structural-Operational	Household appliances		
	• Toilet rebates	80%	55,800
	• Washer rebates	80%	17,000 to 40,200
	Utility water loss reduction	90% of public providers	52,000 to 86,700
	Residential indoor audits	25% residential customers – targeted at high users	2,300 to 6,900
	Commercial indoor audits	25% commercial customers – targeted at high users	800 to 3,800
	Residential landscape audits	25% residential customers – targeted at high users	3,800 to 11,500
	Commercial landscape audits	25% commercial irrigators – targeted at high users	1,500 to 5,800
	Sub-metering in multi-family housing	20%	1,800 to 5,200
	Cooling towers increased cycle concentration	50%	3,100 to 24,500
Socio-political	Turf replacement	25% single family home	125,800 to 211,700
	Rebates for landscape retrofits other than turf	2.5% residential customers	3,100 to 18,400
Economic	Conservation oriented water rates (increasing block rates, water budgets, etc.)	100% municipal customers	30,675
		TOTAL (not including duplication)	286,900 to 458,600

should be involved in water and land use integration. The symposium included facilitated table discussions for participants to share experiences and concerns, identify problems and potential solutions, discuss obstacles and opportunities, and develop recommendations to better integrate and scale water and land use planning for a sustainable future.

4. Short- and long-term recommended strategies. In November 2009 the Advisory Committee met to discuss the symposium outcomes. The Committee identified opportunities that could be realized in the short-term and those that were long-term strategies. The overarching recommendations, listed below, include short- and long-term strategies.

Need for Data: Currently, few data exist regarding the ability of denser and more sustainable developments to reduce water demand in Colorado. These data are necessary so that developers and city and county planners can understand what the best management practices and methodologies are and how much water savings they could expect.

Role of the Market: As the value of water continues to increase, the market may naturally lead to more water-efficient developments. However, it is not clear if current market conditions are sufficient. Therefore, incentives to catalyze the market in ways that will reduce future per capita water demand should be considered.

Infrastructure Replacement: Research at the Brookings Institute shows that approximately 75 percent of the Front Range's infrastructure is going to be replaced or remodeled by 2050. This provides an opportunity to determine how to make this infrastructure replacement more reliably water efficient.

Regional Collaborative Planning: Several case studies and presentations indicate that localized solutions are not effective, since water demand is simply transferred from one jurisdiction to one or many others. Therefore, regional solutions are critical and should be further explored.

Integration: Many other efforts are currently underway that could reduce regional water demand, but are not specifically aimed at achieving that purpose. There are many opportunities for developing partnerships with other water conservation efforts, sustainable/walkable neighborhood developments, energy conservation and CO_2 reduction programs, water quality programs, food security programs, transportation projects, market drivers, and many others.

If your organization is interested in a presentation on the report or additional information about the project, please contact Dr. Lyn Kathlene at lyn@csi-policy.org or at 303-455-1740, extension 110.

NOW AVAILABLE – DVD RECORDING AND PRESENTATIONS FROM THE SPRING 2010 EVAPOTRANSPIRATION WORKSHOP:

DVD Topics and Speakers:

- Historical evolution of ET estimation Methods – Marvin Jensen, USADA ARS and CSU, retired
- Penman-Monteith ET calculations – Richard Allen, University of Idaho
- Crop Coefficients for Colorado: the Rocky Ford Lysimeter – Allan Andales, CSU
- Software for Consumptive Use Calculations – Luis Garcia, CSU and Ray Alvarado, CWCB
- Colorado Weather data for P-M ET calculations – Nolan Doesken, Colorado Climate Center and Mark Crookston, Northern Water
- Weather Data Integrity Assessment – Tom Ley, CDWR
- Calibration for Historical Crop ET Estimates – Tom Ley, CDWR and Ivan A. Walter, Ivan's Engineering
- Evaporation from water surfaces – Marvin Jensen, USDA/ARS and CSU, retired
- Remote Sensing to improve ET estimates – Luis Garcia, CSU

Contact Wendy Ryan at the Colorado Climate Center to reserve your copy (970.491.8506 or wendy.ryan@colostate.edu). Price is $50 and includes shipping and handling. Proceeds will be used for maintenance and upgrades to the Colorado Agricultural Meteorological Network (CoAgMet). More information at: http://ccc.atmos.colostate.edu/ET_workshop.php

Moving from Water Debate to Water Dialogue: A Process Design Experiment

MaryLou Smith, Policy & Collaboration Specialist, Colorado Water Institute

If we want to move beyond non-productive, circular arguments in our statewide and basinwide conversations about water, we need to design those conversations as carefully as we would design a physical water project before we move the first shovel of soil.

In July, at Western State College's annual Colorado Water Workshop, four panelists agreed to assist Colorado Water Institute's MaryLou Smith in testing a "seek to understand" dialogue process designed to avoid positional gridlock on a controversial water issue.

The Issue

Should Colorado adopt legislation to incentivize or mandate landscape water conservation measures for new home construction? The recommendation was made at a recent Interbasin Compact Committee (IBCC) meeting that now may be the time to consider such legislation, before economic recovery leads to the next building boom. About half of all urban water use is for outdoor landscaping. Why not make sure all new houses have water conserving landscapes as a first step toward serious water conservation in order to meet the projected statewide water supply/demand gap?

> I was pleased at the dialogue and thrilled to have the opportunity to provide the home building industry's perspective—that doesn't always happen on topics that could impact us. As they say, if you're not at the table you're likely on the menu—we much prefer being at the table.
>
> - Kim Calomino, Home Builders Association of Metro Denver.

The Process

The panel was designed to be a step by step look at what landscape conservation measures are available, what incentives and mandates are available for moving toward the adoption of such measures, and finally, what might stand in the way of their enactment. Panelists were chosen for their expertise in these areas as well as for their willingness to engage in a productive dialogue which could lead to deeper understanding and even coalition building. "Seek to understand" was the motto agreed upon, instead of "seek to persuade."

The Players

Doug Macdonald, V.P. of Aqua Engineering, Inc., educated workshop participants and the other panelists about measures which could lead to significant conservation of water in Colorado landscapes. He divided the measures into the categories of:

- Efficient Design
- Appropriate Technologies (including the wide array of products available such as soil sensors, "smart controllers," and improved sprinklers)
- Effective System Management

Great Western Institute Executive Director Tracy Bouvette discussed the relative value of incentive programs versus ordinances and regulation of new and existing construction. He included examples of outdoor water use efficiency programs that have been implemented in Colorado in the past few years.

Representative Kathleen Curry, Colorado State House of Representatives, discussed the role of the legislature as it pertains to the question of adopting landscape water conservation measures. She relayed her experience trying to get passage of a related water measure in a recent legislative session.

Kim Calomino, V.P. of Technical and Regulatory Affairs for Home Builders Association of Metro Denver presented her view on the "Best Ways to Work with Homebuilders to Conserve Water in Colorado Landscapes."

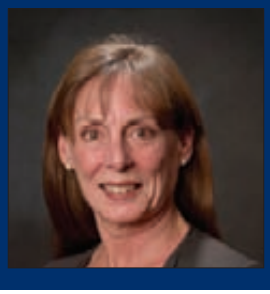
The Dialogue

For the dialogue immediately following the panelists' presentations, the facilitator reiterated the format: This is not a debate about whether we should have legislation leading to landscape conservation for new homes, but a dialogue about it. The bigger question may be, "What approach might we (the landscape industry, the homebuilding industry, water conservation professionals and the legislature) work on together that could result in a significant reduction in landscape water use?" The goal is not to refute another's point but to:

- Gather a better understand about it
- Listen for (and ask about) the related interests

The panelists, from left to right: Kathleen Curry, Doug Macdonald, Kim Calomino, MaryLou Smith, and Tracy Bouvette.





- Experiment with how all interests could be incorporated in a joint strategy, even a coalition going forward
- Explore, not resolve

Though the timeframe did not allow for more than a bite into the dialogue portion of the experiment, the tone of panelists and workshop participants was one of curiosity—how can we tackle this problem together, rather than how can we tackle each others' different positions? Going into the dialogue, the panelists, having shared their presentations with one another prior, were aware that Metro Homebuilders were not in favor of legislation that would cause their industry to jump through what they consider more hoops. Instead of trying to convince, panelists and participants exhibited an exploratory approach—"We heard you. What do you think would work instead?"

In the short time available, a number of ideas emerged, not just from the panelists but from the workshop participants as well, including:

- Let's not forget that energy and water are interconnected. Energy consumption changes can lead to water consumption changes as well. Let's work from that angle.
- How might we use technology instead of mandates? Perhaps more importantly, how can we get homeowners to use available technology in ways that lead to conserved water use? Mandating soil sensors or controllers doesn't mean the customers will use them.
- What is the role of pricing? Are water budgets geared specifically to a particular lot size more effective than just raising rates? How do we deal with the fact that many water utilities need all the revenue they can get just to cover capital costs they are already committed to?
- Would more effective legislation be aimed at licensing irrigation designers, irrigation contractors, and/or irrigation maintenance companies?

The Experiment Results

To achieve meaningful results from a process experiment like this would require seeing this dialogue as only the beginning of a dedicated effort to seek understanding of all points of view and then drilling down into the opportunities and constraints behind various approaches. This long, hard, systematic work does not fit well into our institutional approach to solving problems. Preparing the ground for a mutually beneficial approach for all stakeholders before constructing a bill would be ideal. But, as Kathleen Curry expressed, legislators do not have the time or resources to convene stakeholders for this kind of investigation. More typically, legislators attempt to propose bills they think will gain traction with their fellow legislators and then build coalitions to get them through. The reality is that those coalitions have more to do with politics than with common sense solutions. As the saying goes, a bill never comes out the way it went in, if it comes out at all.

Would this step by step, non-adversarial, non-positional dialogue be a model for the basin roundtables and the IBCC? How can we move from debate to dialogue—from positional posturing to interest-exploring dialogue—in that setting? The difference is lost on many who think dialogue is dialogue and, "let's just suffer through it." Isn't it time we learn that the fine nuances of dialogue design are just as important as engineering blueprints?

Introducing the Colorado Water Innovation Cluster

Joshua Birks, Economic Advisor, City of Fort Collins
Forbes Guthrie, VP Marketing, Stewart Environmental Consultants

Background

The City of Fort Collins is heavily invested in setting the stage for business development, job creation, and a thriving entrepreneurial ecosystem. The Fort Collins City Council adopted an Economic Action Plan in 2006, emphasizing the need to indentify Targeted Industry Clusters as an essential strategy for job creation. Since 2006, significant effort has been made by the city, Colorado State University, and the private sector to implement a cluster strategy to great success.

Over time, the Targeted Industry Clusters have undergone an evolution, and it will be important in the future to continue evolving and improving our approach for supporting target industries. The emergence of the Colorado Water Innovation Cluster (CWIC) is evidence of the continued evolution of this economic development strategy.

Timeline

January 2010 – Prominent companies in the water industry met to discuss;

April 2010 – Companies began to meet regularly to discuss the vision, mission, and purpose;

September 2010 – The cluster opens for business – pursuing strategic projects, membership structure, guidance, and strategic planning.

This Stewart Filtration Skid is used for metals filtration and produced water – this is an example of a process that the Colorado Water Innovations Cluster, still in its infancy, might oversee at some point in the future.

Courtesy of Forbes Guthrie.

Vision, Mission, and Core Values

Vision – The Colorado Water Innovation Cluster leverages the abilities of our members to produce long-term solutions to global water issues. In the next five years, our initiatives will establish our region as a global leader in water innovation, increase regional water-related innovation and primary employment, and contribute to the economic vitality of our community.

Mission – As leaders in water innovation, we provide a framework for collaborative initiatives that make a global impact.

Core Values – Collaborate, Innovate, Leverage

Value Proposition

Membership in the CWIC will fund regional studies, professional branding services, targeted cost sharing of research initiatives, community-based demonstrations, and outreach efforts to communicate the success of the CWIC on an international scale. The result will be more project kick-offs resulting in job growth, international collaboration, and actionable results around strategic focus areas.

Next Steps – Initiatives

The CWIC's goal is to focus on innovative and entrepreneurial ways to grow the water resource and technology sector of our economy through actionable initiatives.

Specifically, the CWIC seeks out initiatives that highlight our region's capabilities, help to address workforce gaps, involve the innovative use of technologies, contribute to the body of research around water, and increase jobs in our region.

Our region's heritage in water expertise is largely due to the leadership of Colorado State University and other great water research and related activities.

If you would like more information, please contact:

Josh Birks
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or
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forbes.guthrie@stewartenv.com

Web-based Wireless Soil Water Content Monitoring

José L. Chávez
Assistant Professor and Irrigation Water Management Specialist, Colorado State University

Water resource scarcity demands close monitoring of irrigation water usage in order to improve the efficiency of applying irrigation water and to sustain or improve crop production by managing water wisely. Farmers need to know the level of water content in their land's soil profile throughout the crop-growing season. This knowledge will allow farmers to monitor the soil volumetric water content (VWC) within set threshold levels like field capacity, permanent plant wilting point, and the critical point. The critical point is based on the crop-dependent soil water management allowable depletion (MAD) level. Therefore, when the soil VWC is nearing the critical point, an irrigation event can be scheduled and the irrigation amount and duration calculated.

Figure 1. *Soil water content reflectometer probes were installed at a depth of one, two and three feet in a sandy soil near La Salle, Colo. to monitor irrigation water management practices.*

Daily time-step monitoring of soil water content via wireless sensors in the ground will allow farmers to evaluate the decisions they make in terms of irrigation scheduling (timing and water amounts). They will be able to see the effects of their irrigation application decisions, i.e., over or under irrigation events. Moreover, the effect of rainfall events on the soil water profile (storage) levels will be captured; therefore, irrigation days and amount of water to apply could be more scientifically adjusted, potentially avoiding one or more unnecessary irrigation events. Wireless soil water content sensors aid in evaluating irrigation management decisions and are therefore a tool to potentially conserve water, soil, and nutrients while protecting groundwater and sustaining agricultural production.

Figure 2. *A wireless (remote) soil moisture monitoring station contains transmitting antenna, a solar panel, a seal battery, and a data logger/radio in an environmental enclosure.*

Under those premises, the Civil and Environmental Engineering Department at Colorado State University has teamed up with the Central Colorado Water Conservancy District (CCWCD) in a pilot project to instrument selected irrigated fields to monitor soil VWC levels. The instrumentation refers to the installed Web-based wireless soil VWC sensor network (one, two, or three sites/stations per field depending on soil textures and slopes). Each remote (wireless) monitoring site/station is composed of three VWC sensors per site/station installed at a depth of one, two, and three feet respectively; a combo data logger and a 2.4 GHz (high frequency) spread spectrum radio for telemetering data; broadcasting antennas; a soil temperature probe; a receiving antenna and radio (base station); surge suppressors; accessories; peripherals; and necessary software. The base station resides in the farmer's house, shed, or barn which can be seven to nine miles away from the remote stations (depending on the line of sight). This base station is connected to a computer server, which is connected to the Internet. Therefore, soil VWC and temperature data can be conveniently monitored at the farmer's

computer location or through the Internet from anywhere in the world.

This summer, we have successfully instrumented a center pivot irrigated alfalfa field near La Salle, Colorado. The soil water content probes that have been installed in this field and the wireless soil VWC monitoring station can be seen in Figure 1 and Figure 2, respectively. The soil moisture probes are water content reflectometer probes that signal travel time periods depending on the soil dielectric permittivity, which is affected by water content. The accuracy of the VWC readings and calibration from the installed probes are being evaluated using soil gravimetric sampling. Figure 3 shows one of these soil samplings being performed by Jordan Varble, who is a Master of Science student at Colorado State University.

Colorado State University and CCWCD expect to expand the network of Web-based wireless soil water content monitoring stations during the next summer (2011) and be able to continue helping farmers assess and evaluate their irrigation management practices.

Figure 3. Jordan Varble, a Master of Science student at CSU, takes gravimetric soil samples in the center pivot irrigated alfalfa field near La Salle, Colo.

In case of questions please contact the author at:
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Colorado State Forest Service Provides Best Management Practices to Protect Water Quality

Ryan Lockwood, Public and Media Relations Coordinator, Colorado State Forest Service

The importance of Colorado's watersheds cannot be overstated. Not only do Colorado's forests, fish and wildlife depend on the water that originates as rain and snow over the high country – thousands of farms and millions of Americans also depend on this water yield. In fact, water from Colorado's mountains and forests meets urban and agricultural demands in 18 states and northern Mexico. Yet the quantity and quality of the state's water yield can be greatly affected by human activities.

Necessary but high-impact forestry activities, like logging and road construction, have the potential to disturb vegetation and soil, which may cause erosion, pollute watersheds and fill reservoirs downstream with sediment. To mitigate this disturbance, the Colorado State Forest Service (CSFS) creates guidelines to protect water quality and minimize erosion. The guidelines provide recommendations for implementing certain forest activities, including logging and road construction, which are based on the collaborative experience and observations of natural resource professionals from multiple agencies.

In July, the CSFS released the most recent revised water quality protection guidelines for individuals and organizations conducting forestry-related activities in Colorado. Forestry Best Management Practices to Protect Water Quality in Colorado: 2010 is a publication designed to help natural resources professionals and private landowners protect Colorado water supplies by providing best management practices (BMPs) for forestry-related activities. The previous guidelines were developed in 1998.

The CSFS and 10 other federal, state, county and private natural resources organizations participated in an audit of six Colorado timber harvesting sites in September 2008 to evaluate the application and effectiveness of the previous guidelines. Sites were selected from a combination of federal, state and private lands. The audit team later provided input for and reviewed the new guidelines described in the 2010 publication.

"Every one of the agencies involved in this review was invaluable in providing the input necessary to make the new guidelines as comprehensive and clear as possible," said Jeff Jahnke, director and state forester for the CSFS.

The water quality BMPs addressed in the publication apply to essentially all forest management activities, including logging operations, fuels mitigation projects, forest health treatments, invasive tree species removal, and road construction. Guidelines include specific advice on such topics as designing and grading roadways, which produce up to 90 percent of sediment in forest activities, and post tree-harvest soil stabilization methods for loggers. The guidelines apply to both forestry professionals and private landowners harvesting timber or extending roads through forested watersheds.

BMPs can help protect the water quality in streams, such as this one near Vail, Colo. Photo by Ingrid Aguayo.

"These guidelines are voluntary, and applying them often requires professional assistance along with personal judgment," said Greg Sundstrom, assistant staff forester with the Forest Management Division of the CSFS. "But they also can be used to develop timber sale and forest treatment contracts, making the application of BMPs a requirement in those situations."

Based on recommendations from the audit of the previous publication, the new BMPs include the following notable revisions:

- Expanded information related to prescribed burning in streamside management zones
- Additional guidance for on-site camp sanitation
- Descriptions of new technologies for mitigated stream crossings
- An emphasis on utilizing existing sites for landings, roads and trails in logging operations
- A new BMP encouraging planning for ongoing monitoring efforts after harvest operations

The CSFS encourages those who work in or own forestland to use the water quality BMPs when constructing roads, establishing streamside management zones, conducting timber-harvesting operations, applying pesticides or fertilizers, or designing stream crossings like bridges and culverts. It also is important to adhere to the BMPs when engaging in pollution-producing activities to reduce or eliminate water contamination.

"It's vital that we safeguard the future of our water resources," Sundstrom said. "If Colorado landowners and forestry professionals adhere to the guidelines in this publication, they can help protect the quality of water that flows from our forests to our faucets and fields."

For more information about the CSFS watershed BMPs or to obtain copies of the publication, contact the local CSFS district office.

District location and contact information is available at csfs.colostate.edu

A Joint Effort

The summarized 2010 watershed BMPs are condensed from a larger publication on watershed BMPs created by the CSFS, Colorado Timber Industry Association, Colorado Nonpoint Source Task Force, and the U.S. Environmental Protection Agency. Funding for the pamphlet was provided by a grant from the Colorado Water Quality Control Division of the Colorado Department of Public Health and Environment.

The following organizations participated in the audit leading to the revised guidelines:

- Colorado Water Quality Control Division in the Colorado Department of Public Health and Environment, which also provided grant funding to print the publication
- U.S. Forest Service
- Watershed Science Department at Colorado State University
- Colorado Division of Wildlife
- Colorado Office of the Natural Resources Conservation Service
- Jefferson County Open Space
- Colorado Tree Farmers
- U.S. Environmental Protection Agency
- Intermountain Forest Association
- Colorado Timber Industry Association.

Getting into the Flow of Archival Research

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

Do you suffer from information overload, being constantly inundated with media, mailings, and more? When you go to look for information you need, can you easily find what you want? With so much available, searching for information can be like going over the edge of a massive waterfall!

Don't let this happen to you! When looking for information related to Colorado water history, consider visiting the Water Resources Archive (WRA), which holds a comprehensive record of events, people, and pictures of Colorado water. While archival research may not always be smooth sailing, it need not be like going over a waterfall. Knowing what you can find in the WRA, how you can find it, and how you can access it can easily get you into the flow of using archives to help solve your information needs.

The archives are stored in these boxes at the CSU Libraries.
Photos by Lindsey Knebel and Patricia J. Rettig.

What You Can Find

What can you find at the Water Resources Archive? The archives hold hundreds of boxes of documents containing materials you might store in a filing cabinet: meeting minutes and agendas, financial and legal papers, correspondence and project files, etc. We also include things like the unpublished items you might keep on shelves: reports, manuals, ledgers, photo albums, and diaries. It is this type of material, generally one of a kind, which dominates the WRA, though other types include media (film, video and audio recordings), varied formats (electronic files, data, maps and charts), and an occasional artifact (an engineer's briefcase and slide rule, for example).

These materials, created or used by people in the course of business or personal activities, are kept because an archivist has determined that they have historical value. Because the context in which materials were created and used is important to understanding them, materials are kept together according to origin as distinct collections, not combined from different sources. Within a collection, archivists attempt to retain the order in which materials are found unless there is no identifiable order. However, every creator has his/her/its own quirks, so sometimes you will have to ascertain these as you examine a collection.

How You Can Find It

How do you find materials of interest in the WRA? Start by determining your information needs: what your subject of focus is, what date span is of interest, whether there will be a geographical focus, and what material type will be most useful. Depending on the questions you are trying to answer, doing some initial reading of books, articles, or reliable websites can help before diving into archival research.

Once you have your research questions identified, visit the WRA Web page (http://lib.colostate.edu/archives/water/). Here, you can search the finding aids, which are created for each collection. A finding aid is a document that details the collection's

context (who created the materials and the background of the people or organizations involved) as well as the collection's content (what is in all those boxes). The contextual descriptions help you understand the bigger picture; the content listings get you to the items you seek.

Keep in mind that finding aids typically focus on the folder level instead of the item level. This means a folder title will be listed, but each and every item in that folder will not be detailed. Because the folders were often labeled by the creator of the collection, the titles may or may not be descriptive enough to be helpful. In these cases, be sure to read the contextual descriptions. An example would be when fifty folders are listed simply as "Correspondence" with chronological dates. The archivist may have written a summary of topics covered in the letters as well as prominent correspondents.

At the WRA, all finding aids are searchable online. A search engine provides keyword searching across all finding aids at once, resulting in a list of relevant finding aids to examine. Further keyword searching is available through the browser functionality once inside a finding aid. Keep in mind when searching that folder titles are unlikely to be standardized. Be sure to try synonyms, abbreviations, broader terms, or narrower terms, depending on your information needs. Keyword searching can be an iterative process to find just exactly what you are seeking, but once you do, the next step is accessing it.

How You Can Access It

How do you get to that potential gem you have identified? Want online access? A small percentage of WRA holdings are accessible online in digital format. When you see a "VIEW" link in a finding aid, you can click on it to get directly to the item. If you are seeking only digital items, you can search CSU's Digital Repository (http://digitool.library.colostate.edu/). Keep in mind, however, that this includes not only archival documents, but also materials from across CSU (including the Colorado Water Institute!).

For material not online, there are several access options. If your research requires only a small amount of material, you can request it via a phone call or email and we will provide it for a fee as a photocopy or a scanned document. In-depth research will require a visit to Fort Collins to the Morgan Library. For this, be sure to plan ahead as some collections are stored offsite and require an appointment for access. To request collections to use in the Archive's reading room in CSU's Morgan Library, you will need to provide the staff with the collection names and box numbers of interest. Staff members will retrieve these, and you will use them on site. Note taking with pencil and paper or a laptop is permitted, and photocopies or scans can be provided for a fee.

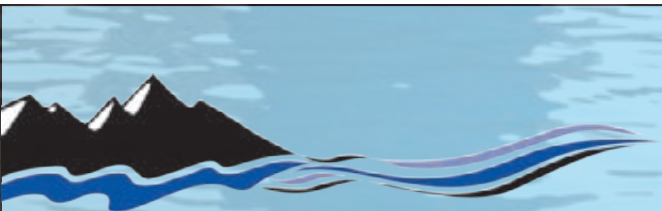
As you examine materials, keep notes about what you consult. If you ultimately use materials in written or presented works, be aware of any copyright restrictions, and make sure to cite your source – you would not want to be accused of plagiarism!

Persistence Pays Off

If you have trouble finding the information you are seeking, consult the archivist (myself). The archivist has a wealth of knowledge she is more than willing to share about the collections in the WRA as well as related collections elsewhere. She can also help with searching tips as well as with navigating through collections which do not yet have searchable finding aids. If you are not sure where to begin your research, the archivist can discuss it with you, suggest potential directions to pursue, and help you on your way. Know that archives maintain patron confidentiality.

The Water Resources Archive believes in learning from the past to prepare a better future. Get into the flow of archival research to be part of the journey.

For more information about the Water Resources Archive,
visit the website (http://lib.colostate.edu/archives/water/)
or contact the author (970-491-1939; Patricia.Rettig@ColoState.edu).



The Colorado Water Institute Announces

Request for Proposals: FY11 Student Water Reseach Program

Proposals due 11/30/10. To apply visit cwi.colostate.edu

Colorado, USGS Welcome John Wesley Powell Center

Lindsey Knebel, Editor, Colorado Water Institute

CSU President Tony Frank, Assistant Secretary for Water and Science in the U.S. Department of the Interior Anne Castle, and USGS Director Marcia McNutt at the opening.
Photo by Lindsey A. Knebel.

On August 19th, the John Wesley Powell Center held a grand opening that included attendees CSU President Tony Frank, Congresswoman Betsy Markey, USGS Director Marcia McNutt, Department of the Interior Assistant Secretary for Water and Science Anne Castle, and others. Several speakers, including Betsy Markey and Marcia McNutt, commented on the significance of opening the center in Fort Collins.

Only a handful of centers exist in the U.S. like this one opened at the Fort Collins United States Geological Survey (USGS) building, just south of Colorado State University's campus – the John Wesley Powell Center for Analysis and Synthesis.

"Analysis and synthesis" means that groups of scientists come together from all over the world in some cases to collaborate on research topics that extend past the boundaries of a single research discipline.

For example, one current working group, according to John Wesley Powell Center Co-director Jill Baron, came from places like Australia, Taiwan, Indonesia, and Columbia to work on a project examining tree mass growth and the terrestrial carbon cycle. The project will analyze "millions of trees and more than 1,000 species," according to the John Wesley Powell Center website, and should result in "key information needed to better forecast how forests will change through time and affect the terrestrial carbon cycle."

How it Started

"National academics of science have called for these centers," says Jill Baron, but the scientific community is slow to respond. Baron was part of a similar center, the National Center for Ecological Analysis and Synthesis, and says that often, 150 research proposals would be submitted every year, and only 15 were accepted.

Baron headed a proposal to the Fort Collins USGS to create the John Wesley Powell Center, along with her co-director Marty Goldhaber and others. She says their goal was to "rethink the mission of this venerable old agency" – the USGS – and they saw a niche for a science strategy team that would focus on major environmental challenges. These challenges, according to her report, included the six areas: ecosystems change, climate change, energy and natural resources, environmental risks to public health, water sources, and national well-being.

Areas like "water, biology and geology" are integrating, according to Baron. Scientific centers like the John Wesley Powell Center allow for that change toward interdisciplinary study. Baron calls this new research method "a more rapid way of pushing knowledge forward."

How it Works

The John Wesley Powell Center is still in its beginning stages, but already, it's beginning to host scientists and research groups. The groups get started when scientists studying environmental problems see a need for collaborative research and send a proposal to the center, which is reviewed by a 10-person team called the Science

U.S. Representative Betsy Markey, CSU Water Center Director Reagan Waskom, and CSU Professor Dennis Ojima have a discussion after the ceremony.
Photo by Lindsey A. Knebel.

Advisory Board, chosen to reflect earth systems science backgrounds. The team is "heavy-handed," says Baron, when deciding which proposals to accept. One of their requirements – the proposed team of scientists has to be diversified. If the groups look too one-dimensional, including age- or gender-wise, the Science Advisory Board will suggest they change their composition.

Working group teams are usually made of 8-20 scientists. For groups whose proposals are approved, the John Wesley Powell Center will cover flight and hotel costs as well as daily living costs and some allocated USGS salary so the scientists can stay in Fort Collins for a period and work at the USGS building. The building provides amenities like an on-site library, conference rooms, and various technologies and expert consultants. For instance, Geographic Information Systems (GIS) experts work out of the building to provide maps and other data compilations. The center runs on newer virtual servers, which means no data will be lost if a server crashes, and the technology experts at the center are also working on a type of computing that makes use of all the desktop computers in a network to run data analyses. Usually, large data analysis projects are run on a mega-computer, which can cost thousands of dollars an hour to rent. Using several personal computers instead of one mega-computer would utilize the unused horsepower in those computers and save time and money for the center.

These technologies and services are available to scientists throughout their research. After their initial collaboration, the scientists work from their respective locations on further analysis, sometimes meeting again, and finally, they reunite to write concluding papers. This is an important step of the process for Jill Baron, who says "more is better" when it comes to the number and type of articles published. She hopes they'll be accessible in a variety of media, from magazines to journals to websites.

The Center's Significance

"The research conducted at the Powell Center will help us to respond better" to environmental conflicts, said Betsy Markey.

Assistant Secretary for Water and Science in the U.S. Department of the Interior Anne Castle commented on the U.S. need for "independent, cutting-edge science to help us all do our jobs better." She used an example to show how multi-disciplinary research will go beyond the bounds of previous research. "Previously," she said, "we only knew [things like] how much coal was in the ground." Research was lacking in things like wildlife impact, environmental impact, and other areas after the coal is taken out of the ground. She hopes the center will involve "young, new minds" and will fill in gaps in research so future scientists

Jill Baron introduces the John Wesley Powell Center.
Photo by Lindsey A. Knebel.

can make better comparisons – can "compare apples to apples," as she said.

John Wesley Powell Center Co-director Marty Goldhaber said that the center will be a "think tank to study the big problems that cross interdisciplinary lines." He cited the well-known quote by naturalist John Muir, "When we try to pick out anything by itself, we find it hitched to everything else in the universe." Goldhaber and other speakers emphasized the importance of understanding whole ecosystems, not just one piece of an ecosystem – thus, when scientists from geology, water, and other disciplines work together, they are more able to see the bigger picture.

Co-director Jill Baron also spoke at the opening, saying, "We hope to grow, and we hope you will be able to watch us." She calls the center a sort of "summer camp" for scientists. She later explained that sentiment, saying that scientists are "continually bombarded" – rarely do they get a chance to focus on just one topic.

Baron says it was an honor to have such distinguished guests in the audience of the grand opening.

As for water research - Baron says that CSU representatives of groups like the Consortium of Universities for the Advancement of Hydrologic Science, Inc., (*CUAHSI*) and the John Wesley Powell Center are in the formative stages of adding water-related topics to the John Wesley Powell Center's list. She says to "stay tuned" for the outcome of these preliminary talks.

For more information about the John Wesley Powell Center for Synthesis and Analysis, visit powellcenter.usgs.gov

Wrapping up the 2010 Water Year

Nolan Doesken, Colorado State Climatologist,
Colorado Climate Center

Defining a "water year" as many of us do, October 1-September 30, we have almost made it through the 2010 water year. There have been dry times and dry places, but all things considered, water supplies are stable.

The water year is the 12-month period that best coincides with the annual cycle of winter snow accumulation, spring snow melt, and the growing season when most of the year's consumptive use takes place. Reservoir operators in Colorado prefer a slightly different definition for the "water year." They start their water year calendars on November 1 and wrap up the following October 31. This different definition makes sense because reservoir draw-down (lowering surface water elevation) typically continues from midsummer through October before we move back into storage mode in November.

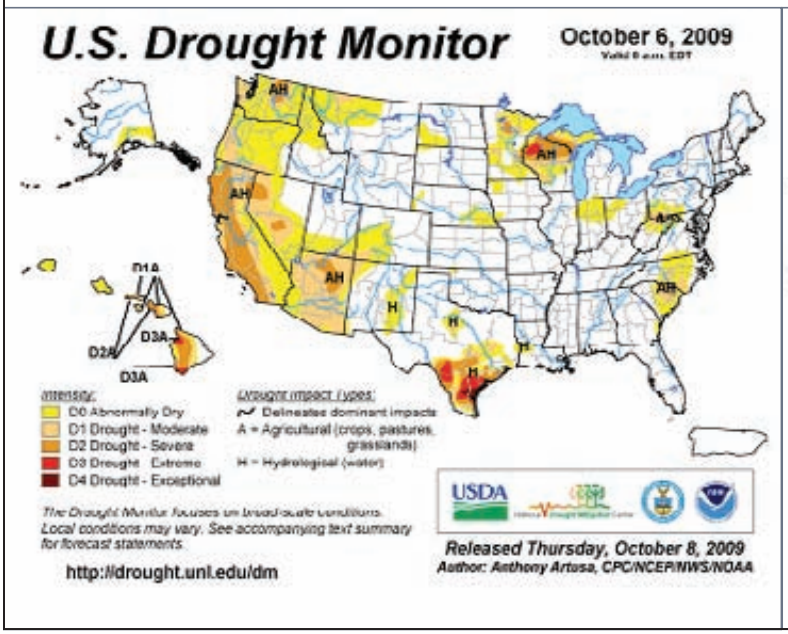
The 2010 water year has been interesting, entertaining, and a bit nerve racking for weather and water watchers. We have had the typical variety of dry episodes interrupted occasionally by showers and storms. On several occasions, areas of the state dried and were lagging with much-below-average precipitation for a period of months only to have timely storms bail us out. As is so often the case here, drought seems to be knocking at the door, but at least for 2010, it didn't settle in.

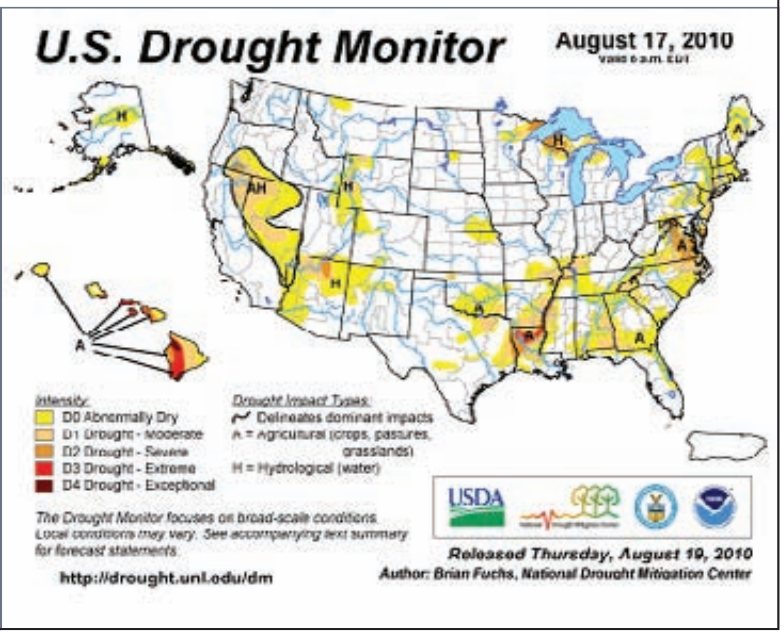
2010 Water Year Highlights

Reviewing some highlights of this year, the 2010 water year began with moisture on the Eastern Plains when two widespread storms passed over last October. This gave both winter wheat and Great Plains rangeland a good boost to carry them through winter with adequate soil moisture. Northern Colorado got an early dose of deep snow and some of the coldest October temperatures in many years. November was mild and dry, so mountain snowpack was off to a slow start. Fortunately, December brought cold and fairly snowy weather to much of the state. For the rest of the midwinter months, the storm track favored southern Colorado with deep snow accumulation and mostly skipped over the northern mountains and the upper Colorado river basin. By March, some areas around Grand County had only received about half of their average winter precipitation. Weather patterns then changed, and for the next several months, storms favored northern Colorado while strong winds and occasional dust storms buffeted southwest parts of the state.

One of the hydrometeorological surprises of the year was the large surge of runoff and minor flooding in June that resulted from a combination of cool weather in May and a prolonged heat wave in June, followed by heavy rains in parts of northern Colorado. The South Platte River surged

These two images show how the drought conditions have changed from October 2009 through August 2010. Specifically in the Upper Colorado basin, we can see that western Wyoming, northeastern Utah and northwestern Colorado have experienced an increase in drought conditions while southwestern Colorado has experienced improved conditions. Eastern Colorado has experienced favorable moisture conditions all year.





to levels not seen in over a decade. The Yampa River made a great comeback, and the Colorado River, where summer flows were predicted to be low, experienced more than a week of surprisingly high flows for a year with consistently low snowpack most of the winter.

The southern Colorado mountains missed the June surge since their snowpack had melted earlier. By midsummer, very dry conditions developed over southwest and south central Colorado. Several June and early July forest fires ignited and spread. But just when it was looking a little scary, the North American Monsoon circulation began pumping moisture northward across Arizona and New Mexico and for several weeks from late July into August, and showers and soaking rains fell almost daily. Rainfall was adequate to improve summer stream flow to near normal levels. Summer storms were also regular occurrences on the Eastern Plains. Though storms were scattered as always, most of eastern Colorado was still running near or above average for 2010 water year precipitation as the summer progressed. For the second year in a row, parts of Kit Carson and Yuma Counties experienced higher than normal precipitation. Burlington has totaled over 55 inches of precipitation since October 1, 2008 – their all-time greatest two-year total.

Reservoir levels in Colorado remain in fairly good shape. Just when water demand was peaking in mid-July, more rainfall and higher humidity associated with the summer monsoon helped slow the demand. We won't have the final numbers until the end of October, but these will likely be the best end of season reservoir levels we've seen since 1999.

Dry Weather Ahead?

The National Oceanic and Atmospheric Administration (NOAA) recently issued a special climate statement describing the change that has occurred this summer in the tropical Pacific Ocean. What had been the strongest El Niño (warm sea surface temperatures and related current flows, etc.) in the eastern Pacific near the equator since 1997 is now quickly cooling. By winter, the opposite phase of the El Niño Southern Oscillation (La Niña) will likely be established. The cool phase of this oscillation, if it becomes well established in time for winter, is sometimes associated with below average precipitation across southern Colorado, fewer than average big winter storms along the Front Range, and good midwinter snows in the northern mountains. More downslope winds east of the mountains are also possible this winter, and the likelihood for generous spring precipitation from the Front Range eastward onto the plains is reduced somewhat. La Niña doesn't dictate Colorado's upcoming weather patterns for the next year, but it does shift the odds a bit. Stay tuned and we'll all see how this plays out.

And don't forget, Happy New Year as the new 2011 water year begins October 1. Unless you manage reservoirs – then you'll have to wait another month.

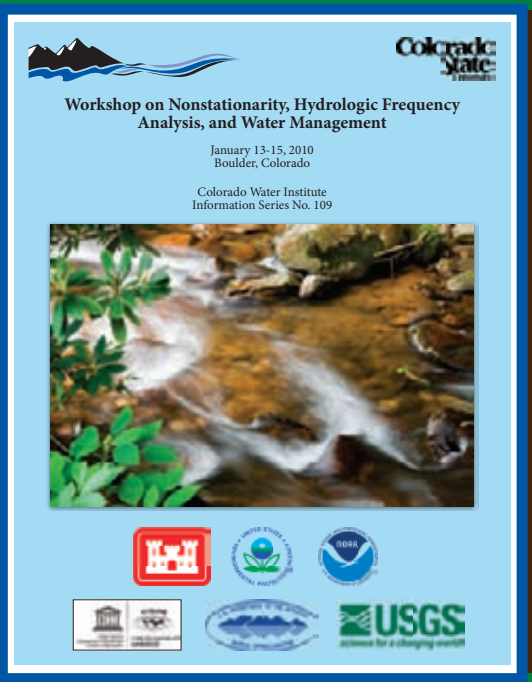
For more on Nolan Doesken or the Colorado Climate Center visit:
http://ccc.atmos.colostate.edu

Workshop on Nonstationarity Proceedings now available:

The workshop was held in Boulder, Colorado from January 13-15, 2010, and brought together researchers and practitioners from the U.S. and international institutions. The workshop program included five Nobel Peace Prize laureates, who were lead authors for Intergovernmental Panel on Climate Change reports. International participants came from Canada, the United Kingdom, Japan, Poland, Greece, and Italy.

The workshop objectives were to discuss in detail how water management agencies should plan and manage water resources in the face of climate change, and to form a coordinated action plan to help the agencies move forward. The workshop was organized into several main themes:

- Introduction to the problem nonstationarity poses for water management
- Understanding nonstationarity through data analysis and statistical methods
- Forecasting future hydrologic frequency through the use of climate model information
- Decision making with a highly uncertain future
- International perspectives on nonstationarity
- Summary and conclusions



Copies available online at http://www.cwi.colostate.edu/NonstationarityWorkshop

CSU Offers Continuing Online Education in Water

Lindsey Knebel, Editor, Colorado Water Institute

Carl Melle, program director for continuing education at Colorado State University (CSU), points to the website www.learn.colostate.edu/water as a "landing page" that lists "everything related to water" that CSU offers online. The site includes water-related courses, water-related degrees, free videotaped lectures, and other helpful links for those "continuing education" students interested in water. The most recent program, then – a nine-credit online Water Resource Certificate – is just "the newest edition to [our] robust online water programs," says Melle.

The Water Resources Certificate is made up of three courses, all offered through the distance learning program. The classes are designed for "people who want to retool" their current water careers or "move into a water-related area or career," says Melle. The course creators, made up of water experts at CSU, picked topics for the certificate based on what they consider in-demand skills and knowledge in the current water industry. The resulting three classes, which can be found on the website listed below, are: Water Resource Development, Water Law and Policy for Non-Lawyers, and Concepts in GIS: Water Resource Analysis. The course creators have already filmed and posted a few introductory videos along the Poudre River for enrolled students to view. Video chat, discussion boards, and other online learning tools will also be available.

Look for the courses to start becoming available during the spring, summer, and fall of 2011.

"I've seen a few hundred online courses as a program director," says Carl Melle, "and the [Water Resources Certificate] courses are by far the best I've seen in a long time." Melle credits the organization, the instructional designs, the wealth of content, and the courses' clearly-stated objectives. He predicts that the courses will be very "student-friendly" – easy to navigate and understand for the students who wish to participate.

Carl Melle is the program director for continuing education at CSU.

Melle welcomes any feedback about the program – his contact information is listed on the below site. "We're interested in hearing from professionals in the water community as to what courses and skill sets might be good additions to this certificate program," he says.

Visit the site at www.learn.colostate.edu/certificates/water-resources.dot

2010 Colorado Water Congress Summer Conference August 25-27, 2010

The 2010 Colorado Water Congress (CWC) Summer Conference kicked off on Wednesday, August 25, 2010, with four workshops: Water Quality, Water Conservation, Wild and Scenic Rivers, and Professional Skills Development (including programs on the Colorado Decision Support System and Communication Skills).

The 2012 Year of Water committee met to review proposed logos and plans to celebrate 2012 as a yearlong, statewide water event. Year 2012 will be the 75th anniversary of the Colorado Water Conservation Board (CWCB), Northern Colorado Water Conservancy District (NCWCD), and the Colorado River Water Conservation District (CRWCD). Many water organizations plan to unite for a public awareness campaign focused on the value of water. For more information, contact Nicole Seltzer at the Colorado Foundation for Water Education.

CWC President Chris Treese kicked off the opening general session on Thursday morning with a look at state budget and water concerns. Several Colorado senators and representatives discussed the anticipated $900 million shortfall looming for FY (fiscal year) 11-12. It was noted that the CWCB has lost approximately $130 million from program accounts, significantly impacting water programs and projects. U.S. Representative John Salazar noted that, "In this political environment, you could walk on water and be criticized for not swimming." He went on to prognosticate that economic recovery would, unfortunately, be slow.

Travis Smith, Senator Bruce Whitehead, and former Agricultural Commissioner Don Ament at the Water Congress meeting.

Nolan Doesken, State Climatologist for Colorado, and Brad Udall, Western Water Assessment, University of Colorado- Boulder.

Other speakers on Thursday included Floyd Ciruli, who discussed the 2010 election and voter dissatisfaction. Brad Udall provided attendees with a summary of lessons learned from the prolonged drought in Australia, noting that it had resulted in changed policy, infrastructure, water rights, water markets, desalination, recycling, and rain water harvesting. Major reform of water law and administration occurred to deal with over-allocated systems and to provide water for the environment. He noted that a 20 percent decline in precipitation resulted in a 40 percent decline in runoff in the Murray Darling Basin, an important agricultural region in Australia.

Congresswoman Betsy Markey addressed the congress via Web-link, highlighting her work on the Arkansas Valley Conduit, a project to improve water quality in the Arkansas River Valley, and the importance of agricultural water and agricultural communities in 4th District. A number of other political hopefuls addressed the Congress, including gubernatorial hopefuls John Hickenlooper and Dan Maes.

The next meeting of the Colorado Water Congress will be held January 26-28, 2011 in Denver. For more information, go to http://www.cowatercongress.org

Faculty Profile: Patricia Rettig

Lindsey Knebel, Editor, Colorado Water Institute

Patricia J. Rettig, Head Archivist for the Water Resources Archive at Colorado State University (CSU) Libraries, says she enjoys working with the archive because "water issues are critical for everybody to know about, especially in Colorado."

Background

Rettig has been working with the water archive collections since funding came to the CSU Libraries in 2001, but before her work in libraries during college, she says she didn't know archives existed.

Rettig was first interested in libraries because of her love of books – she still enjoys reading literary novels, histories, and biographies on the side. She earned a Bachelor of Arts in English from Wittenberg University in Springfield, Ohio followed by a Master of Library Science from the University of Maryland, College Park. During her junior year, she did a semester-long internship in Washington, D.C. with the Manuscripts Division at the U.S. Library of Congress.

The Library of Congress internship "got me hooked on archival work," says Rettig. "I like organizing things," she says. The challenge of figuring out how to organize materials so that other people can use them and writing about materials seemed to fit well with Rettig's skills and interests.

Prior to the Water Resources Archive, Rettig was employed within the cataloguing department at the CSU Libraries. When water archive funding came through, the library brought her to the archival department because of her background. She credits books such as *Beyond the Hundredth Meridian* (about John Wesley Powell), the *Headwaters* magazine, and experts in the water community for her initial understanding of water issues. She says she spent a lot of time when she first arrived in the archives learning how much she didn't know about water.

Working with Archives

Rettig is involved with every side of the water archive's acquisitions, organizing, and reference – "I do all of it," she says, which is unique for an archivist. She even works on the website and teaches classes about the archive. Sometimes she has help from student interns, who come and go at various steps of the process and are, she says, "invaluable to our progress."

Rettig often finds herself doing "a dozen things at a time" – right now, in addition to duties outside the archives, she's working on a collection from the Platte River Whooping Crane Maintenance Trust, website upgrades, and a digitization project funded by the Colorado Water Conservation Board. Her job, she says, is challenging, but "in a good way."

Patricia J. Rettig. Photo by Lindsey A. Knebel.

Her favorite collection, because of "the significance of what he did and what he saved," is the papers of Delph Carpenter, who served as a Colorado Senator from 1909-1913 and argued the *Colorado v. Wyoming* lawsuit before the Supreme Court in 1916 and 1918, among other accomplishments. He's known as the "father of the Colorado River Compact" for his work with the compact. His collection fills 127 storage boxes. "At some point, I almost had it memorized," says Rettig of the collection.

What She's Working on Now

This year, Rettig received the 2010 CSU Libraries Faculty Award for Excellence "for outstanding contributions to the Libraries, to the University, and/or to the library profession." The CSU Libraries credited her work not only organizing the archives, but also taking them on the road and creating displays to spread the word. She makes presentations about the water archive at conferences like the Colorado Water Congress meeting and others. She's taught herself these marketing skills to educate and spread

the word so that archives are "not such a foreign concept." Rettig says she's "re-energized" when she finds herself among members of the water community – it's a group she very much enjoys being a part of.

Rettig is also currently on track for tenure within CSU.

Rettig's activities outside the library are numerous, including chairing the CSU Committee on University Programs and being an active member of the Society of Rocky Mountain Archivists.

This year, Rettig will take on the duties of visiting an undergraduate history class, Jared Orsi's HIST 353 – Colorado History, to give them hands-on experience with historical documents. She will spend one session in the class and two sessions at the archives with the students.

Future of the Archive

Ms. Rettig's archives are the only archives in Colorado that focus on Colorado water history. "We're still trying to catch up with everything that hasn't been collected for the last 100 years," says Rettig.

To help collect funds, Rettig takes part in organizing a fundraising event called Water Tables, now an annual event for the past five years. The event has grown every year and is a huge success in Rettig's eyes. She calls Water Tables a unique event within the water community, hosted by prominent water professionals who come to discuss and learn about Colorado water history. The funds raised at the event go to purchasing special archival supplies and to fund student assistants as well as Rettig's outreach efforts. New projects, products, and services can be provided with additional funding, she says. Rettig visualizes interpretive items that go beyond archived documents, like online exhibits, histories, and bibliographies.

Rettig says she hopes people will use the water archive to better educate themselves about water issues and Colorado's water history, which she describes as complex and "fascinating." "Water is essential to every part of life," she says. "There's a lot of infrastructure, planning, people and organizations behind [water] that people take for granted."

See the article by Rettig (page 30) for more information about research using the Water Resources Archive.

Patricia J. Rettig
Head Archivist of the
Water Resources Archive

Colorado State University

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Fort Collins, CO 80523-1019
Tel: (970) 491-1939
patricia.rettig@colostate.edu

Water Research Awards

Colorado State University (June 15 to August 15, 2010)

Bauder, Troy A, Soil & Crop Sciences, Colorado Department of Agriculture, Training and Education for Agricultural Chemicals and Groundwater Protection, $185,000

Bauerle, William L, Horticulture & Landscape Arch, USDA-ARS-Agricultural Research Service, Measurement and Modeling Plant Water Use to Quantify Nursery Water Requirements, $48,780

Belisle, John T, Micro, Immuno & Path, HHS-NIH-NIAID-Allergy & Infect Diseases, RP-010 Treatment of Acute West Nile Virus Disease and Neurological Sequelae, $248,398

Bestgen, Kevin R, Fish, Wildlife & Conservation Biology, DOI-USFWS-Fish & Wildlife Service, Monitoring Non-Native Species & Native Species; Native Species Taxonomy Studies, $25,000

Bestgen, Kevin R, Fish, Wildlife & Conservation Biology, Wyoming Game & Fish Department, Hornyhead Chub Investigations, $30,910

Browne, Katherine E, Anthropology, NSF - National Science Foundation, A Double Dunk: How the Oil Spill is Affecting Katrina-Impacted Residents, $35,023

Brummer, Joe E, Soil & Crop Sciences, Utah State University, Reducing Nitrogen Fertilizer Inputs to Irrigated Pastures and Hayfields by Interseeding Legumes, $49,849

Cooper, David Jonathan, Forest Rangeland Watershed Stwrd, DOI-NPS-National Park Service, Vanishing Wetlands of Yellowstone National Park's Northern Range: Watersheds, Hydrology, Soils, and Vegetation Past, $15,021

Cooper, David Jonathan, Forest Rangeland Watershed Stwrd, DOI-NPS-National Park Service, Evaluate Reference Meadows and Develop Restoration Concepts for Halstead Meadow, $57,205

Fausch, Kurt D, Fish, Wildlife & Conservation Biology, Wyoming Game & Fish Department, Climate Change Tool for Cutthroat, $87,571

Funk, William Christopher, Biology, Colorado Division of Wildlife, Population Genetic Analysis of Arkansas Darter (Etheostoma cragini) in Colorado: Characterization of Population, $42,501

Goemans, Christopher G, Agric & Resource Economics, Colorado State Water Conservation Board, Feasibility Study to Assess the Potential of Urban Water Conservation to Meet Colorado's Future Water Supply Needs, $26,670

Graham, James J, Natural Resource Ecology Lab, DOI-USGS-Geological Survey, Improving Web Site Capabilities for the Global Invasive Species Information Network (GISIN), $74,576

Hansen, Neil, Soil & Crop Sciences, Alliance for Sustainable Energy-NREL, Biomass Production Potential in Central Great Plains Cropping Systems, $74,972

Johnson, Brett Michael, Fish, Wildlife & Conservation Biology, DOI-NPS-National Park Service, Tracking Brown Trout and Lake Trout Predation on Kokanee at Curecanti National Recreation Area, $19,975

Johnson, Jerry J, Soil & Crop Sciences, Colorado Sorghum Producers, Getting Sorghum Going in Colorado - 2010, $15,000

Julien, Pierre Y, Civil & Environmental Engineering, Korea Institute of Construction Technolo, Restoration of Abandoned Channels, $49,308

Kampf, Stephanie K, Natural Resource Ecology Lab, DOE-US Department of Energy, Climate Change Impacts to Hydropower Generation in Pacific Northwest River Basins, $106,627

Knapp, Alan Keith, Biology, MTU - Michigan Technological University, Interactive Effects of Altered Rainfall Timing and Elevated Temperature on Soil Communities and Processes, $21,227

Larson, Kevin, Plainsman Research Center, Oklahoma State University, Expanding Production Area and Alternative Energy Crop Market of Proso Millet for Water Deficient Lands, $28,105

Lemly, Joanna, Fish, Wildlife & Conservation Biology, USDA-USFS-Forest Research, Wetland Mapping for the Medicine Bow-Routt National Forest, $16,000

Loftis, Jim C, Civil & Environmental Engineering, DOI-NPS-National Park Service, Assessment of Aquatic Invasive Species in National Park Waters, $45,000

Moore, Chester G, Micro, Immuno & Path, City of Fort Collins, West Nile Virus Testing, City of Fort Collins, Colorado, 2010, $37,409

Myrick, Christopher A, Fish, Wildlife & Conservation Biology, Wyoming Game & Fish Department, Development of Barriers and Passage Requirements for Native and Nonnative Fishes in the Green River System, $24,000

Myrick, Christopher A, Cooperative Fish & Wildlife Research, Colorado Division of Wildlife, Evaluation & Development of Fish Passage Designs, $11,000

Noon, Barry R, Fish, Wildlife & Conservation Biology, DOI-NPS-National Park Service, 2010 Occupancy of Beaver (Castor canadensis) and Beaver-Habitat Relationships in Rocky Mountain National Park, Colorado, $7,055

Poff, N LeRoy, Biology, DOI-USGS-Geological Survey, Effects of Water Management and Climate Change on the Dynamics of Native and Invasive Wetland and Riparian Plants in, $91,575

Ramirez, Jorge A, Civil & Environmental Engineering, USDA-USFS-Forest Research, Enhanced Assessment of Vulnerability of US Water Supply to Shortage, $40,000

Ramirez, Jorge A, Civil & Environmental Engineering, NSF - National Science Foundation, WATER-IGERT: Integrated Water Atmosphere and Ecosystem Education and Research, $134,682

Reardon, Kenneth F, Chemical & Biological Engineering, CSURF-CSU Research Foundation, Multichannel Optical Biosensor for Detection of Contaminants in Water and Food, $75,000

Stednick, John D, Forest Rangeland Watershed Stwrd, Colorado Division of Wildlife, Monitoring Impacts of Irrigation Recharge Projects on Main Stem South Platte Native Fish Populations, $85,675

Swift, David M, Natural Resource Ecology Lab, DOI-NPS-National Park Service, Investigation of Nitrogen Deposition into Loch Vale, $10,000

Waskom, Reagan M, Colorado Water Institute, Colorado Dept Public Health & Environ, NPS Outreach Coordinator, $22,000

Waskom, Reagan M, Colorado Water Institute, Colorado State Water Conservation Board, CWCB/CWI Cooperative Intern Program, $7,044

Winkelman, Dana, Cooperative Fish & Wildlife Research, Colorado Division of Wildlife, Evaluation & Control of Whirling Disease in the White River, CO, $20,000

Calendar

October

20-21 **2010 South Platte Forum; Longmont, CO**
21st Annual South Platte Forum with the theme "High Stakes Games"
www.southplatteforum.org

21 **Guidebook of Best Practices for Municipal Water Conservation in Colorado Workshop; Westminster, CO**
A free conservation workshop to introduce Colorado WaterWise's Guidebook of Best Practices for Municipal Water Conservation in Colorado
www.cfwe.org

21-22 **Greater Western Libraries Alliance/Center for Research Libraries Jointly Sponsored Presentation: "Global Resources Network (GRN) Forum: Global Water - 2010 and Beyond"; Denver, CO**
Study the nature and sources of documentation on water issues; assess how scholars, policymakers, and nongovernmental organizations make use of such data; and propose a series of strategies, policies, and practices that libraries, archives, and other repositories can adopt to accommodate the realities of the field.
www.crl.edu/grn

November

1-4 **2010 American Water and Resources Association (AWRA) Annual Water Resources Conference; Philadelphia, PA**
Explore a wide range of water resources research, policy, management, and other technical topics.
www.awra.org/meetings/Philadelphia2010

9 **Water Smart Landscapes; Fort Collins, CO**
Discover how small changes-from efficient watering to Xeriscape-can result in a big water savings for businesses of all sizes and homeowner's associations.
fcgov.com/beps

15-19 **66th Colorado Association of Conservation Districts (CACD) Annual Meeting; Colorado Springs, CO**
www.cacd.us

December 2010

3 **Ditch and Reservoir Company Alliance (DARCA) train tour of water history in Colorado; leaving from Denver, CO**
This workshop is intended to give participants an inside look at Colorado water as well as an enjoyable weekend getaway.
www.darca.org

January 2011

26-28 **Water Congress Annual Conference; Denver, CO**
Speakers provide technical expertise as well as a wide variety of political, scientific and socioeconomic points of view on water issues.
www.cowatercongress.org

February 2011

15-17 **Nutrients and Water Quality Workshop; Salt Lake City, UT**
The goal of the workshop is to build a better informed and more tightly linked community of nutrient researchers, regulators, managers, policy makers and stakeholders leading to collaborative approaches for developing and achieving nutrient controls.
www.cwi.colostate.edu/Workshops/Region8Nutrient

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http://www.watercenter.colostate.edu

The Estes Powerplant uses Olympus Dam to regulate water levels between Lake Estes and Mary's Lake - water transfer allows the powerplant to generate a small amount of hydroelectricity. Photo by Lindsey A. Knebel.