

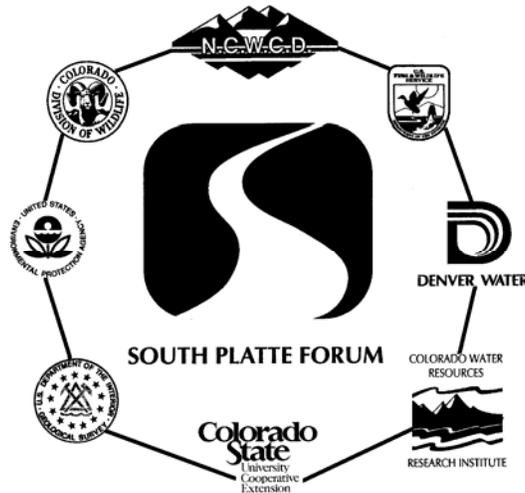
# Money Flowing through the South Platte Basin: The Business of Water

*Proceedings of the 11<sup>th</sup> Annual  
South Platte Forum  
October 24-25, 2000  
Longmont, Colorado*

Jennifer Brown, Editor

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**October 24-25, 2000  
Raintree Plaza Conference Center  
Longmont, Colorado**

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**Colorado Water Resources Research Institute  
Colorado State University, Fort Collins, CO 80523-2033  
Robert C. Ward, Director**

## **PREFACE**

The South Platte Forum was initiated in 1989 to provide an avenue for a timely, multi-disciplinary exchange of information and ideas important to resource management in the South Platte River Basin. Its stated mandates are:

- to enhance the effective management of natural resources in the South Platte River Basin by promoting coordination between state, federal and local resource managers and private enterprise, and
- to promote the interchange of ideas among disciplines to increase awareness and understanding of South Platte River Basin issues and public values

As indicated by the title, this year's forum will focus on the economics and business of water. As this precious resource has increasing demands placed on its limited supplies, the business of water becomes ever-more important.

The water we have in the South Platte Basin is used for municipalities, industry, agriculture, the environment and recreation. With so many interests pursuing a limited water supply, the competition for water is getting intense. "Money flows uphill to water," is becoming a commonly heard phrase.

While some parties are alarmed by the skyrocketing price of water others feel the increase is justified given water's critical role in the growing economy. Some basin users feel the water should go to the highest bidder while others would like to see it go to the use with the most social or environmental value.

Please join us to explore these and other issues surrounding the business of water from a variety of different perspectives.

# TABLE OF CONTENTS

## KEYNOTE SPEAKERS

**A CHANGING AGRICULTURE**  
BILL JACKSON.....1

**AN ALTERNATIVE FUTURE FOR COLORADO**  
GOVERNOR RICHARD LAMM.....2

## CHANGING CONDITIONS IN THE SOUTH PLATTE – CAN WE SUPPLY THE DEMAND?

**AN ECONOMIST’S VIEW OF COMPETITION FOR WATER IN THE SOUTH PLATTE**  
DR. MARIE LIVINGSTON.....3

**CHALLENGES OR GRIDLOCK?**  
ERIC WILKINSON.....4

**REPLACEMENT OF THE SUSTAINABLE WATER SUPPLY DEFECIT IN THE SOUTH DENVER METROPOLITAN AREA**  
STEVE BOAND.....5

## THE SKYROCKETING PRICE OF WATER – ARE WE GETTING SOAKED?

**MODERATOR: MIKE SMITH, CITY OF FORT COLLINS**

**CAN WATER RUN UPHILL? IT CAN FOR A PRICE**  
EVERRETT SCHNEIDER.....7

**OBTAINING WATER FOR A GROWING CITY IN A SEMI-ARID REGION**  
FRANK JAEGER.....8

**PLACING A VALUE ON NORTHERN COLORADO’S FUTURE**  
MIKE APPLGATE.....9

**HOW MUCH GREEN TO KEEP IT CLEAN**

**MEASURING THE TOTAL ECONOMIC VALUE OF RESTORING ECOSYSTEM SERVICES IN THE PLATTE RIVER BASIN**  
DR. JOHN LOOMIS.....10

**WETLAND MITIGATION BANKING – A GREEN SOLUTION FOR THE SOUTH PLATTE BASIN**  
LAURIE RINK.....11

**HEY MISTER! HOW MUCH WOULD YOU TAKE FOR THAT WATER YOU OWN?**  
JACK ODOR.....12

**GROWING CROPS OR GROWING HOUSES – RURAL V. URBAN WATER COMPETITION**

**MODERATOR: DOUG KEMPER, CITY OF AURORA WATER RESOURCES DIVISION**

**CAN AGRICULTURE AND MUNICIPALITIES BOTH SURVIVE IN THE FUTURE?**  
TOM POINTON.....13

**AGRICULTURAL WATER IN LARIMER COUNTY**  
RICHARD SEAWORTH.....15

**POSTER SESSION**

**SOUTH PLATTE DECISION SUPPORT SYSTEM – GOALS AND OBJECTIVES**  
RAY R. BENNETT.....16

**DYNAMIC SYSTEMS MODELING: A METHOD FOR INTEGRATING THE DIVERSITY OF WATER MANAGEMENT SYSTEMS**  
JIM B. FINLEY AND BARRY CARLSON.....17

**VALUING IRRIGATION WATER IN THE PLATTE RIVER BASIN**  
ERIC HOUK, MARSHALL FRASIER AND GARTH TAYLOR.....18

**RECENT FINDINGS ON HABITAT USE BY STATE-THREATENED BRASSY MINNOW ACROSS A GRADIENT OF INTERMITTENCY IN AN EASTERN COLORADO PLAINS STREAM**  
JULIE A. SCHEURER AND KURT D. FAUSCH.....20

**MITIGATING THE EFFECTS OF A RESERVOIR SEDIMENT RELEASE ON THE DOWNSTREAM CHANNEL: A CASE STUDY FROM THE NORTH FORK CAHCE LA POUDDRE RIVER**  
SARA L. RATHBURN.....21

**A CHANGING AGRICULTURE**

## BILL JACKSON<sup>1</sup>

This talk will center on agriculture in northern Colorado and its relationship with water and development over the past 25 years and continue with where agriculture in the region may fit in the next 25 years and how it is, and will have to continue, to adapt. Water has been an integral part of the industry dating back to the Union Colony (now Greeley) and the people who recognized the need to store water to utilize it on the desert of the eastern plains to develop into one of the most agriculturally important areas not only in Colorado but the United States.

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<sup>1</sup> Agriculture/Business Writer, Greeley Tribune, 501 8<sup>th</sup> Ave., Greeley, CO 80631, (970) 352-0211

# **AN ALTERNATIVE FUTURE FOR COLORADO**

**GOVERNOR RICHARD LAMM<sup>1</sup>**

The history of the West teaches two conflicting lessons. The first is that creative and industrious people can take a desert and make it into a paradise. Our forebearers took the West, which was a semi-desert, and gave us the Rocky Mountain West that we know and love. Another lesson of the West, however, seems to be that nature bats last and that one has to be respectful of the caring capacity of the land. Thus, as you can overgraze the pasture, you can overpopulate a geographic area to the extent that it diminishes the quality and perhaps even sustainability of life. The Anaszi, after all, were hit with a 50-year drought which would be unthinkable under present population pressures. I will expand upon the two cultures of the West and explore what both will mean to some decisions that lie in Colorado's future.

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<sup>1</sup> Director, Center for Public Policy, University of Denver, 2199 S. University Blvd., Ste. 107, Denver, CO 80208, (303) 871-3400

# **AN ECONOMIST'S VIEW OF COMPETITION FOR WATER IN THE SOUTH PLATTE**

DR. MARIE LIVINGSTON<sup>1</sup>

Increasingly, economic forces prevail in determining who has access to resources and how resources prices change. Water is no exception; everyone knows water flows uphill to money. But exactly how do the competing forces for water interact? This speaker presents the standard economic framework used to analyze resource markets. The model will be applied to water in the South Platte Basin. The model will show how various categories of water demand (use types) and characteristics of water supply (ground and surface water) interact to produce changing water prices and availability.

Demand side changes (like growth) and supply side changes (like drought) can be analyzed in terms of how water will be transferred between uses and what will happen to prices. While the model can generate important insights, it can also produce a grossly oversimplified view of the world. Understanding water markets requires a combination of physical, economic and political knowledge. For example, the model must be adapted to recognize the fairly unique physical features of water. In this regard, mobility issues and the critical role of water infrastructure will be addressed. The way in which overlapping political, economic and legal boundaries may fragment and skew water markets will also be discussed.

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<sup>1</sup> Department of Economics, University of Northern Colorado, Greeley, CO, (970) 351-1890

# CHALLENGES OR GRIDLOCK?

ERIC WILKINSON<sup>1</sup>

In the future, we, as water users within the South Platte Basin of Colorado, will be faced with a great and ever-growing number of challenges to meet the water demands of the basin. These challenges will stem from an ever-increasing demand for water, not only for the conventional and historic beneficial uses with which we are all familiar, but for uses that are emerging and may, in and of themselves, impose a controlling influence on stream flows and water supplies. These uses could include: flows for threatened and endangered species, as well as species of concern; recreational instream flows; aesthetics; and other uses not yet even imagined.

Several things will influence, if not control our ability to meet the “demand”. The most significant of the factors could be: 1) the character of the societal “demands” for water in the future, including the array of uses for water within the basin that are, or will be, considered beneficial uses; 2) the societal values associated with water use and the standard of living, including: impacts on various aspects of the environment; preservation of agriculture; direct use of wastewater for potable use; use of dual water supply systems to provide treated and raw water; costs associated with providing adequate water supplies, etc.; 3) the increasing role of the federal government in regard to water related issues and the impacts of federal laws, rules, and regulations on the basin’s water users’ ability to beneficially use and manage available water supplies; and 4) the potential of a changing flow regime on the river.

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<sup>1</sup> General Manager, Northern Colorado Water Conservancy District, PO Box 679, Loveland, CO 80539, (970) 667-2437

# **REPLACEMENT OF THE SUSTAINABLE WATER SUPPLY DEFICIT IN THE SOUTH DENVER METROPOLITAN AREA**

STEVE BOARD<sup>1</sup>

Growth in the southern Denver metropolitan area counties has been fostered by relatively inexpensive and abundant groundwater supplies. This water is a non-renewable water resource derived from the Denver basin aquifer system. These groundwater supplies will likely be used to point of economic exhaustion unless cost-effective alternatives are developed. Sustainable water supply planning has begun in the region and, if successful, will result in significant added demands on the renewable water resources of the State of Colorado.

Unprecedented growth occurred in Arapahoe and Douglas Counties during the 1990's. Population increases in the region totaled approximately 211,000 persons in 85,300 new households. Water demands within the region increased by approximately 42,500 acre-feet per year (Af/Yr) during the decade with the use of nonrenewable groundwater supplies accounting for a significant portion of new water supplies developed.

Future water planning efforts are focused on the development of renewable water supplies. Studies completed by the Douglas County Water Resources Authority in 1995 indicate that 65% of the 23,300 Af/Yr municipal demand was met with non-renewable water supplies. Water providers indicate that buildout of development approvals will increase the water supply demand in Douglas County to approximately 117,000 Af/Yr. Existing renewable assets can meet only 19% of this projected demand. A sustainable water supply deficit of 15,100 Af/Yr in 1995 is expected to grow to 99,000 Af/Yr or more unless additional renewable resources are procured.

Water supply economics will play a significant role in the direction of water resource planning for the area. Nonrenewable groundwater development costs are significantly less than the cost of renewable water supplies. Currently, development of raw water from Arapahoe aquifer groundwater costs approximately \$1,450 per single family unit. Acquisition of a similar quality renewable raw water supply is expected to cost \$9,600 or more per dwelling unit. At current market prices, procurement of raw water sufficient to replace the sustainable supply deficit is estimated to cost water consumers \$1.5 billion or more.

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<sup>1</sup> Principal Hydrologist, HydroLogic Technology, Ltd., (303) 688-8386

Three options are being considered for replacement of depleted groundwater reserves. Twelve water providers in the region are currently investigating cooperative actions with Denver Water. Re-regulation of Denver's system could replace a portion of the sustainable yield deficit. A second alternative is the acquisition and banking of groundwater reserves in undeveloped areas. Denver basin aquifer groundwater supplies can currently be acquired for approximately \$1,500 per acre-foot for "100 year" water. This alternative, however, may reduce the potential for cooperative planning with providers who require that sustainable water supply systems be developed as a part of cooperative agreements.

South metro water providers will also consider water importation as an alternative. While the cost of importation projects is unknown, transbasin diversions will be compared to market acquisition and groundwater costs. Replacement of the mounting sustainable supply deficit, irrespective of the replacement source, will likely result in additional regional and statewide conflict as the south Denver metropolitan area seeks to secure a sustainable water future.

## **CAN WATER RUN UPHILL? IT CAN FOR A PRICE**

EVERRETT SCHNEIDER<sup>1</sup>

Everrett will begin his presentation sharing some interesting facts about CBT water. Since the project began, the capacity and how the shift from agricultural ownership has changed to a larger municipal ownership. The laws that determine water usage were established during the gold rush. All water was created equal, but today it has specific uses determined by its decree. Many farmers have sold off water rights to stay "afloat". Tenant farmers have a different situation with the increasing value of the land. Land owners are having difficulty justifying retaining ownership of the farms when other investments return greater profits. Underground water supplies are affected by surface water and this will become a larger issue. Neighboring states are equally wanting to get their share of water, so we all must remember that what we do affects someone else.

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<sup>1</sup> WW Auctions and Real Estate, Inc., 1732 E. Mulberry, Ft. Collins, CO 80524, Phone: (970) 221-4300, Fax: (970) 221-4301

# **OBTAINING WATER FOR A GROWING CITY IN A SEMI-ARID REGION**

FRANK JAEGER<sup>1</sup>

More wells, deeper wells, declining aquifer levels, additional power requirements to supply larger pumps and motors -- all of these items lead to higher costs for production of ground water.

As water production requirements continue to grow, so do the costs associated with producing water from deep aquifer sources. Declining aquifer levels require pumps to be set deeper; therefore requiring larger pumps with higher energy costs.

To produce more water requires more wells. This will have associated costs for drilling, outfitting with pumps, providing power to the equipment, meeting county and local development guidelines for the types of structures that can be built to house the equipment, pumping stations to move the water from the wells to storage tanks electrical costs associated with pumping, adequate storage tanks to meet peaking requirements and the list of costs goes on.

Add to the cost of producing, moving, and storing water produced from aquifers, costs associated with finding and developing long term renewable surface water to protect and increase the longevity of the aquifers and you find that the price of water in communities that rely on ground water can be quite extraordinary.

Environmental concerns have added enormous financial burdens to water providers. Protecting the environment for endangered species is an admirable goal albeit a costly one in terms of time and money.

Providing a cost effective water supply to a community whether from groundwater or surface water has become increasingly more difficult due to all of the listed issues.

Providing water at any cost may become the watchword of the future.

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<sup>1</sup> District Manager, Parker Water and Sanitation District, 19801 E. Main St., Parker, CO 80138, (303) 841-4627

# **PLACING A VALUE ON NORTHERN COLORADO'S FUTURE**

MIKE APPLGATE<sup>1</sup>

The prior appropriation doctrine has been used successfully in Colorado for the past 120 years in applying water to beneficial use and implementing a system of administering our water short streams that is considered by many to be a model of efficiency. Growth in Colorado for almost eight years has been rapid and widespread to the point that there is fierce competition for a scarce resource, which has consequently driven the price for senior water rights higher and higher.

Agricultural uses of water are being removed from productive land and placed into municipal and industrial uses partially because of the currently poor market for agricultural products and partially due to the ability of municipalities, industrial users and developers to pay the attractive prices. Concerns are being expressed by some interests outside of agriculture that the loss of open space from the development of ag lands should be stopped.

Environmental interests are also concerned about preserving the environment in and around water systems for recreational uses as well as maintaining minimum streamflows in rivers and preserving wetlands. The Federal Government is interested in controlling water uses for the recovery of endangered species. These interests also have exerted pressures on the water market and will have a bigger influence on it in the coming years.

The presenter will discuss these topics and offer a viewpoint of what the citizens of Northern Colorado need to understand on water issues and the actions that will be necessary to preserve a viable water market as well as provide for the water resources needs.

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<sup>1</sup> President, Larimer/Weld Water Issues Group; President, Tuttle-Applegate, (303) 452-6611

# **MEASURING THE TOTAL ECONOMIC VALUE OF RESTORING ECOSYSTEM SERVICES IN THE PLATTE RIVER BASIN: RESULTS FROM A CONTINGENT VALUATION METHOD SURVEY**

**JOHN LOOMIS<sup>1</sup>, PAULA KENT<sup>2</sup>, LIZ STRANGE<sup>3</sup>,  
KURT FAUSCH<sup>4</sup> and ALAN COVICH<sup>1</sup>**

Five ecosystem services that could be restored along a 45-mile section of the Platte River were described to respondents using a building block approach developed by an interdisciplinary team. These ecosystem services were dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation. Households were asked a dichotomous choice willingness to pay question regarding purchasing the increase in ecosystem services through a higher water bill. Results from nearly 100 in-person interviews indicate that households would pay an average of \$21 per month for the additional ecosystem services (95% confidence interval is \$20.50 to \$21.65). Generalizing this to the households living along the river yields a value of \$30 million to \$70 million depending on whether those refusing to be interviewed have a zero value or not. Even the lower bound benefit estimates greatly exceed the high estimate of water leasing costs (\$1.13 million) and Conservation Reserve Program farmland easements costs (\$12.3 million) necessary to produce the increase in ecosystem services.

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1. Professor, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO 80523

2. Economist, Northwest Economics Associates, Vancouver, WA

3. Ecologist, Stratus Consulting, Boulder, CO

4. Professors , Department of Fish and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

# **WETLAND MITIGATION BANKING – A GREEN SOLUTION FOR THE SOUTH PLATTE BASIN**

LAURIE RINK<sup>1</sup>

Development pressures often result in unavoidable wetland impacts. Public or private development interests who need to impact wetlands must seek prior regulatory approval in the form of a Section 404 permit from the U.S. Army Corps of Engineers. The permit requires that any unavoidable impacts be compensated for by creating new wetlands. Prior to the advent of mitigation banking, project developers were faced with building and maintaining wetlands on their own properties. However, a nationwide study of wetland mitigation found that these projects failed more than fifty-percent of the time. Due in part to this significant failure rate, the government has issued new regulations that encourage the establishment of larger-scale mitigation banks.

Banks are designed to create, restore, and/or enhance large, ecologically important wetland tracts in advance of permitted impacts. Based upon the type, size, and function of the improvements, the bank is authorized by the regulatory/resource agencies to sell a certain number of credits. As part of the sales transaction, the number of credits necessary to satisfy the requirements of a permit holder's Section 404 permit are debited against the mitigation bank's assets.

The Mile High Wetland Bank, located near Brighton just north of Barr Lake, was developed to compensate for wetland impacts occurring within the South Platte River basin. Mile High Wetlands Group, LLC, a partnership of local interests, is the Bank sponsor developing the 600-acre property to meet regional development needs. The Bank was sited in a location where it could provide significant water quality and wildlife benefits, in synergy with the South Platte River corridor and Barr Lake. Up to 170 acres of new wetland will be created from pasture ground. Another 220 acres of low quality wetland will be enhanced to its natural condition. The remaining acreage will be restored as upland buffer to protect the integrity of the wetland ecosystem. Both the physical and legal availability of water is a key component that dictates the bank's long-term success.

Banks can be an environmentally positive solution to the regulatory requirement for mitigation compensation. Mitigation banks are generally established in advance of impacts, so there is little to no "ecological lag-time" between when a wetland is lost and another created. Banks can also consolidate many small, isolated wetland mitigation projects into a single, large-scale ecosystem. The significant technical and financial resources that go into establishing and operating a mitigation bank should guarantee a high degree of success.

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<sup>1</sup> Manager, Mile High Wetlands Group, LLC, 80 S. 27<sup>th</sup> Ave., Brighton, CO 80601, (303) 659-7002, [www.wetlandbank.com](http://www.wetlandbank.com)

# **HEY MISTER! HOW MUCH WOULD YOU TAKE FOR THAT WATER YOU OWN?**

JACK ODOR<sup>1</sup>

2000 has been a significant year in water marketing in the South Platte Basin. Nothing comes into sharper focus than water value during a drought. As cities and towns compete with agriculture for scarce supplies, some interesting arrangements emerge. Third party interests also must be addressed. Should we rent? Buy? Sell? Hold? Develop? Quit? Or grab a shotgun?

Let's Talk!

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<sup>1</sup> Manager, Groundwater Appropriators of the South Platte (GASP), PO Box 974, Fort Morgan, CO 80701, (970) 867-5298

# **CAN AGRICULTURE AND MUNICIPALITIES BOTH SURVIVE IN THE FUTURE?**

TOM POINTON<sup>1</sup>

Coexistence with a growth that threatens to be urban from Cheyenne to Pueblo is a reality, but people don't want to live in reality. Yet reality has a way of forcing its way into human consciousness, and sooner or later we must acknowledge that our relationship to water is intimate, complex and primal. If we abuse it, we will suffer the consequences. Outnumbered and so outvoted, how does agriculture survive, even though agricultural folks own most of the water rights?

When the interest earned from the proceeds of a water sale exceed the average annual income of an irrigated farm, and you get to keep your home and all improvements, and the work load goes from 16 hours a day to almost zero, there is a big incentive to let the water be transferred from agriculture to municipal and industry. This is true especially for those of retirement age.

Water transfers in the Arkansas River Basin have been numerous, but had there never been any water transfers from mining and agriculture to municipal and industry, where would we be today?

Historical transfers have removed approximately 56,100 acres of land from agricultural production in the Arkansas River Basin. There is another 3000 acres in the process.

In Bent County, according to the assessor, the value of irrigated land is roughly at about ten times the value of dry pasture land, or \$40 v. \$400. Yet water sales haven't had that much of an impact to Bent County because the water is still in Bent County. Most of the water is still leased back for farming and the land is assessed as such.

In Otero County the difference is much greater. The water is gone and the loss of tax dollars is about \$34,700, or a 98.3% loss on 3300 acres of irrigated land that is now revegetated grassland. There is also a proposed sale that will take another 2850 acres of irrigated land out of protection in the county.

In Crowley County irrigated agriculture assessed valuation has decreased by about 63% from its high of \$2.06 million to \$770,000 in 1999. I don't think the total loss was a direct affect of water sales. Irrigated agriculture has always gone up and down for other reasons. However, their total valuation has gone from \$11.5 million in 1997 (their first water sale) to over \$23 million in 1999. I don't know how much of that is a result of reinvesting in new houses and businesses with water money.

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<sup>1</sup> Producer, 34805 Rd. 17, Las Animas, CO 81054, (719) 456-0413

We must be very frugal with our water in the future, both mining and agriculture and municipal and industry. The projected population growth just in the Southeast Water Conservancy district is expected to require 100,000 acre feet of additional water. The district takes in Colorado Springs to Pueblo and Salida to Lamar. Water management will be the key to our success. That 100,000 acre feet of water is now being used mainly by agriculture. The impact on agriculture will be enormous. Those acres left in production will have to be managed in the most efficient manner to survive, especially in short water years that everyone knows we will have.

*“In the world, there is nothing more submissive than water; yet for attacking that which is hard and strong, nothing can surpass it.” -- Lao-Tzu, 500 B.C.*

# **AGRICULTURAL WATER IN LARIMER COUNTY**

RICHARD SEAWORTH<sup>1</sup>

This presentation will cover Richard's experiences as an irrigation farmer in Larimer County over the past 40 years. It will touch on the loss of water and the loss of control irrigators have experienced. It will also cover what Larimer County is doing through the Larimer County Agriculture Advisory Board.

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<sup>1</sup> Owner, Seaworth Ag Enterprises, 11801 N C Rd. 9, Wellington, CO 80549

# **SOUTH PLATTE DECISION SUPPORT SYSTEM – GOALS AND OBJECTIVES**

RAY R. BENNETT<sup>1</sup>

To meet the challenge of managing water into the next century, the State of Colorado is performing a feasibility study to define the purpose, use, users, components, data, cost and schedule required to develop a decision support system (DSS) for the South Platte River Basin. This paper presents a brief summary of Colorado's existing DSS system, the objectives of the feasibility study and a vision of what the South Platte Decision Support System will contain.

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<sup>1</sup> Colorado Division of Water Resources

# **DYNAMIC SYSTEMS MODELING: A METHOD FOR INTEGRATING THE DIVERSITY OF WATER MANAGEMENT SYSTEMS**

JIM B. FINLEY<sup>1</sup> AND BARRY CARLSON<sup>1</sup>

Water management systems inherently require the consideration of a broad spectrum of information. The nature of the information may include descriptions of physical processes (affecting the timing and quantity of water availability), chemical process (affecting the quality of the water), and economics (affecting costs at all parts of the water management system). In addition, many of the water management challenges facing managers are related to the relative differences in time-dependent processes (e.g., rainfall runoff versus groundwater flow). As a result, there is a need for a tool that allows the water manager to integrate the diversity of relevant information. Some of the goals of such a tool might include: (1) evaluating the relative importance of different processes within the water management system to identify how to best allocate funds for monitoring, enhancing, and/or optimizing the system, (2) conducting “what-if” scenario evaluations regarding the potential effects of changes to a water management system, (3) developing consensus across a broad spectrum of water stakeholders by effectively communicating a “picture” of the water management system, and (4) building a “living” model of a water management system that can grow, change, and evolve as the need arises.

Dynamic systems modeling is a method for representing time-dependent water management systems. The water management systems is represented in a graphical manner, for ease in communicating a “picture” of the system, and offers the capability to change (e.g., add, delete, or re-route a flow) in a rapid and efficient manner. “What-if” scenario testing can be completed rapidly and efficiently. A description of the theory, model development, and application of a dynamic systems model for water management will be presented. With the increasing interest and challenge in managing water resources, including the increasing demands on water supply and water allocation systems, the capabilities offered by dynamic systems modeling can provide the water manager with a valuable management tool.

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<sup>1</sup> HSI GeoTrans, 9101 Harlan St., Ste. 210, Westminster, CO 80031, (303) 426-7501, [jfinley@hsigeotrans.com](mailto:jfinley@hsigeotrans.com)

# VALUING IRRIGATION WATER IN THE PLATTE RIVER BASIN

ERIC HOUK<sup>1</sup>, MARSHALL FRASIER<sup>2</sup>, AND GARTH TAYLOR<sup>3</sup>

The Platte River Basin has four species listed as threatened or endangered under the federal Endangered Species Act (ESA) and a 56-mile long section of the Central Platte River designated as critical habitat. To comply with the ESA mandate for species recovery, an estimated 373,000 acre-feet of additional water might be necessary to augment current flows. Identifying new water for endangered species is prohibitively expensive and water in the Platte Basin is fully appropriated. As such, agriculture, being the largest and least valued water user, will thus be targeted to fulfill endangered species habitat water requirements. The transfer of water from agriculture to instream flows for species recovery have proposed a myriad of conservation, water markets, water banking, and pricing solutions. All of these require evaluation as to the foregone benefits of that water in agriculture, and/or the costs to agriculture.

The goals of this study are to value irrigation water in the Platte River Basin: (1) over a cross section of agriculturally distinct regions of the Platte River Basin, (2) over times of the growing season; (3) over differing institutional arrangements for water transfers; and (4) the risk response to changing water supplies.

Agricultural production is sequential in nature, where many farm decisions are influenced by earlier decisions and information that becomes available only after earlier choices have been made. To solve this we used a model that will incorporate the risks of crop production into the objective function. Discrete Sequential Stochastic Programming (DSSP) is a technique where decisions will be optimized through multiple stages of expected occurrences. The structure of the model can be viewed as a decision tree, where the decisions are arranged in proper sequence and include their associated probabilities. Five representative farming regions along the basin have been modeled from survey and census farm data. The model will produce optimal crop mix and optimal irrigation plan by maximizing the expected profit of each representative farm. Along with estimating the marginal value of water in each representative region the model will show the producer response to diminished water supplies.

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Results will show that the marginal value of irrigation water varies throughout the basin. Water value will be affected by the value of farm crop mix, higher value crops will cause higher water values. Areas in the basin that have better climate and soil quality should have higher water value due to increases in crop yields. The timing of the water will also impact the value of water. The expected producer response to changing water supplies will be to reduce irrigations to low valued crops or those crops that have a relatively low yield response to irrigation deficit.

Understanding how the value of irrigation water changes will allow policy makers to more fully compensate producers for their water supplies. It will also be important to understand how producers will adapt in the long run to these changing water supplies so that the benefits and costs of these water management decisions are realized.

# RECENT FINDINGS ON HABITAT USE BY STATE-THREATENED BRASSY MINNOW ACROSS A GRADIENT OF INTERMITTENCY IN AN EASTERN COLORADO PLAINS STREAM

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Among competing demands for water in the South Platte and other watersheds in Colorado's eastern Plains is the need to sustain populations of native fishes, but little is known about most of their habitat requirements. Recent surveys showed apparent declines in distribution of 10 Plains fish species, of which 5 were designated as threatened or endangered by the State of Colorado in 1998 (none are federally listed). We are studying one of the most abundant of these, the state-threatened brassy minnow (*Hybognathus hankinsoni*), to assess its critical habitat requirements in the Arikaree River, a tributary of the Republican River in eastern Colorado. Three 4-mile segments were chosen for study across a gradient of intermittency, from perennial to seasonally dry. During the dry summer of 2000 most of the lower segment, and some of the middle segment dried up between May and August, extirpating brassy minnows. Brassy minnow in the lower segment became restricted to one isolated pool and a single perennial tributary that provided refuge, but populations were able to persist in intermittent and perennial habitat in the other two segments. Fish persisted in harsh conditions in isolated pools where temperatures exceeded 30 C (86 F) and dissolved oxygen was low. Female brassy minnow ready to spawn were found in pools and backwaters in May and June, but some of these habitats dried by August. Young brassy minnow were captured in July in the two upstream reaches but rearing habitat had dried by then in the downstream reach. Observations during fall 1999 indicated that brassy minnow rapidly recolonized dry reaches as flow returned. Although brassy minnow appear able to persist in streams that become seasonally intermittent, increasing human demands for water may fragment habitats beyond the point where populations can be sustained.

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# **MITIGATING THE EFFECTS OF A RESERVOIR SEDIMENT RELEASE ON THE DOWNSTREAM CHANNEL: A CASE STUDY FROM THE NORTH FORK CACHE LA POUDE RIVER**

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It has long been recognized that river regulation resulting from dams causes major alteration in sediment dynamics and channel morphology in downstream reaches of the river. Upstream from the dam, sediment accumulation within the reservoir will eventually threaten the storage capacity of the reservoir and the operating efficiency and expected life of a dam. In the semi-arid western U.S., where sediment fluxes from hillslopes may be greater than under any other climate, the hundreds of small irrigation reservoirs constructed in the last century are undergoing siltation, forcing irrigation companies to address sediment management issues. The estimate of world wide reservoir storage capacity loss, resulting from siltation alone, is approximately  $4.9E^{10}$  m<sup>3</sup>, or the equivalent of \$6 billion in replacement costs every year. Sediment management practices within reservoirs may include flushing or sluicing reservoir sediments, sometimes voluminously and catastrophically, into the downstream channel. In Colorado alone, five large-scale sediment releases from reservoirs within the last decade have resulted in massive fish kills. Sediment released into the downstream channel can be highly detrimental to the aquatic biota and their habitat, can significantly alter the channel morphology, and can impair diversion and irrigation structures, water quality, and recreational opportunities down stream. The sediment infilling may also affect the capacity of the channel to convey water and sediment, especially during floods. One such release occurred along the North Fork Cache la Poudre River in September 1996, resulting in a massive fish kill from sedimentation that filled pools up to 3.5 m deep with fine-grained sediment.

Given the current regulatory, environmental, and recreational interests in rivers downstream from dams, indiscriminate releases of large volumes of sediment are no longer acceptable. If sediment releases are desirable to manage the recognized problem of sediment accumulation in reservoirs, then methods for assessing the degree of channel change and channel recovery time are required to understand the potential downstream impacts of sediment releases. To date, methods for addressing the impacts of reservoir sediment releases on the downstream channel include: 1) field work to quantify the volume and spatial distribution of the released sediment, 2) repeat field surveys to track sediment movement over time, 3) sediment transport modeling to predict channel recovery, and 4) a combination of all three to fully understand channel response to the sediment influx, and to calibrate sediment transport models. Increasing amounts of time, expense, and knowledge of hydraulics and sediment transport accompany the various

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methods for addressing the impacts of reservoir sediment releases. One advantage of sediment transport models is the ability to establish a reservoir operating regime or minimum flushing discharge necessary to remove sediment introduced into the downstream channel during reservoir sediment removal. Particularly in situations of limited water availability, where any discharge release is expensive and undesirable, models may be the most useful tool in answering questions about channel recovery.