FINAL REPORT

Prepared for
Lower South Platte Water Conservancy District, Sterling, Colorado
and
The Colorado Water Conservation Board, Denver, Colorado

Northeast Colorado Water Cooperative

Feasibility Study and Operational Analysis

June 30, 2020

Northeast Colorado Water Cooperative Feasibility Study and Operational Analysis

Prepared for
Lower South Platte Water Conservancy District
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And
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Denver, Colorado

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AF	acre-feet
ATM	Alternative Transfer Method
cfs	cubic feet per second
CSU	Colorado State University
CU	consumptive use
CWCB	Colorado Water Conservation Board
GRC	Grant Review Committee
LSPWCD	Lower South Platte Water Conservancy District
NECWC	Northeast Colorado Water Cooperative
PWSD	Parker Water and Sanitation District
SPBIP	South Platte Basin Implementation Plan
SPROWG	South Platte Regional Opportunities Water Group
SWSP	Substitute Water Supply Plan
WSRF	Water Supply Reserve Fund

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Executive Summary

The Northeast Colorado Water Cooperative (NECWC) is an organization that was created by water users along the South Platte River in northeastern Colorado. It was formed to create a framework for maximizing the beneficial use and reliability of agricultural water supplies and for fostering partnerships among local and regional water providers and users.

The overall objective of the NECWC is to preserve and enhance water supply and economic security for its members and for the lower South Platte basin.

Organization History and Formation

An organization like the NECWC was identified as a need many years ago. In 2008, Mike Groves, an agricultural producer in the Fort Morgan area, brought together a small group of water users and consultants to begin discussing his creative vision and the possibility of developing a water management organization in the area of Water Districts 1 and 64 in the lower South Platte River. The early discussions led to initial technical evaluations to explore the feasibility of an organization. The preliminary analyses were favorable, and the group decided that additional research and outreach to potential stakeholders and participants was warranted.

Research and outreach on the member organization was pursued as a result of the initial feasibility efforts and water user interest. The additional work was funded by the Colorado Water Conservation Board (CWCB) through three grants – a Water Supply Reserve Fund grant and two Alternative Agricultural Water Transfer Method grants.

Initial research focused on identifying a structure for the organization and forming the organization. Another objective of the analysis was to research and evaluate water law issues related to a water cooperative. The selection of an organizational structure should be guided and approved by the stakeholders who would eventually participate in the organization, and extensive outreach was conducted to gather stakeholder feedback. Stakeholders identified key goals that needed to be met in forming an organizational structure:

- Membership criteria should be balanced, fair, and accessible for local water users.
- The organization should operate in a transparent manner.
- Board of Directors criteria should be representative of members yet functional and effective.

After evaluating alternatives, a cooperative was determined to be the organizational structure that best fit the criteria that had been developed. The cooperative was incorporated on January 1, 2014 and currently has 22 members.

The business plan is a key organizational document that has guided the evolution and development of the NECWC

The NECWC business plan is a key organizational document that describes a vision for the short- and long-term services the NECWC intended to evaluate and provide to members:

- **Short-term services**: The NECWC would provide several services in the short term to coordinate the lease, exchange, and retiming of unused recharge credits from members who at times have available credits to members who at times need credits.
- **Long-term services**: In the long term, the NECWC would explore incorporation of ATMs and working with partners to provide access to infrastructure that could help manage and optimize the use of available supplies (unused recharge credits or unappropriated supplies) for the benefit of District 1 and 64 water users.

Operational Analyses and Planning

Extensive operational analyses and planning were conducted to evaluate the short- and long-term services described in the business plan. The operational analyses were the primary focus of ATM grant work described in this report. The NECWC explored operating alternatives under various assumptions related to supplies, demands, and infrastructure.

Maximizing the beneficial use of available water supplies is an important goal of the NECWC. Infrastructure is critical to managing and delivering water supplies. Water supplies that have been the focus of the NECWC analyses include unused recharge credits, unappropriated water supplies, and senior water rights leased via ATMs (described in further detail below):

- Unused Recharge Credits: Unused recharge credits originate in augmentation plans. Many augmentation plans rely on alluvial aquifer recharge and resulting stream accretions ("recharge credits") as a source of water supply to replace out-of-priority depletions to the river caused by well pumping. Based on the multiple and varied locations of wells and recharge sites, and differences in the timing of lagged depletions and recharge accretions, augmentation plans at times may have more recharge credits available than are needed to replace their depletions. These "unused recharge credits" are not needed by the augmentation plans and in many cases may be available for lease. Unused recharge credits were quantified in Districts 1 and 64 and ranged from 30,000 AF in some years to 80,000 AF in other years depending on the number of augmentation plans considered and the hydrologic conditions. Unused recharge credits generally occur in the spring and early summer and can vary significantly on a seasonal basis, with periods when unused recharge credits may not exist and some periods when higher amounts are available.
- Unappropriated Supplies: Unappropriated supplies are stream flows that occur when existing demands are satisfied, and excess supply is available for a new use. The amount of available unappropriated supply was quantified for recent years, and it varied significantly by year, season, and river location. In dry years, very little unappropriated supply was available, and in wet years, several hundred thousand acre-feet of supply were available in various locations in the basin.
- Alternative water transfer methods: Alternative water transfer methods (or ATMs) allow water users to periodically lease the transferrable portion of senior water rights as an alternative to traditional "buy and dry" water transactions. The amount of supply potentially derived from ATMs depends on several factors, such as consideration of whether ATMs provide firm or interruptible supplies.

Water users in Districts 1 and 64 do not currently have access to the supply of water needed to fully meet irrigation requirements. Unmet demands were investigated from a variety of perspectives. Interviews were conducted with NECWC members and potential partners that identified unmet demands of around 40,000 AF/year during dry times. Other studies have identified larger overall agricultural water demands in Districts 1 and 64 that total over 100,000 AF/year.

Operational modeling and planning was conducted in a phased approach and evaluated potential strategies and needed infrastructure to manage and deliver supplies to meet currently unmet demands in Districts 1 and 64.

Phase 1: The first phase examined the operational benefits of member-to-member transactions of unused recharge credits.

Phase 2: The second phase built on Phase 1 and evaluated the operational benefits of infrastructure and additional sources of supply such as unappropriated stream flows and ATMs.

Member-to-member transactions were analyzed (absent infrastructure) in Phase 1, because the NECWC anticipated these types of transactions could be more easily pursued in the short term from both an operational and legal perspective. The benefits of Phase 1 operations are highly dependent on exchange potential, because absent infrastructure (either new infrastructure or existing infrastructure that could be used by NECWC), supplies would need to be delivered by exchange to upstream end users or by stream conveyance to downstream end users.

Exchange potential associated with member-to-member transactions was evaluated in Phase 1. The findings suggested that exchange potential exists but can be highly variable both geographically and seasonally. Exchange potential has historically been impacted periodically or regularly by ditches that place a call or otherwise dry the river.

The results of the analysis of Phase 1 operations suggested that while member-to-member transactions can be conducted periodically, it may be difficult to ensure that future projected unused recharge credits could be exchanged to a location of demand. Many South Platte River augmentation plans have a projection requirement that balances lagged and projected well pumping depletions against available replacement supplies. Projected unused recharge credits could fulfill a long-term supply need and allow higher levels of current-year pumping, which would be of value to NECWC members. However, the variability of exchange potential tends to diminish the reliability of member-to-member transactions, and infrastructure would be needed to help ensure that supplies can be delivered when needed. Legal evaluations of Phase 1 operations identified several risk factors that were considered by the NECWC Board of Directors and membership.

Phase 1 operations alone did not provide sufficient value given the potential risk and expense of Phase 1 operations. As a result, the NECWC board and members decided to investigate Phase 2 operational strategies.

Phase 2 operational analyses focused on the potential benefits of infrastructure to temporarily store or retime unused recharge credits and make them available to meet future demands. Infrastructure was also evaluated with respect to the benefit of storing available supplies and exchanging those supplies to upstream storage when potential is available. Supplies located upstream could then be released and delivered to meet downstream demands. In addition to unused recharge credits, unappropriated stream flows and ATMs were evaluated as a source of supply that could potentially meet currently unmet demands in Districts 1 and 64. The Phase 2 operational analyses concluded that infrastructure, including reservoirs, recharge facilities, and bypass/measurement structures would be very useful for conjunctively managing several sources of supply to meet a significant amount of unmet demand in Districts 1 and 64.

Phase 2 analyses indicated that infrastructure is needed to better manage water supplies available to District 1 and 64 water users.

Accurate water accounting will be a critical short- and long-term need of the NECWC. To meet this need, an Accounting Tool was developed that is currently capable of tracking and managing Phase 1 operations and can be modified to incorporate Phase 2 operations.

Implementation and Next Steps

The implementation steps undertaken by the NECWC have been guided by the results of technical and legal analysis and by the NECWC board and membership. The evolution of the NECWC and its operational planning started with evaluating the resources available to the members in the form of unused recharge credits and the benefits that could be derived from transacting those credits. Subsequent analyses pointed to the need for infrastructure to fully realize the benefits that could be derived from additional resources to manage water supplies. Upon reaching this conclusion the NECWC began and has continued to pursue partnerships with entities that could help it develop water supply projects that benefit all participants. An important next step in the evolution of the NECWC is the development of a proposed water supply project being pursued by Parker Water and Sanitation District and the Lower South Platte Water Conservancy District (LSPWCD). The NECWC Board and membership supports this project and is continuing to evaluate its role, with LSPWCD, in helping provide water supply security for the membership and District 1 and 64 water users.

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Section 1

Introduction

The Northeast Colorado Water Cooperative (NECWC) is an organization that was created by water users along the South Platte River in northeastern Colorado. The overall objective of the NECWC is to preserve and enhance water supply and economic security for its members and for the lower South Platte basin as a whole. It was formed to create a framework for maximizing the beneficial use and reliability of agricultural water supplies and for fostering partnerships among local and regional water providers and users. The goals of the NECWC could be achieved by providing various services to its members, which include:

- Facilitating the lease and exchange of water owned by the members, typically on a short-term basis, thus allowing those members with water supplies to make them available to those members with water demands.
- Providing a means for leasing the transferrable portion of senior water rights as an alternative to traditional "buy and dry" water transactions (known as alternative transfer methods or ATMs).
- Using existing infrastructure or building new infrastructure to help improve water use efficiency by its members.
- Developing new appropriations of storage or recharge for a variety of beneficial uses.
- Providing a central organization through which partnerships with local and regional water users can be established.

Maximizing the beneficial use of available water supplies is an important goal for water users in northeast Colorado. Water supplies that have been the focus of the NECWC analyses include unused recharge credits, unappropriated water supplies, and senior water rights leased via ATMs.

Infrastructure is required to manage each of the water sources considered and make it available when needed. Also, each of the supplies requires water court proceedings or other state approval to authorize use.

Unused Recharge Credits

Unused recharge credits originate in augmentation plans. Augmentation plans enable water users to divert alluvial groundwater out-of-priority by providing a means to offset stream flow depletions caused by out-of-priority diversions of alluvial groundwater. Augmentation plans are decreed by Colorado's Water Court.

Many augmentation plans rely, either primarily or in part, on intentional alluvial recharge and resulting stream accretions ("recharge credits") as a source of water supply to offset or replace out-of-priority depletions to the river caused by well pumping. Based on the multiple and varied locations of wells and recharge sites, and differences in the timing of lagged depletions and recharge accretions, augmentation plans at times may have more recharge credits available than are needed on any given day to replace the out-of-priority depletions associated with the wells included in the plans. These "unused recharge credits" are not needed by the generating augmentation plans, and if not retimed by exchange, in many cases may be available for lease. Section 4 and Appendix A provide additional detail regarding the variability of recharge activities and the origin of unused recharge credits.

The NECWC was formed, in part, to facilitate the lease and use of these unused recharge credits by other NECWC members. Leased unused recharge credits can be used either directly or as a source of substitute supply for exchange and can be moved up or down the river to provide an additional replacement source for member augmentation plans as needed.

Unappropriated Supplies

Unappropriated supplies are stream flows that occur when the Division Engineer is not administering any calls for water, all water demands are being satisfied, and excess supply is available for a new use. The amount of available unappropriated supply varies significantly by year, season, and river location. Given this variability, infrastructure is needed to store and retime available unappropriated supplies so that demands can more consistently be met.

Alternative Transfer Methods

Alternative water transfer methods, or ATMs, provide an opportunity for northeast Colorado water users to periodically lease the transferrable portion of senior water rights as an alternative to traditional "buy and dry" water transactions. Strategies like ATMs can help irrigators obtain additional economic returns on their water supply while both protecting agricultural uses and providing needed supplies for growing municipalities.

Focus Area

The focus area for the NECWC has been in the lower South Platte River basin between Greeley, Colorado and the Colorado-Nebraska state line. In addition, outreach with upstream water users has been ongoing and will continue into the future. A map of these two general focus areas is shown in the figure below.

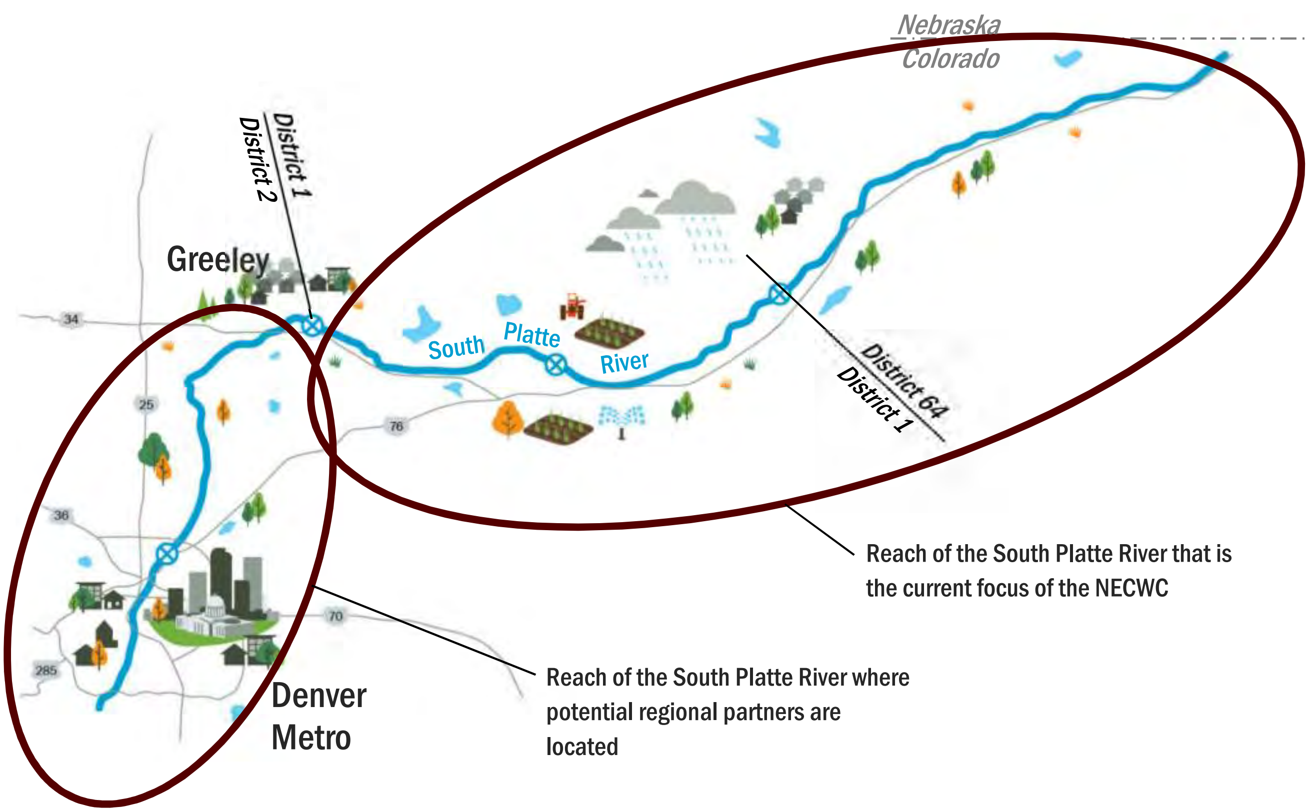

Figure 1-1. General Focus Areas of the NECWC

1.1 Purpose of the Report

The purpose of this report is to describe feasibility and operational study results from technical and legal analyses that have been conducted on behalf of the NECWC through grant funding provided by the Colorado Water Conservation Board (CWCB). The report provides a summary of the history of the NECWC and the original organizational analyses that contributed to its formation. It describes the analyses that were used to quantify potential water supplies, water demands, and exchange potential. Short- and long-term operational strategies are described that seek to maximize the demand that can be met with available supplies by using existing or potential new infrastructure. Current implementation activities and future steps towards achieving the goals of the organization are also described.

The NECWC has prepared this report and its transparent explanation of the evolution of the organization, operational strategies, physical river limitations, and outreach activities with the goal of helping with the formation of similar organizations or strategies that seek to collaboratively develop water supplies.

1.2 Project Funding

The NECWC and water users in northeast Colorado have greatly benefited from generous funding opportunities from the CWCB and from the contributions of NECWC members and interested stakeholders. This section describes the funding used to create and implement the NECWC and to develop operational strategies.

CWCB Grants

The NECWC was investigated, created, and implemented using funding from Water Supply Reserve Fund (WSRF) and Alternative Agricultural Water Transfer Methods (ATM) grants from the CWCB. The analysis work described in this report was conducted via the Alternative Agricultural Water Transfer Methods grants from the Colorado Water Conservation Board (CWCB). The objectives of each of the grants and their role in creating and implementing the NECWC are described below.

This report was written to satisfy the requirements of the Alternative Agricultural Water Transfer Methods Grants, CWCB contract numbers:

- **CTGGI 2015-2938**
- **CTGGI 2015-496**

- Lower South Platte Water Cooperative Organizational Analysis (WSRF grant): The work under this grant primarily focused on the organizational analysis that informed the creation of the NECWC. The project also focused on operational considerations that contributed to the subsequent analyses in later grant projects. The work associated with the WSRF grant was completed in July 2015 and is summarized in Section 3 of this report. The WSRF grant work is not the primary focus of this report, but it is summarized to provide context about the NECWC and the work done pursuant to the ATM grants.
- Lower South Platte Water Cooperative, Operational Development of Alternative Agriculture Water Transfer Methods (ATM grant): The work under this grant primarily focused on assembling foundational data sets that could be used for operational planning, developing operational strategies, and creating an accounting system. The work included evaluation of potential water rights issues, economic assessment of ATMs, and investigation of organizational issues. The work was funded by an Alternative Agricultural Water Transfer Methods grant (CWCB contract number: CTGGI 2015-2938, PO number: POGG1 PDAA 201800000699). The specific project objectives as described in the ATM grant application are:
  - Develop an operational plan that identifies water supplies (including direct flow and/or storage water transferred through alternative means, unused recharge credits, new junior

water rights, etc.), demands, and the means and infrastructure needed to provide water when and where it is needed.

- Identify existing and potential infrastructure that could help increase the ability of the organization to match supplies with demands.
- Obtain feedback from stakeholders on the operational plan.
- Identify specific data, water measurement, and accounting needs and work with potential members on developing data transfer methods.
- Gain a general understanding of options for funding the new organization.

- Northeast Colorado Water Cooperative Implementation (ATM grant): The work under this grant focused on implementation of the NECWC and investigation of operational issues and strategies associated with the NECWC membership. The work was funded by an Alternative Agricultural Water Transfer Methods grant (CWCB contract number: CTGGI 2015-496, PO number: POGG1 PDAA 201800000675). The work consisted of three general phases as described below:
  - Engineering: The objective of the engineering phase was to evaluate the supplies, demands, and delivery strategies for the specific initial participants in the new organization.
  - Accounting: The objective of the accounting phase was to refine and implement an accounting system to track the movement of water among members of the new organization. Work on the accounting system involved acquisition and input of necessary data and information from participating augmentation plans, ditch companies, water providers, etc. and testing of the accounting system. The project team consulted with the Division Engineer to ensure that the accounting protocols were appropriate. Grant funds were also obtained to cover actual water accounting costs for the first year of operation.
  - Project Report: A project completion report was written and submitted to the CWCB.

Member Funding and Stakeholder Support

A wide variety of organizations in the lower South Platte basin and elsewhere provided matching cash, in-kind services, and consulting services during the ATM and WSRF grant work. Table 1-1 lists the collaborating organizations. The collaborating organizations were instrumental in contributing to the vision for the NECWC and the evolution of the organization.

The degree of stakeholder support for investigating and developing a water organization like the NECWC has been significant and is highly appreciated

Table 1-1. Collaborators that have Provided Cash and In-Kind or Consulting Services to the NECWC		
*22 Ranch Limited Partnership	*Geisick Brothers Farms Augmentation	*North Sterling Irrigation District
*Baessler Farms	Groves Farms	*Northern Colorado Water Conservancy District
*Bijou Irrigation Company	Harmony Ditch Company	*Pioneer Irrigation Company
*Bijou Irrigation District	*H-R-R Farms Augmentation	*Prewitt Reservoir Operating Committee
Brown and Caldwell	*Jackson Lake Reservoir and Irrigation Company	*Putnam Ditch Company
CCII, LLC	*Jensen & Teague Augmentation	*Riverside Irrigation District
*Central Colorado Water Conservancy District	*Julesburg Irrigation District	*Riverside Reservoir and Land Company
*City of Sterling	*Logan Well Users	South Platte Ditch Company
*Colorado Corn Growers Association	*Lower Logan Well Users, Inc.	*Springdale Ditch Company
Colorado Division of Water Resources	*Lower Platte and Beaver Canal Company	*Sublette, Inc.
Colorado Open Lands	*Lower South Platte Water Conservancy District	*Upper Platte and Beaver Canal Company
Colorado State University	*Lowline Ditch Company	Vranesh and Raisch, LLP
*Deuel and Snyder Ditch Company	*Morgan County Farm Bureau	*Washington County
Dunn & Phillips LLC	*Morgan County Quality Water District	*Weimer Farms
*Ft. Morgan Reservoir and Irrigation Company	*Mowery Farms	*Weldon Valley Ditch Company

**Indicates collaborators that provided matching cash for ATM grants*

WaterSMART Grant

The NECWC, through the Lower South Platte Water Conservancy District (LSPWCD), applied for and was awarded a grant under the U.S. Bureau of Reclamation's WaterSMART, Water Marketing Strategy Grants program to conduct outreach/partnership building and scoping/planning activities to broaden its membership and marketing opportunities both locally and regionally. The WaterSMART grant will build upon the work conducted through the WSRF and ATM grants described above. The WaterSMART grant contract extends through December of 2021. Through the WaterSMART grant, additional partnerships benefiting water users in the lower South Platte basin will be pursued, and additional technical, legal, and organizational issues will be investigated. The final report for the WaterSMART grant, when issued in 2021, will provide additional information on operational strategies, partnerships, and organizational considerations.

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Section 2

History of the NECWC

Early Discussions and Analyses

Mike Groves, an agricultural producer in the Fort Morgan area, identified a need to enhance the use and management of water supplies for the benefit of water users in the lower South Platte basin. In 2008, he brought together a small group of water users and consultants to begin discussing his creative vision and the possibility of developing a water management organization in the area of Water Districts 1 and 64 in the lower South Platte River. The water users were interested in creating a means for making unused recharge credits from one augmentation plan available to other augmentation plans that had a temporary or periodic need for additional replacement water. The water users met numerous times to discuss the availability of unused recharge credits and the research needed to explore the feasibility of the organization and to plan a path forward. Over time, these water users became known as the "Steering Committee."

As the Steering Committee was conducting its initial meetings, work was also being conducted under an Alternative Transfer Methods (ATM) grant through the Colorado Corn Growers Association (CCGA), in partnership with Ducks Unlimited and the City of Aurora (collectively, "CCGA Study Team"). The CCGA Study Team was analyzing the challenges of implementing ATMs and exploring potential solutions. The concept of a water organization like the one researched and created by the Steering Committee (the NECWC), provided a potential way to overcome some of the ATM challenges identified by the CCGA Study Team. As a result, the Steering Committee and CCGA Study Team worked together to explore the technical feasibility of a potential organization. Technical analyses under the CCGA ATM grant included quantification of potential unused recharge credits that could be leased and an assessment of the ability to deliver unused recharge credits via exchange to water users upstream.

The preliminary analysis of unused recharge credits and available exchange potential was favorable, and the Steering Committee decided that additional research and outreach to potential stakeholders and participants was warranted. The reader is referred to a report entitled "Completion Report: Development of Practical Alternative Agricultural Water Transfer Methods for Preservation of Colorado Irrigated Agriculture" (CCGA, et al., 2011) for more information on the technical and feasibility analyses of the NECWC (or "the potential Lower South Platte Water Cooperative" as referenced in the report).

During 2010, Steering Committee members met with numerous ditch and reservoir companies, irrigation districts, augmentation groups, and conservancy districts to discuss whether there was sufficient interest in developing a new water organization. Responses to the potential water organization were positive. To research and address issues raised during meetings with water users, the Steering Committee prepared a work plan to outline a course of action. The primary goals of the Steering Committee were to:

- Develop an organizational structure for the new organization.
- Develop a detailed draft operational plan.
- Request necessary funding to accomplish this work.

The LSPWCD has been the primary applicant for grant projects aimed at developing a proposed organizational structure and operational plan for the organization. In addition, several entities have expressed interest in, and have provided financial assistance to, the formation of the organization, including individual agricultural producers, augmentation plans, ditch companies, municipalities, and water conservancy districts (see specific list of collaborators presented in Table 1-1).

Formation of the NECWC

Research and outreach on the member organization was pursued as a result of the initial feasibility efforts and water user interest. As described in Section 1.2, WSRF funding from the CWCB was used to conduct the outreach and research.

A Grant Review Committee (GRC) consisting of ten members (five from District 1 and five from District 64) was formed to oversee and contribute to the research for the new organization. The GRC took the place of the Steering Committee described above. The GRC met regularly during the course of the research projects to discuss results, collaborate on important organizational concepts and needs, develop communication strategies with stakeholders, and guide the overall process of forming the organization and developing operational strategies.

Based on the WSRF grant work, the GRC concluded that a cooperative would be the organizational structure that best fit the needs of the stakeholders. Through the WSRA grant work, organizational documents (articles of incorporation, bylaws, business plan, etc.) were developed. The cooperative was officially incorporated as the Northeast Colorado Water Cooperative on January 1, 2014. A summary of the organizational outreach and analysis findings is included in Section 3.

A key organizational document was the business plan, which was written in late 2013 (see Section 3 for more detail on the business plan). The business plan describes a vision for the short- and long-term services that the NECWC intended to evaluate and provide to its members:

The 2013 business plan is a key organizational document that has guided the operational analyses and partnership building efforts of the NECWC

- **Short-term services**: The NECWC would provide several services in the short term to coordinate the lease, exchange, and retiming of unused recharge credits from members who at times have available credits to members who at times have a need for credits.
- **Long-term services**: In the long term, the NECWC would explore and implement services to further maximize water uses in Districts 1 and 64 and potentially other parts of the South Platte basin.
    1. The NECWC planned to research the historical timing and amount of unappropriated waters in Water Districts 1 and 64 and to utilize existing and new infrastructure to strategically divert and beneficially use such water to meet existing agricultural, municipal, industrial and non-consumptive shortages for both members and non-members.
    2. The NECWC planned to research and potentially coordinate various means to conduct ATMs and facilitate the lease, exchange and re-diversion of the transferrable portion of historic consumptive use water from both senior direct flow and reservoir water rights, while maintaining ownership of the agricultural water rights.
    3. The NECWC planned to investigate the need for utilizing existing infrastructure and building additional infrastructure to help improve water use efficiency by its members both for short- and long-term operations.

The vision described in the 2013 business plan guided the NECWC's operational analyses and efforts at developing local and regional partnerships.

Upon formation of the NECWC, a Board of Directors was established to oversee the organization on behalf of the members and to conduct additional research and outreach. Nine of the original members of the GRC were named as the initial Board of Directors during the first year of the cooperative. In May of 2015 the number of directors on the board was reduced to five persons. The LSPWCD is the current General Manager of the NECWC.

Operational Planning and Partnership Building

Since the formation of the organization in 2014, and in concert with the business plan, the NECWC has focused on evaluating short- and long-term operational strategies and building partnerships with water users that could benefit from working with the NECWC. Funding from the ATM grants described in Section 1.2 was used to advance these activities.

The NECWC Board of Directors and the General Manager have overseen operational planning and partnership building activities since the formation of the organization. The Board has consistently consulted with the NECWC membership, has shared the results of research, and has confirmed that next steps and overall direction of the organization are consistent with member expectations.

Through time, the NECWC has taken a stepwise approach to evaluating operational strategies and the need for partnerships. Below is a general description of the timeline and focus of the work undertaken by the NECWC:

- Evaluation of member-to-member transactions: The short-term services described in the business plan focused on member-to-member transactions of unused recharge credits. Transactions of unused recharge credits between members were evaluated from the inception of the project until 2016. Detailed analyses of the reliability and potential legal risks/requirements of member-to-member transactions were conducted. The potential benefits, costs, and risks associated with member-to-member transactions were evaluated by the membership, and they authorized the NECWC to investigate additional long-term services that the organization could provide.
- Evaluation of benefits of unappropriated supplies, infrastructure and ATMs: Research on long-term services was conducted from 2016 to 2017. As describe previously, the long-term services included development of unappropriated supplies, utilization of existing or new infrastructure, and facilitation of ATMs. Detailed modeling of operational concepts including storage and recharge infrastructure were conducted to evaluate the degree to which currently unmet demands could be satisfied. The benefits, costs, and risks of long-term services were considered by the membership. The potential benefits of long-term services were attractive, and the membership authorized the NECWC to pursue partners that could help develop mutually beneficial infrastructure projects that would be necessary to implement long-term services.
- Development of partnerships: The NECWC has been seeking to develop partnerships with water users that could help facilitate the construction of infrastructure, and it continues to do so. To support these efforts, the NECWC obtained additional funding in 2019 from the WaterSMART grant program. Concurrently, the NECWC has been involved in other significant studies in the South Platte basin focused on the development of infrastructure and implementation of ATMs. The relationship with Parker Water and Sanitation District is a key partnership that has been cultivated over the last several years and has resulted in the pursuit of an actual water supply project involving storage, exchanges, conveyance pipelines and recharge that will benefit both Parker and water users in Districts 1 and 64. The NECWC membership and Board of Directors directed the LSPWCD to actively pursue this project to the benefit of District 1 and 64 water users (including current NECWC members).

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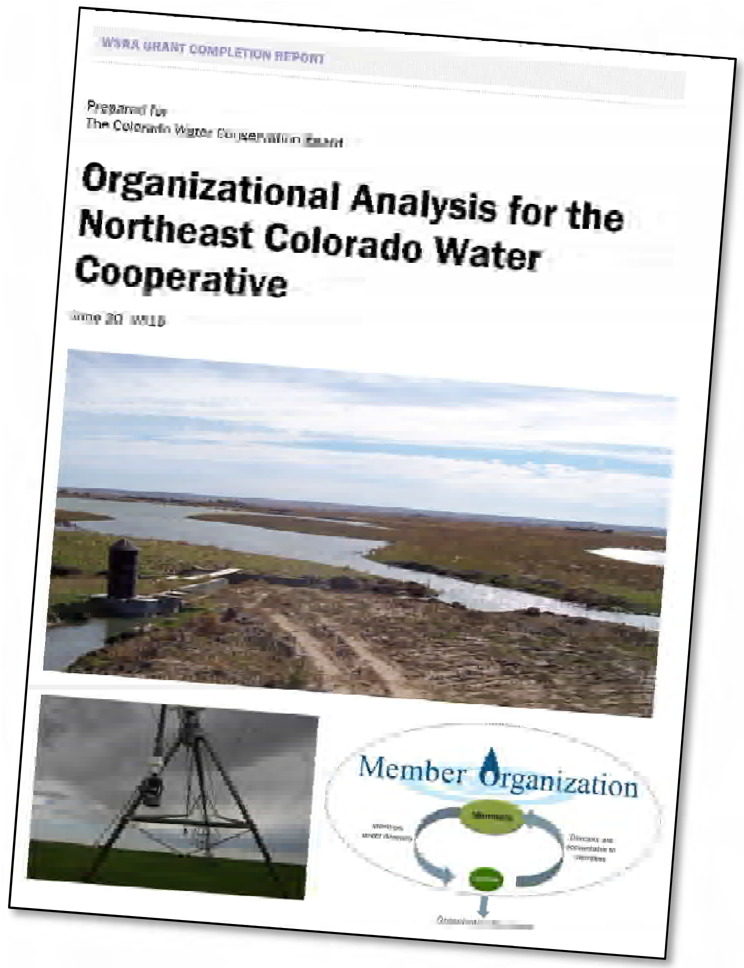
Section 3

Organizational Analysis

The organizational investigation and analysis conducted for the NECWC was completed June 30, 2015. Section 3 of this report provides a summary of the analysis. The reader is encouraged to download and review the report for further information on the organizational analysis as well as water rights considerations and initial operational analysis.



The full report from the organizational analysis can be viewed using this link: http://www.lspwcd.org/index_files/Page313.htm.

The objectives of the organizational analysis were to analyze and determine the best organizational structure for the NECWC and finalize the findings to the point of potential initiation of a water cooperative organization. Another objective of the analysis was to research and evaluate water law issues related to a water cooperative.

Research into appropriate organizational frameworks began with a fairly broad consideration of alternatives and factors that might be considered in evaluating different alternatives. The GRC firmly believed that the selection of an organizational structure should be guided and approved by the stakeholders who would eventually participate in the organization. As a result, stakeholder meetings were held early in the evaluation process and GRC meetings were announced and open to stakeholder participation.

Following an initial screening process of organizational alternatives, the GRC consulted with a corporation attorney who had worked with the Super Ditch, an organization in the Arkansas River basin. The attorney suggested that, given the flexibility needs of the organization, a for-profit organization might not be the best model. However, a cooperative formed pursuant to the Colorado Uniform Limited Cooperative Association Act could potentially work.

The GRC met several times and held a larger public meeting to gather broad water user input. Based on input from other organizations and stakeholders, several key goals were identified that needed to be met in forming an organizational structure:

- Design membership criteria to be balanced, fair, and accessible for local water users.
- Design an organization that would operate in a transparent manner so that water users can see how decisions are made.
- Design Board of Directors criteria to be representative of members yet functional and effective.

After researching various organizations, talking with experts and members of other organizations, and obtaining input from stakeholders, the GRC determined that a cooperative was the organizational structure that best fit the criteria that had been developed.

3.1 Formation of the Organization

The GRC worked with a cooperative attorney to develop organizational documents and to deal with issues such as qualifications for membership, defining "patronage" of the cooperative, conditions for leaving the NECWC, costs for membership, qualifications for the Board of Directors, size of the Board of Directors, types of membership, etc. The cooperative was officially incorporated on January 1, 2014.

Many of the foundational features of the NECWC are defined in its Articles of Incorporation, Bylaws and business plan. These documents and features of the NECWC are described below.

- **Articles of Incorporation.** A cooperative may be a stock or membership cooperative, and the Articles of Incorporation provide the rights of the members. Those rights may include the right to vote, the right to be a member of the Board of Directors, and the right to distributions. NECWC's Articles of Incorporation provide for two classes of membership stock, one with voting rights (Class A) and one without voting rights (Class B).
- **Bylaws.** A cooperative's Bylaws are used by the cooperative's Board of Directors and management team as the operational structure for the cooperative. Several components of the bylaws are described below.
  - **Membership qualifications.** In the NECWC, there are two classes of membership, voting and non-voting. All members must patronize the cooperative and abide by the Articles of Incorporation, Bylaws, etc. The two main distinguishing characteristics for Class A voting members are that they own a decreed or pending application for an augmentation plan that includes water rights or a water recharge facility authorized by decree from a recognized Colorado Water Court (not including persons who are individual shareholders, members or users of an entity with such a right, plan or facility) and that they have a principal office or residence located in either Water District 1 or 64. The price for one share of Class A voting stock would be $2,000 and one share of Class B non-voting stock would be priced at $1,000.
  - **Board of Directors**. The NECWC Bylaws also include the provisions for the Board of Directors. Nine of the original members of the GRC were named as the initial Board of Directors during the first year of the cooperative. In May of 2015 the number of directors on the board was reduced to five persons.
  - **Management**. The Lower South Platte Water Conservancy District has been hired, per a written services agreement, to operate the cooperative for the foreseeable future.
  - **Membership Benefits**. The purpose of any cooperative business is to benefit the members of the cooperative, whether through services, purchasing power, for marketing and administrative services or, in the case of NECWC, for the efficient use of water owned by the members.

- **Business Plan**. The business plan describes the vision for the organization and the services it was formed to provide. Components of the business plan are described below. The full business plan is included in Appendix A.
  - **Services**. The services the organization intends to provide both in the short term and long term are described.

    Short term: The NECWC would provide several services in the short term to coordinate the lease, exchange, and retiming of unused recharge credits from members who at times have available credits to members who at times have a need for credits.

    Long term: In the long term, the NECWC would explore and implement services to further maximize water uses in Districts 1 and 64 and potentially other parts of the basin.

    1. The NECWC planned to research the historical timing and amount of unappropriated waters in Water Districts 1 and 64 and to utilize existing and new infrastructure to strategically divert and beneficially use such water to meet existing agricultural, municipal, industrial and non-consumptive shortages for both members and non-members.
    2. The NECWC planned to research and potentially coordinate various means to conduct ATMs and facilitate the lease, exchange and re-diversion of the transferrable portion of historic consumptive use water from both senior direct flow and reservoir water rights, while maintaining ownership of the agricultural water rights.
    3. The NECWC planned to investigate the need for utilizing existing infrastructure and building additional infrastructure to help improve water use efficiency by its members both for short- and long-term operations.
  - Membership and Management. Membership qualifications and requirements are summarized as well as the management structure and duties of the Board of Directors.
  - Risk. Potential risks to prospective members of the organization are described. Risks focus on financial as well as those associated with water court proceedings.
  - Finance. Financial information are described such as potential sources of funding, the need for funding, and a pro forma budget for the first three years of operation.

3.2 Water Law and Water Rights Considerations

The project team researched water law and water rights issues related to the goals of the organization to determine the best approach for achieving those goals and to evaluate items that might impact the organization or its members.

A primary goal of the organization is to provide a framework for more efficiently using unused recharge credits from decreed recharge water rights and augmentation plans. Numerous augmentation plan decrees were reviewed to identify the common provisions (described below) related to end uses of unused recharge credits that might be applicable to NECWC's cooperative operations.

- Many decrees adjudicating recharge water rights allow for the lease of unused recharge credits to other water users for either short-term or long-term periods, subject to certain approval requirements. Generally, the person or entity leasing unused recharge credits must have an approved Substitute Water Supply Plan (SWSP) or plan for augmentation.

- Many decrees adjudicating plans for augmentation allow for the plan owner to add additional replacement sources to the augmentation plan, subject to notice and comment requirements concerning the water source to be added.

Several considerations were identified with respect to future activities related to water court as a result of research into water law and water rights issues and the provisions of the reviewed recharge water right and augmentation plan decrees.

- An area-wide augmentation plan might be developed to allow flexible use of unused recharge credits.
- Decreed exchanges might be used to move these credits to upstream facilities for better water management.
- New places of storage and recharge might be added to facilitate use of unused recharge credits.
- Changes of water rights were also evaluated as a possible means to include other water sources and water users into the NECWC operations.
- New water rights for unappropriated supplies were evaluated as a source of supply for members, but infrastructure would be needed to store, manage, and deliver the water.

3.3 Operations and Financing of Similar Organizations

Research was conducted to assess how other, similar organizations operate and finance their operations. The NECWC is a unique organization – it is the first cooperative formed for the management of water in the state of Colorado and perhaps the nation. While the NECWC is unique, it shares similar characteristics of water banks and the Super Ditch organization in the Arkansas River basin and has similar goals and objectives. Organizations like this have been set up in other states, although each one has different goals and legal settings.

The research informed the development of the NECWC, and the findings were considered and integral to the organizational research described in the Organizational Analysis report. Some of the key findings from these investigations and interviews with similar organizations are described below:

- Many water bank organizations are run by government entities.
- Data management is an important aspect of operations. Effective tools are needed to manage large amounts of data.
- Most organizations tend to rely wholly or in part on per-acre-foot transaction fees to finance themselves. Incremental pricing for supplies with varying reliability has been used as a tool to capture the differing values of water rights transferred into water banks.
- In one instance, a water bank organization did not have an adequate understanding of the water demands it was attempting to serve. The organization paid farmers for water supplies but could not complete transactions for all of the water it purchased, resulting in financial losses. In subsequent years of operations, end user agreements were established ahead of time.
- Generally, two to three people are needed to run the organizations that were interviewed. However, in some instances, work backlogs have hindered customer responsiveness and service.
- Several types of example materials were gathered by the project team including applications for leases or water deposits, annual reports, staff job descriptions, operations handbooks, member databases, member responsibility materials, etc.

The information derived from this analysis was useful to the cooperative organizers in planning operational activities and needs.

Section 4

Operational Analysis Input Data

The operational analysis was the primary focus of ATM grant work described in this report. During the analysis, the NECWC explored its alternatives for operating under various assumptions related to supplies, demands, and infrastructure. The relative success and benefits of operations under various assumptions were weighed against considerations such as water law issues, the need for infrastructure, and the need for partnerships with local and regional water users/providers.

The operational analysis required an understanding of potential supplies available to members, potential demands that could be met, and the ability to move water from location of supply to location of demand, both physically and within the legal framework of the members' existing augmentation plans and/or any new plans that might be developed. The operational analysis was conducted using a phased approach:

> **Phase 1:** The first phase examined the operational benefits of member-to-member transactions of unused recharge credits.
>
> **Phase 2:** The second phase built on the first phase and evaluated the operational benefits of incorporating infrastructure and additional sources of supply such as ATMs and unappropriated stream flows.

The assessment of supplies, demands, and exchange potential are described below, followed by a description of the subsequent operational analyses that were conducted.

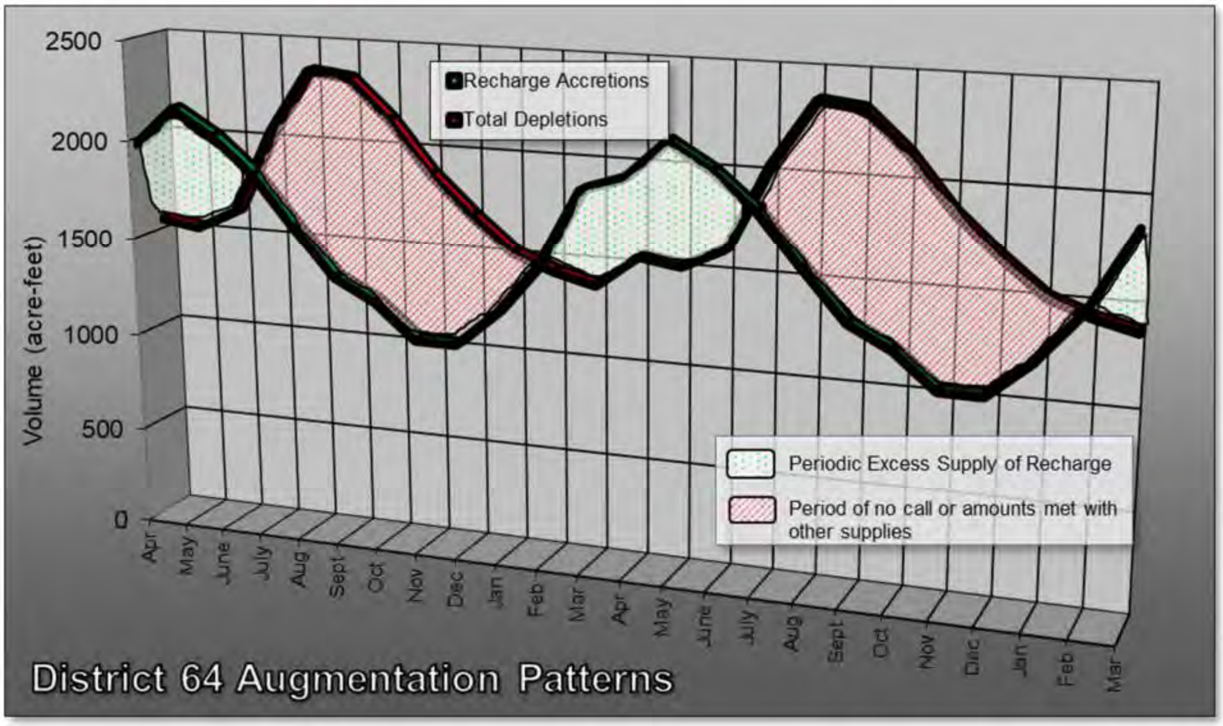
4.1 Quantification of Potential Supplies

The primary sources of supply that could be utilized to meet the needs of NECWC members, water users in Districts 1 and 64, and potential regional partners in other areas of the lower South Platte River include unused recharge credits, unappropriated stream flows, and water derived from ATMs. These sources were evaluated and quantified in the operational analyses for the NECWC. Other sources of supply, such as nontributary groundwater or reusable return flows could be available but are not likely to be a significant source of supply to water users in Districts 1 and 64 and were therefore not considered for the purposes of the operational analyses.

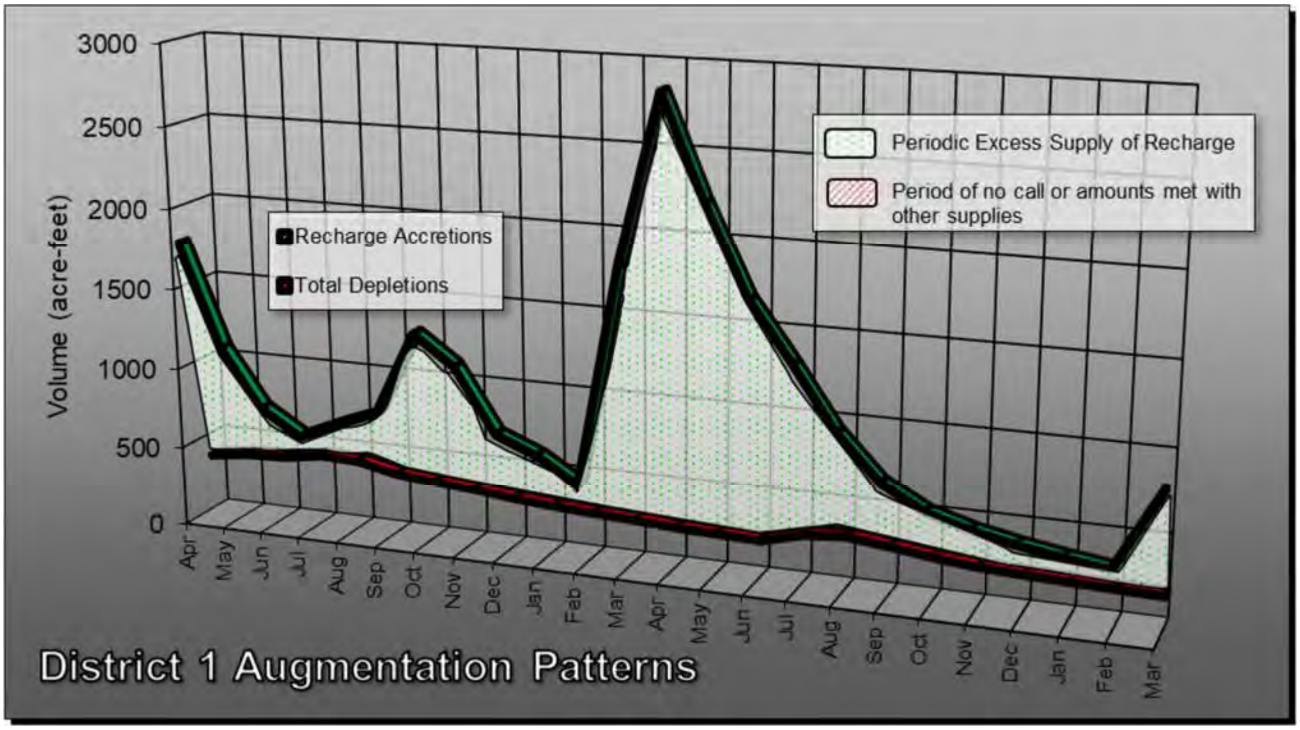
Unused Recharge Credits

Water rights for recharge are relatively junior. As a result, when there is a senior call on the river, recharge rights are not in priority and cannot be diverted. In drier years, the opportunities to divert junior recharge rights might be few and far between and in short windows of time. In normal years, there may only be certain seasons when recharge rights are in priority – like the spring for example. However, even in dry years, the delayed accretions (credits) from previous diversions will be used in the augmentation plans.

Because junior recharge rights will only be in priority intermittently or in short windows of time, augmentation plan operators must recharge as much as possible in accordance with their decrees when they are in priority, because they do not know when they will be able to recharge again. And, the timing of when the recharge rights are in priority (generally in the spring or during winter months in District 64) seldom matches the timing of when water is needed from wells to irrigate crops. The illustration below depicts this timing issue. It depicts the general variability in patterns of depletions and recharge in District 64. In late winter and spring, recharge exceeds depletions. However, in the summer and fall, depletions are more than recharge credits, and augmentation plans need to rely on other sources of water for augmentation supply.



Locations of recharge ponds and other recharge facilities relative to irrigation wells also present timing difficulties for augmentation plans. For example, if recharge ponds are located closer to the river than the irrigation wells in an augmentation plan, the recharge credits reach the river more quickly than the depletions (given similar aquifer characteristics). Augmentation plans need adequate water supplies to fully cover their pumping depletions at all times that they are out of priority. However, on the days that the junior recharge rights are in priority for diversion, it is impossible to know what the river call will be on the days that the recharge accretions and the well depletions will reach the river, which will be months, years, and decades into the future. The graphic below illustrates this issue and shows a typical recharge and depletion time series for a District 1 augmentation plan. In District 1, augmentation plans frequently need to recharge as much water as they can in the spring pursuant to their decrees so that the lagged accretions last them through the summer, fall, and early winter when the opportunity to recharge using junior water rights may not be available. The graphic shows that augmentation plans like this can generate more recharge credits early in the irrigation season in an effort to cover their well depletions as the accretions diminish later in the fall and winter.



These variabilities in recharge mean that it is impossible to divert and recharge only the amount of water ultimately needed to offset the well depletions. As a result, most augmentation plans will have some extra recharge credits from time to time so that they can provide adequate supplies to cover depletions year-round. However, this does not mean that the plans "have more than they need." Any plan can have surplus credits at some times and be barely adequate or short of credits at other times during the same year.

Unused recharge credits for a variety of augmentation plans in Districts 1 and 64 were quantified for the years 2008 through 2010 and were presented in the Organizational Analysis report. As a part of that work, unused recharge credits were quantified for most of the augmentation plans in Districts 1 and 64 using augmentation plan accounting data for 2009 and 2010. In addition, data describing 2008 unused recharge credits in Districts 1 and 64 were incorporated from a previous ATM project conducted by the Colorado Corn Growers Association and others (2011). The quantification of unused recharge credits in the Organizational Analysis report considered data from 29 plans in District 1 and 20 plans in District 64. Table 4-1 shows the total estimated amount of unused recharge credits in Districts 1 and 64 for 2008 through 2010.

Table 4-1. Estimated Amount of Unused Recharge Credit from 2008 through 2010 (acre-feet)

	2008	2009	2010
District 1	20,000	60,000	60,000
District 64	10,000	20,000	20,000
Total	30,000	80,000	80,000

The scope of work for the implementation-focused ATM grant included conducting a rough quantification of unused recharge credits associated with NECWC member plans for the years 2011 and 2012. The same procedure used for quantifying unused recharge credits for the Organizational Analysis report was used for this analysis. The quantification process used augmentation plan accounting spreadsheets that were downloaded from the Colorado Division of Water Resources' Laserfiche WebLink (https://dnrweblink.state.co.us/dwr/search.aspx).

The focus of the 2011/2012 quantification of unused recharge credits was on the current membership of the NECWC, which includes many, but not all, of the augmentation plans that were evaluated in the Organizational Analysis report. Table 4-2 describes the augmentation plans that were considered. A few plans were not included because they primarily provide recharge credits to other plans or their available accounting data could not be interpreted.

Table 4-2. Augmentation Plans Included in the 2011/2012 Unused Recharge Credit Quantification

Riverside Irrigation District	Teague Enterprises	Lower Logan Well Users, Inc
Bijou Irrigation Company	Morgan County Quality Water District	Stromberger Land and Cattle Company
Sublette, Inc.	Ft. Morgan Farms, LLC	South Platte Ditch Well Users
Wiggins Farms, LLC	Deuel and Snyder Ditch Company	LSPWCD Water Activity Enterprise
Weimer Farms	Lower Platte and Beaver Canal Company	Logan Well Users, Inc.
Groves Farms	Pioneer Water & Irrigation, Inc.	Lowline Ditch Company

Table 4-3 shows a rough estimate of the unused recharge credits for the above plans, by Water District, based on their 2011 and 2012 accounting data. The calculations considered total depletions from well pumping (regardless of whether they were in or out-of-priority), total accretions from recharge activities, and documented leases of recharge credits. If the calculated, net unused recharge credit was negative (indicating depletions were greater than recharge accretions) other augmentation sources available to the plan would have been used to mitigate the deficit. The estimated unused recharge credits were calculated as the net difference between the amount of accretions from recharge and the depletions, plus documented leases of recharge credits. It should be noted that in one of the plans, only out-of-priority depletions were reported, and the amount of unused recharge credit was calculated on a slightly different basis than in other plans and could potentially be lower if all depletions were considered.

A broad spectrum of augmentation plans was evaluated in the quantification of unused recharge credits for 2008-2010 shown in Table 4-1. The quantification for 2011/2012 in Table 4-3 focused only on NECWC members.

Table 4-3. Estimated Amount of Unused Recharge Credit for NECWC Member Plans for 2011 and 2012 (acre-feet)

	2011	2012
District 1	41,000	18,000
District 64	15,000	9,000
Total	56,000	27,000

The bullets below provide some observations on the unused recharge credit data in Tables 4-1 and 4-3:

- Amounts of unused recharge credit vary for the years examined. Substantially more unused recharge credits occurred in 2009 and 2010 than in 2008, as shown in Table 4-1. This variation is due to the multiple operations and river hydrology factors that impact augmentation plans and daily operations (wet or dry hydrologic conditions, river calls, timing of well pumping and recharge accretions), and is to be expected based on the requirements that most water users face when seeking a decreed plan for augmentation that relies, at least in part, on recharge accretions as a source of replacement water for lagged well depletions. While only the NECWC membership was considered in Table 4-3, the data also varied, with 2012 unused recharge credits being approximately half of the amount quantified in 2011.
- The amount of unused recharge credit appears to be less variable in District 64 based on the years examined. Annual amounts of unused recharge credits in District 64 varied from 10,000 to 20,000 acre-feet in Table 4-1. Unused recharge credits shown in Table 4-3, while generally less than the credits in Table 4-1 because fewer plans were considered, show a similar range of variation.
- Annual amounts of unused recharge credit appear to be more variable in District 1 than in District 64. Annual amounts of unused recharge credits varied from 20,000 acre-feet in 2008 up to 60,000 acre-feet in 2009 and 2010. Table 4-3, while only based on two years of data, indicates a somewhat higher degree of variation in unused recharge credits in District 1 than District 64.
- 2008 through 2010 were good years for recharge. It is likely that, during drought, unused recharge credits will be much reduced, if not eliminated. The data in Table 4-3 reflect this observation. Drought conditions set in during 2012, and unused recharge credits for NECWC members were less than half of the unused recharge credits quantified in 2011.
- While not specifically indicated in Tables 4-1 or 4-3, unused recharge credits generally occur in the late spring and early fall.
- While the amount of unused recharge credits from NECWC members shown in Table 4-3 is less than the amount quantified for a wider spectrum of augmentation plans in Table 4-1, significant amounts of unused recharge credits were quantified and available from NECWC member plans at times. In other times, no unused recharge credits were available. As described earlier in this section, unused recharge generally occurs due to timing differences between well depletions and recharge accretions. The presence of unused recharge credits is not indicative of "over recharging" or poor management. Rather, it is due to varying hydrology and river administration and locational differences between recharge facilities and wells.

Unused recharge credits can, at times, constitute a significant portion of stream flow. A high-level evaluation was conducted to assess the significance of unused recharge credits as a proportion of stream flow. The analysis compared, on a daily basis, the amount of unused recharge credits in the river to the amount of flow in the river during free river conditions and when a call was being administered. The evaluation was considered to be approximate, because the amounts of unused recharge credits were derived on a monthly basis and were broken down to a daily time step for the purposes of the analysis. The results of the analysis are summarized in Figure 4-1.

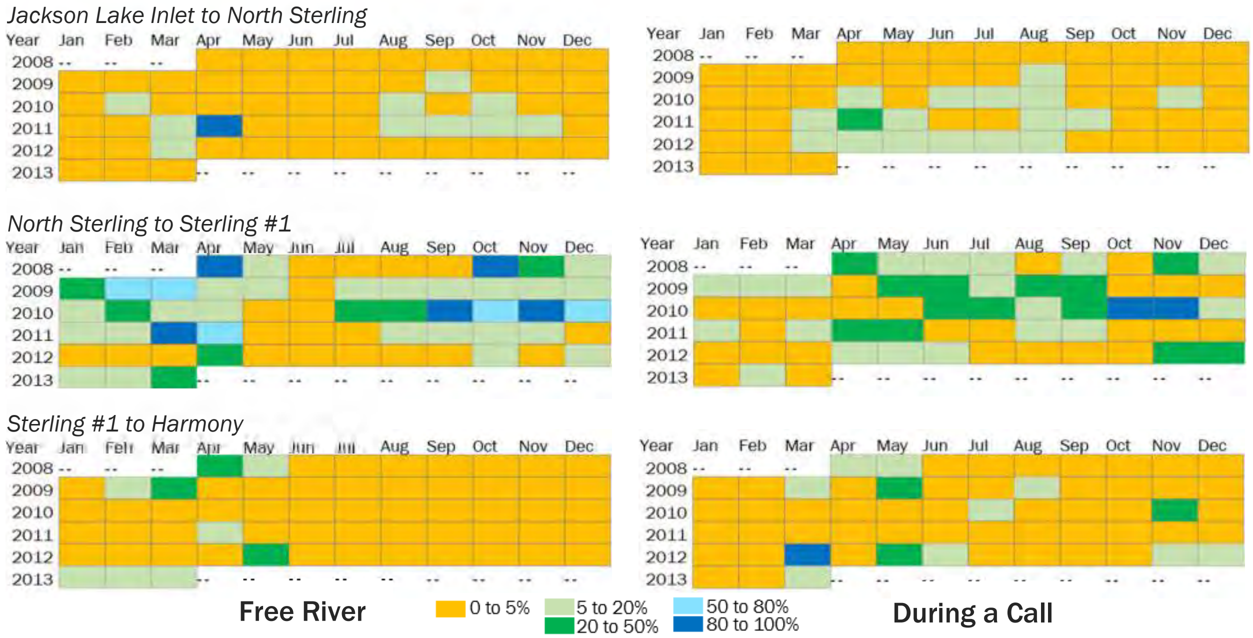


Figure 4-1. Unused Recharge Credits as a Proportion of River Flows during Free River and Call Conditions

Comments on Figure 4-1 include:

- The proportion of stream flow made up by unused recharge credits varied substantially under free river and call conditions. Changing river flows, call regimes, and volumes of unused recharge credit all contributed to the variability.
- It should be noted that when either no free river conditions occurred in a particular month, or no calls were administered in a particular month, the amount of unused recharge credits as a proportion of river flows was 0 percent. For example, in June of 2008, a call was being administered during the entire month in each of the reaches shown in Figure 4-1. As a result, the unused recharge credits were 0 percent of free river flows (no free river occurred in that month) but were between 5 to 20 percent of river flows during a call in the North Sterling to Sterling #1 reach.
- During some periods of time, unused recharge credits made up most of the flow in the river. These periods tend to occur when river flows are generally low, either because of drought conditions or from diversions. For example, in October 2008, calls were administered for both the North Sterling and Prewitt inlets, and free river conditions existed downstream. In the reach of the South Platte River below these inlets, unused recharge credits made up most of the flow in the river.

Unappropriated Stream Flow

Unappropriated stream flows diverted under a new, junior water right could be a source of supply to NECWC members. Because the South Platte River is overappropriated, a new water right would not be in priority on a regular basis and typically not during times when the needs are greatest. As a result, infrastructure is needed to retime unappropriated supplies. For example, water diverted under a junior right could be stored in a reservoir and be released later when needs arise. In addition, junior water rights could be used to supply recharge facilities that have long lag times for accretions. New recharge rights could be used to deliver water to these facilities during relatively wet hydrologic conditions. During times of extended drought (when individual member augmentation plans may not be able to support 100 percent well pumping quotas and no unused recharge credits are available), recharge credits from NECWC facilities could be a source of additional augmentation supply to members.

Volumes and locations of unappropriated stream flow along the South Platte River have been quantified in various studies associated with the NECWC, the latest study being the Organizational Analysis. The analysis tool used in these studies was updated with more recent input data and used to quantify unappropriated stream flows for the purposes of the operational analysis described in this report.

The quantification of unappropriated supply was performed using the point flow and call analysis tool originally developed during the CCGA ATM project. The tool has been used for a wide variety of South Platte basin assessments of available stream flow, exchange potential, and operation of proposed water supply infrastructure (including the South Platte Basin Implementation Plan, the South Platte Storage Study, and the South Platte Regional Opportunities Water Group Feasibility Study). Inputs to the tool include daily call, stream flow, and diversion data for the diversion structures between the Burlington Ditch and the state line. River flows are calculated upstream and downstream of each headgate on the river. River gains and losses are estimated by the tool and considered in these calculations. The most recent version of the tool runs over a 20-year period from October 1, 1995 through September 30, 2015.

Figure 4-2 shows output from the tool with respect to the annual volume of unappropriated supply that flowed past each headgate in the South Platte River downstream of the Burlington Ditch to the state line. Data from water years 2002 through 2015 are shown in Figure 4-2. While the tool includes data back to water year 1996, NECWC evaluations have generally focused on a more recent and representative time period when water administration in the South Platte basin was more comprehensive and transparent, starting with the drought of the early 2000s. Average annual volumes, high volumes occurring in water year 2015, and extremely low volumes in water year 2004 are the focus of Figure 4-2, but other years are also shown to illustrate the variability of unappropriated stream flow.

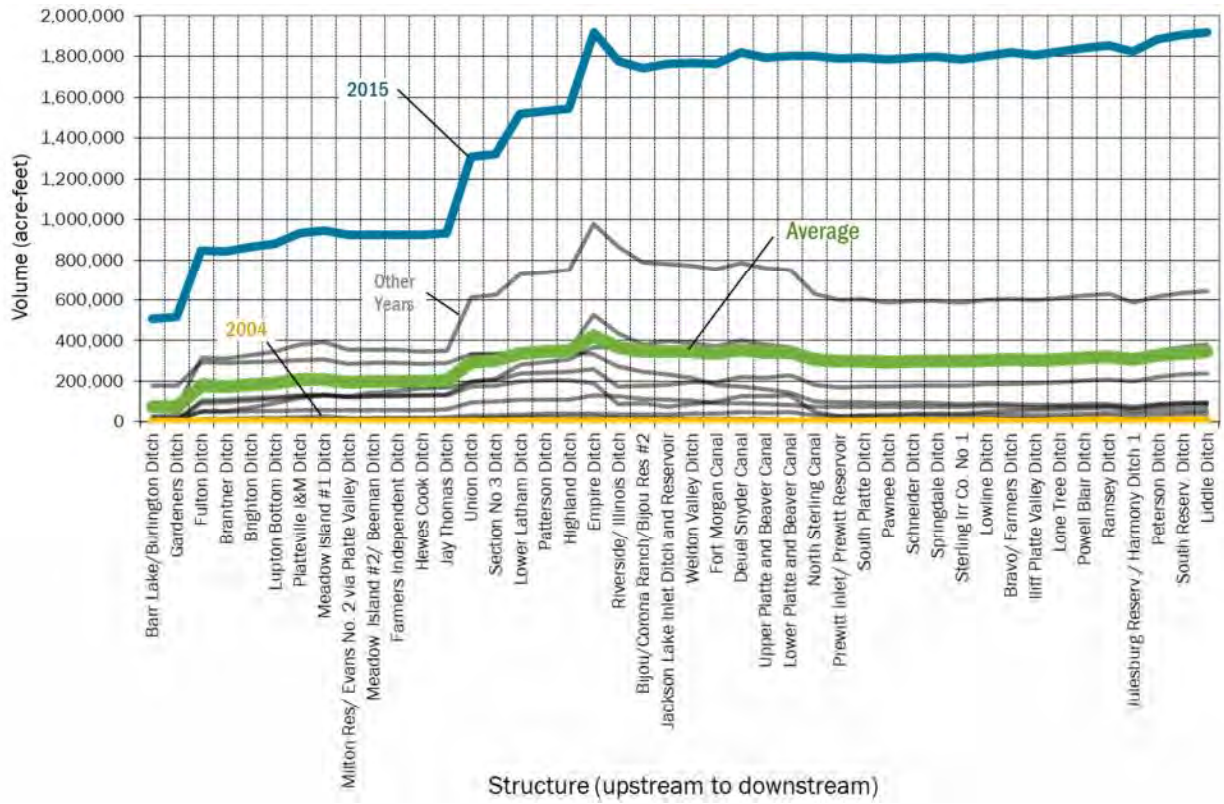


Figure 4-2. Yearly Volume of Free River Passing Diversion Structures in the South Platte River, 2002 to 2015

Observations on Figure 4-2 include:

- The amount of unappropriated stream flow on the South Platte River downstream of Denver varies significantly by location and by year.
- The volume of unappropriated stream flow in the South Platte River tends to increase between Denver and the confluence with the Cache la Poudre River. In this stretch of the South Platte River, several tributaries that have headwaters in the Front Range discharge into the South Platte River and contribute stream flow.
- Unappropriated stream flow downstream of the Cache la Poudre River exhibits a slight downward trend in most years with a slight upward trend nearer to the state line. Return flows from irrigation projects contribute significantly to stream flows downstream of the Cache la Poudre River.
- The amount of unappropriated steam flow varied significantly over time. During the drought of the early 2000s, almost no unappropriated stream flow was available. This was in contrast to 2015 when between 1 and 2 million acre-feet of unappropriated stream flow were available in many segments of the South Platte River.
- The average amount of unappropriated stream flow at headgates along the South Platte River is shown in Figure 4-2 with the amounts of 70,000 AF/year near the Burlington Ditch, increasing to 420,000 AF/year downstream of the confluence with the Cache la Poudre River, with 345,000 AF/year near the state line.
- While unappropriated stream flow is periodically available, it is highly variable. Creating a firm and reliable source of supply from unappropriated stream flows requires infrastructure to store supplies when they are available and then releases of stored supply during times of need.

Alternative Transfer Methods (ATMs)

In the future, the NECWC could potentially facilitate leases of senior water rights via ATMs, which could provide supplies to various end users while providing an economic benefit to the irrigators who own senior water rights. Alternative transfers using senior water rights may be a useful way for the organization to increase reliability of water delivery to members and other partners given the variability of unappropriated stream flow and unused recharge credits. ATMs could be conducted in a variety of methods including rotational fallowing and interruptible supply agreements. In addition, if infrastructure partnerships are established, part of the agricultural supply associated with the infrastructure could periodically be used by a municipal partner as a firming supply, which in concept is consistent with the intent of ATMs like interruptible supply agreements.

The amount of potential firming supply under alternative transfer scenarios was quantified and described in the Organizational Analysis report. The assessment method was similar to what was used in feasibility studies for the Super Ditch organization in the Arkansas River basin. The analysis conducted for the Organizational Analysis assumed firming supplies could be made available through rotational fallowing programs under ditch systems in Districts 1 and 64. In addition, the analysis assumed that 65% of shareholders would be interested in participating in a rotational fallowing program (if the price is right for water) and that 25% of their land would be fallowed to generate transferrable consumptive use. Further, it was assumed that direct flow rights would be made available through rotational fallowing programs and that water supplies from storage, the Colorado-Big Thompson project, and groundwater would continue to be used for irrigation purposes and would not be incorporated into a rotational fallowing program. Consumptive use data from StateCU, a modeling tool available from the South Platte Decision Support System, was used for the analysis.

Using the assumptions and analysis process described above, approximately 30,000 to 40,000 AF/year was estimated to be available through rotational fallowing in Districts 1 and 64. The results of the analysis were broken down into different segments of the South Platte River in Districts 1 and 64 to generally describe the range of amounts (minimums and maximums) and locations of potential supply from rotational fallowing ATMs that were estimated. Figure 4-3 shows this breakdown and suggests that supplies from ATMs could be derived throughout Districts 1 and 64, but more potential supply may be located in District 1 than in District 64.

It should be noted that the analysis was conducted for planning-level purposes and is not indicative of actual amounts of supply from ATMs that could be provided by an individual ditch or group of specific ditches. It should also be noted that total amount of water that could be supplied by ATMs could be substantially more or less depending on shareholder interest, the price for water, and the method of alternative transfer. For example, if a large number of irrigators participated in an interruptible supply program rather than a rotational fallowing program, it is possible that periodic amounts of supply could be temporarily transferred that exceed the estimates described above.

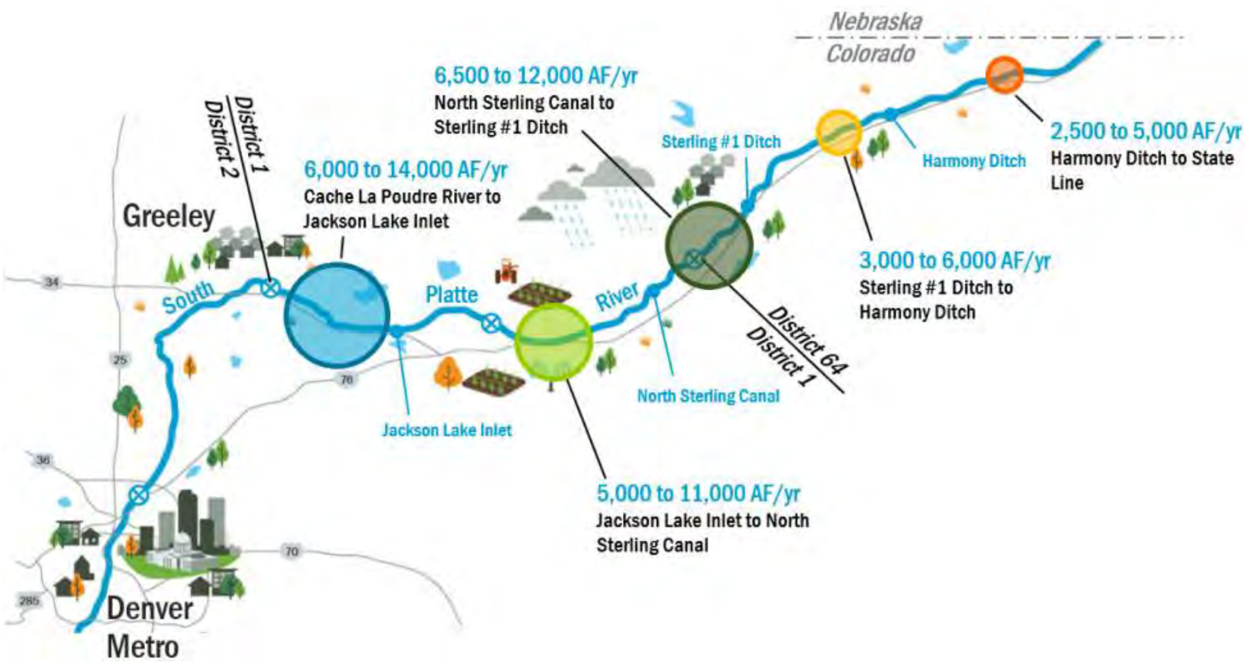


Figure 4-3. Potential Supply from Rotational Fallowing ATMs in Districts 1 and 64

Recent discussions with agricultural waters users conducted during the South Platte Regional Opportunities Water Group (SPROWG) Feasibility Study provided perspectives that inform the NECWC's potential approach to ATMs. Agricultural water users stated that ATMs are preferable to traditional buy-and-dry methods for water acquisition by municipalities. However, agricultural water users stated strongly that ATMs should not be the primary source of supply for municipalities. Rather, municipalities should focus on developing unappropriated supplies before relying on supplies from agriculture. In other words, ATMs should be a source of last resort. In addition, ATMs need to be economically attractive to agricultural water users and should be conducted in a way that considers the seasonal characteristics of farming operations (e.g. adequate notice should be provided when an ATM is to be implemented so that the agricultural water supplier can adjust its operations for the year).

In summary, significant amounts of water from ATMs could be made available through leases to NECWC members or other partners. The role of ATMs may be that of a firming supply, which would be accessed when other sources of supply are unavailable. The NECWC could facilitate these types of transactions on behalf of its members.

4.2 Quantification of Potential Demand

Water needs of NECWC members, other water users in Districts 1 and 64, and potential regional partners has been the subject of evaluation not only in this project, but other regional studies like the SPROWG Feasibility Study. The variety of water demands among different water users was considered in the operational planning conducted for the NECWC and in other studies.

Current water supplies do not fully meet overall demand. For the purposes of this analysis, "demand" was quantified as the additional water supply needed to meet demands of existing water user that are currently unmet.

Water needs were evaluated and described in the Organizational Analysis report in a generalized fashion. Water needs of NECWC members and other District 1 and 64 water users were investigated more thoroughly during this study. The NECWC and consultants conducted meetings and interviews with a number of water providers and augmentation plans to assess potential permanent or temporary demands for water that could be made available through the cooperative. Water needs varied. Below is a summary of the water needs investigations conducted for the ATM grant studies:

- Most users expressed interest in water supplies during droughts. Many District 64 and some District 1 augmentation plans need water in the second year of a drought to maintain 100 percent pumping quota or without relying on other sources besides recharge for augmentation supply. In the first year of a drought, accretions from previous years' recharge activities are generally adequate to meet their needs. However, if their junior recharge rights are not in priority during the first year of drought, their available recharge credits dwindle in the second year.
- Several District 1 augmentation plans with quotas that are consistently less than 100 percent expressed a need for firm supplies to allow full pumping.
- Municipal providers generally have adequate supplies in most years but may need water during drought conditions or for drought recovery.
- Some augmentation plans handle a variety of supplies and demands in terms of amounts and locations. These plans may already have some degree of operational flexibility, but they expressed that an additional source of supply could enhance their flexibility.
- Several industrial and municipal water users were interviewed. Most of these entities stated that they either have adequate supplies or that they are currently developing supplies that will meet their needs. However, they also expressed interest in working with the NECWC in the future as a way to develop additional water supply options.
- Local water users mentioned a need for additional water supplies to meet demands of new industry in the lower South Platte basin.
- Augmentation plans are a source of potential water supply with respect to unused recharge credits but can also have water needs as described above. A key benefit of the NECWC is providing a means to better utilize all sources of supply to meet periodic or chronic water needs of members and other partners.

The interviews conducted with NECWC members and potential members included questions related to average and dry year volumetric needs. The volumetric needs expressed by interviewees reflected varying perspectives on how they could potentially work with the NECWC. For example, some augmentation plans consistently issue augmentation quotas that are below 100 percent. In these cases, their volumetric needs reflect a deficiency of supply that could be mitigated by working with the NECWC. In other cases, a volumetric need could reflect a supply that an augmentation plan is currently relying on but could be held in reserve (for example, water in storage) if an alternate source of supply (such as unused recharge credits) could be facilitated by the NECWC. In all cases, the results of the interviews reflect needs that are currently being unmet or could be met in a more efficient or economic way.

Table 4-4 describes total water needs, by Water District, of NECWC members and others that were derived from interviews and input from water users in Districts 1 and 64. The data in Table 4-4 should not be interpreted as a reflection of all the water needs in Districts 1 and 64. Rather, the data reflect the needs of nine water users who responded to NECWC inquiries. The data are likely not reflective of full NECWC membership and are not representative of all the water needs in Districts 1 and 64. It is anticipated that as the NECWC or other water supply efforts are further implemented, additional needs will be identified.

Table 4-4. Water Needs Identified by Potential NECWC Members and Partners (acre-feet)		
	Average Year	Dry Year
District 1	25,000	35,000
District 64	-	5,000
Total	25,000	40,000

The data in Table 4-4 are of the same general magnitude of water needs considered in the SPROWG Feasibility Study. Table 4-5 summarizes the municipal and agricultural water demands that were considered in the SPROWG Feasibility Study. It should be noted that the SPROWG Feasibility Study, like this analysis, did not seek to quantify or develop strategies to supply all the water needs in the lower South Platte River. Rather, the SPROWG Feasibility Study considered the needs expressed by individuals and organizations that responded to inquiries during the outreach process.

Table 4-5. Summary of District 1 and 64 Water Needs Considered in the SPROWG Feasibility Study (acre-feet)				
	Low Range		High Range	
	Average/Wet	Dry	Average/Wet	Dry
Municipal	2,000	2,000	15,000	15,000
District 1	2,250	7,500	6,750	22,500
District 64	2,000	2,000	5,000	5,000
Total	6,250	11,500	26,750	42,500

The water demands identified for NECWC members and potential partners and the demands considered by the SPROWG Feasibility Study are not reflective of all the agricultural water demands in the lower South Platte basin. The Technical Analysis and Update to the Colorado Water Plan (or "Technical Update") conducted a comprehensive evaluation of agricultural water demands in the South Platte River basin. The evaluation was conducted using data and models available from the South Platte Decision Support System. The Technical Update found that, on average, agricultural water users experience shortages of over 90,000 AF/year in District 1 and over 20,000 AF/year in District 64 for surface and groundwater uses. In other words, to meet the full irrigation water requirement of crops in Districts 1 and 64 combined, irrigators could use over 110,000 AF/year of additional supply.

The water needs described in Table 4-4 were the focus on the operational planning and modeling conducted for this project. As additional work is conducted by the NECWC to explore potential local and regional partnerships with water users, it is anticipated that water needs will be recharacterized and re-evaluated.

4.3 Exchange Potential

Exchanges are a common and important tool for moving water from a downstream location to an upstream use or diversion location. The NECWC and its members would like to use exchanges as much as possible in their operations to move water efficiently and relatively inexpensively as opposed to conveying supplies via pumping stations and pipelines. However, the ability to conduct exchanges can be impeded by calls that occur between the exchange "from" and "to" locations. In addition, river reaches with low or no flow limit "exchange potential" and the ability to conduct exchanges between an exchange "from" and "to" location.

Exchange potential in the South Platte River was analyzed by the CCGA in their 2011 ATM project completion report (CCGA, et al., 2011) and also by the NECWC in the Organizational Analysis report. The exchange potential analyses were updated to incorporate more recent stream flow, diversion, and call data for the purposes of this report. In addition, the exchange potential data were evaluated in new ways that were not considered in previous reports.

Methodology

The point flow and call analysis tool used to estimate amounts of unappropriated stream flow described in Section 4.1 was used for the exchange potential analysis. The tool uses daily point flow data and call information to determine when exchanges could have been run and how much water could have been exchanged through various points on the river during the historical study period of the tool. Key operating features or considerations in the point flow and call analysis tool with respect to exchange potential are descried below:

- Exchange potential through a diversion structure was 0 AF on days when the water right associated with the diversion structure was calling for water.
- If a diversion structure was not calling, the exchange potential through the structure was calculated to be the physical flow passing the structure minus an allowance for bypass flows that the Division Engineer may be shepherding through the structure (typical bypass flow amounts were provided by the Division Engineer).
- Daily exchange potential between “from” and “to” locations was determined by identifying the minimum flow passing diversion structures between the “from” and “to” locations. If a structure between the “from” and “to” locations was calling for water, the exchange potential was 0 AF.

The reader is referred to the CCGA ATM project completion report for a full description of the tool and data inputs. As noted in Section 4.1, the most recent version of the tool runs over a 20-year period from October 1, 1995 through September 30, 2015.

The exchange potential analyses examined two primary questions:

1. How reliably can water be exchanged in various reaches of the South Platte River?
2. How much water can be exchanged?

The first question was important to understand with respect to operational analyses that focused on member-to-member transactions of unused recharge credits. The operational analyses are described in more detail in Section 5, but a key consideration in the analyses was the frequency with which various diversion structures may impede exchange via calls or their diverting the entire flow of the river (especially during low flow conditions). Member-to-member exchanges through a stream reach with intervening diversion structures that dry the river will diminish the reliability of those exchanges.

The second question was an important consideration when evaluating operational scenarios that include infrastructure that could be used to manage exchanges. Again, these operational scenarios are described in greater detail in Section 5.

Reliability of Exchanges

The reliability of exchanges was evaluated by identifying and summing the number of days each year that diversion structures along the South Platte River placed a call or otherwise dried the river. The analysis focused on the irrigation season when direct flow water rights are typically used (generally, from April through the end of October) and the storage season (from November to the end of March).

Figure 4-4 shows the results of analyses focused on the irrigation (or direct flow) season. The annual average number of days a diversion structure dried the river is shown as well as the maximum and minimum number of days. Note that the maximum and minimum number of days a diversion structure dried the river are not necessarily associated with the same year for all structures. Information from water year 2013, a particularly dry year until the last half of September, is presented in Figure 4-4 to illustrate drought conditions. Data from 2002 to 2015 were considered in this analysis, which reflects a recent and representative time period when water administration in the South Platte basin was more comprehensive and transparent.

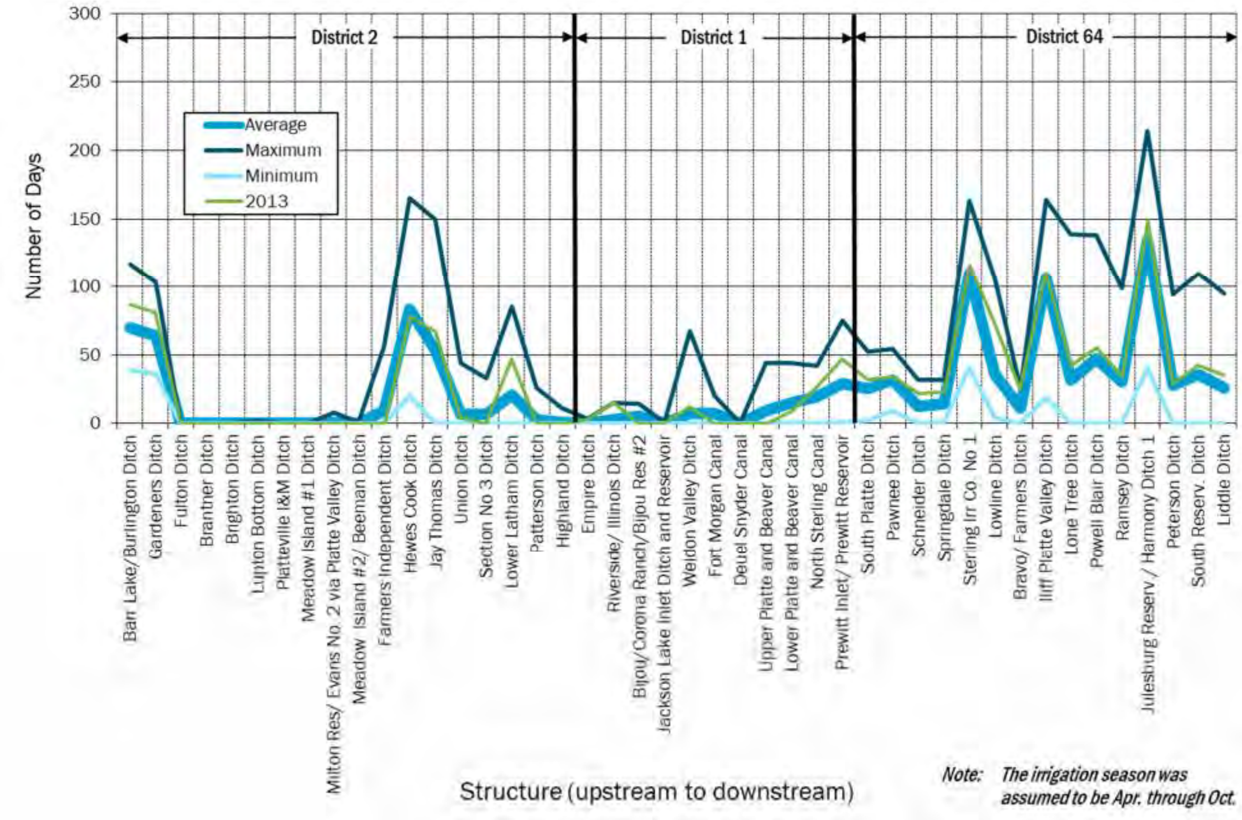


Figure 4-4. Number of Days per Irrigation Season when Exchange Not Possible through Various Diversion Structures in the South Platte River, 2002 to 2015

Observations on Figure 4-4 include:

- Most of the diversion structures on the South Platte River impede exchange for at least a few days each year.
- Structures such as the Hewes Cook Ditch, Sterling No. 1, Iliff and Platte Valley Canal, and Harmony Ditch impeded exchange for a period of time during the irrigation season in every year of the analysis. On average, these diversion structures impeded exchange from around 80 (Hewes Cook Ditch) to 130 days (Harmony Ditch) on average during the irrigation season.
- The only segment of the South Platte River with no significant impediments to exchange during the analysis time period is upstream of the Farmers Independent Ditch to the Fulton Ditch.
- In many segments of the South Platte River, diversion structures dried the river relatively infrequently during the irrigation season. However, the days of dry-up and resulting impediment to exchange reduce the potential reliability of exchange through those river segments.
- During most of water year 2013, stream flows were low, and Figure 4-4 indicates that several ditches dried the river and would have impeded potential exchanges.

Figure 4-5 shows the number of days during the storage season when various diversion structures dried the South Platte River during water years 2002 through 2015. Average, maximum, and minimum data are presented along with conditions in 2013.

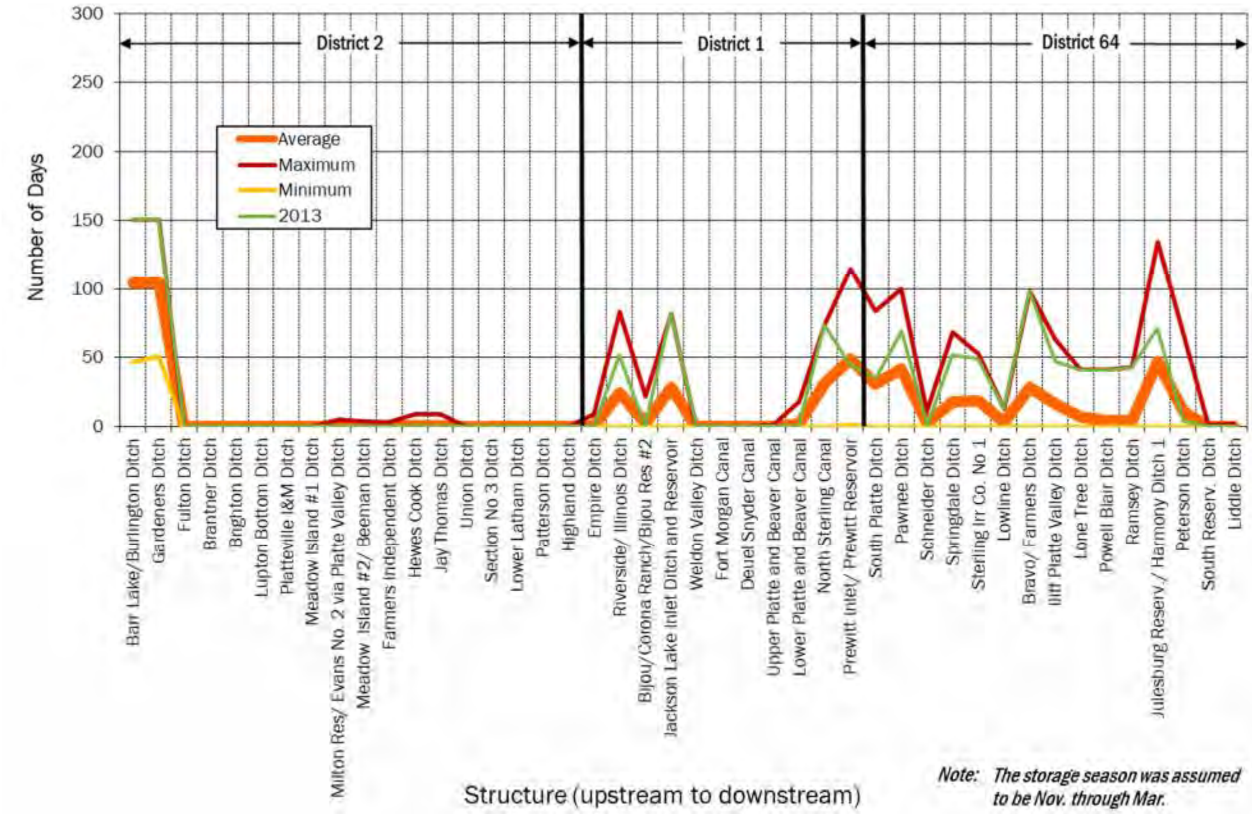


Figure 4-5. Number of Days per Storage Season when Exchange Not Possible through Various Diversion Structures in the South Platte River, 2002 to 2015

Observations on Figure 4-5 include:

- Storage season exchange impediments during 2002 to 2015 storage seasons were fewer in District 2 than Districts 1 and 64. During the study period, most ditches from the Highland Ditch upstream to the Fulton Ditch did not place a call in the storage season.
- Diversion structures that fill reservoirs such as Riverside, Jackson Lake, North Sterling, Prewitt, and Julesburg created exchange impediments during the storage season. The North Sterling and Prewitt diversion structures are close to one another and create the most significant impediment to exchange during the storage season with an average combined total of 80 days per season when they are calling for water.
- Diversion structures at ditches with recharge rights, such as the South Platte Ditch, Pawnee Ditch, and others created periodic exchange impediments.
- During the dry conditions of 2013, nearly all of the ditches from the North Sterling Canal downstream to the state line impeded exchange for at least part of the storage season.

In summary, the data shown in Figures 4-4 and 4-5 indicate that most ditches would have impeded exchange either on a regular basis or periodically. The ability to conduct exchanges in different parts of the river changes on a seasonal basis and can vary greatly depending on hydrologic conditions. Exchanges could be conducted with 100 percent reliability throughout the year or on a seasonal basis in very few locations on the South Platte River. While various diversion structures may impede exchange during some parts of the year, exchange potential may be available during other parts of the year. An analysis of overall exchange potential through diversion structures was conducted to investigate the potential to conduct exchanges if the timing of exchanges could be controlled.

Volume of Exchange Potential

The point flow and call analysis tool was used to evaluate the daily volume of exchange potential through each diversion structure on the South Platte River from the Burlington Ditch headgate to the stateline. As described previously, if a diversion structure was calling or otherwise drying the river, the exchange potential at that structure was 0 AF. If a diversion structure was not drying the river, the exchange potential was calculated as the physical flow passing the diversion structure minus bypass allowances. Daily exchange potential data were summed annually by water year. The following are additional considerations on the exchange potential analysis:

- The analysis does not consider existing conditional exchanges that may be fully utilized in the future. Conditional exchanges that were fully or partially implemented in the 2002 to 2015 timeframe are reflected in the data.
- Some evaluations of exchange potential conducted for the NECWC did not consider exchange potential at various diversion structures during free river conditions. This analysis incorporated days of free river to help illuminate the full potential to move water over the study period.

Figure 4-6 shows the results of the exchange potential analysis. To convey the variability of exchange potential, each year of the analysis (2002 to 2015) is shown in the figure, and years with the highest (2015) and lowest (2004) exchange potential are highlighted. Average exchange potential through each diversion structure is also shown.

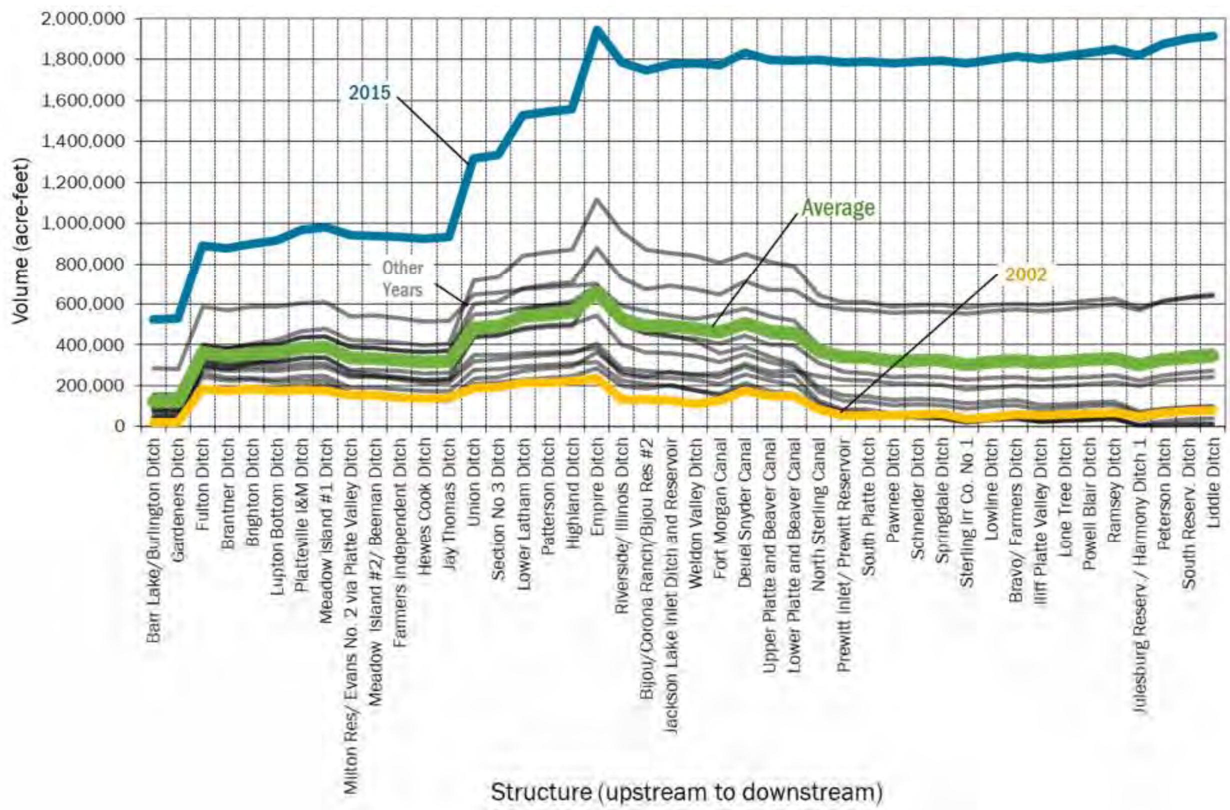


Figure 4-6. Yearly Volume of Exchange Potential Through Various Diversion Structures in the South Platte River, 2002 to 2015

Observations on Figure 4-6 include:

- Exchange potential along the South Platte River generally increases from Denver to the confluence with the Cache la Poudre River, where exchange potential peaks. Downstream of the Cache la Poudre River, exchange potential diminishes slightly but holds relatively steady after the North Sterling Canal and Prewitt inlet diversion structures.
- The trends and pattern of exchange potential from upstream to downstream river segments in Figure 4-6 are similar to the pattern of available free river shown in Figure 4-2, especially in years with higher flows and relatively fewer calls. Both exchange potential and free river are dependent on river flow and the presence of calls. In wet years with very few calls, exchange potential at each diversion structure was very similar to the physical flow and free river passing each structure. In dry years when calls were frequently administered, free river was minimal to non-existent, but exchange potential (while relatively low) still existed upstream of senior calls.
- Exchange potential is highly variable from year to year.
- In general, exchange potential exists at every diversion structure in the river. In average conditions, over 300,000 AF/year of exchange potential was available at every diversion structure from the Fulton Ditch to the state line.
- During dry years, such as 2002, exchange potential was present periodically at nearly all of the diversion structures, but it was greatly diminished overall, especially in District 64.
- Existing conditional exchanges, if implemented, would likely decrease the amount of available exchange potential. The degree to which conditional exchanges will be implemented is currently unknown. The SPROWG Feasibility Study considered this and assumed that 300 cfs of future exchange potential could be taken by existing conditional exchanges. If that occurs, over 200,000 AF/year of potential for new exchanges could be eliminated. It is likely that effects of implementing existing conditional exchanges would be most significant during drier periods when exchange potential is lowest.

Summary of the Exchange Analysis

As stated previously, most diversion structures during the 2002 to 2015 time period would have impeded exchange either on a regular basis or periodically because of calls or diverting the entire flow of the river. The analysis suggests that exchange potential in most segments of the river may not be 100 percent reliable under all conditions. However, the data in Figure 4-6 shows that at least some exchange potential existed under nearly all conditions throughout the South Platte River, and under average conditions, significant amounts of exchange potential existed. Implementation of existing conditional exchanges could diminish the exchange potential observed during the 2002 to 2015 time period. The operational planning analyses described in Section 5 considered these factors when developing operational scenarios for the NECWC.

4.4 Assessment of Infrastructure

The NECWC identified and conducted limited investigations into existing and proposed infrastructure that could potentially be used to help manage water supplies. The identification of infrastructure occurred over the course of several NECWC planning meetings involving the Board of Directors and consultants. During the meetings, existing and proposed infrastructure were marked on base maps of District 1 and 64. The identified infrastructure was based on NECWC board member and consultant knowledge of the basin. The maps of infrastructure were reviewed and revised periodically during the project.

Figures 4-7 and 4-8 show existing and proposed infrastructure that were identified. Infrastructure included recharge facilities, off-channel reservoirs, reservoirs located on tributaries, pumping stations, and pipelines. Figure 4-7 shows infrastructure in District 1 along with the geographic span of the augmentation plans that are members of the NECWC. Figure 4-8 shows similar information focused on District 64.

The NECWC Board of Directors and consultants discussed potential benefits and issues associated with the use of existing and proposed infrastructure. In addition, consultants contacted some of the owners of existing infrastructure to explore the possibility of joint usage. Below is a summary of these discussions:

- Some owners of infrastructure were willing to explore potential partnerships with the NECWC and coordinated usage of infrastructure. Some were not interested at this time.
- Owners of existing infrastructure would likely have the first priority of infrastructure usage and may use the infrastructure to its full capacity. As a result, the NECWC may not be able to utilize the capacity of existing infrastructure when it would be most advantageous for retiming available supplies or delivering supplies to members.
- Use of existing infrastructure may be costly due to rising pumping costs.
- Water rights issues and decrees would need to be carefully considered when evaluating joint usage of infrastructure.
- Several existing and proposed recharge and storage facilities were identified in District 1 and in locations upstream of many NECWC members. From an operational perspective, facilities located upstream could be advantageous and offer the potential to release supplies to meet downstream demands, which could be done more reliably than exchanging downstream supplies to meet upstream demands.
- Infrastructure was identified that is located within the stream reaches impacted by many NECWC member augmentation plans. This infrastructure could be used to temporarily store supplies with the intent of exchanging supplies upstream when exchange potential exists. In addition, this infrastructure could be used to deliver supplies to meet the needs of adjacent NECWC members or partners in a way that minimizes transit losses.

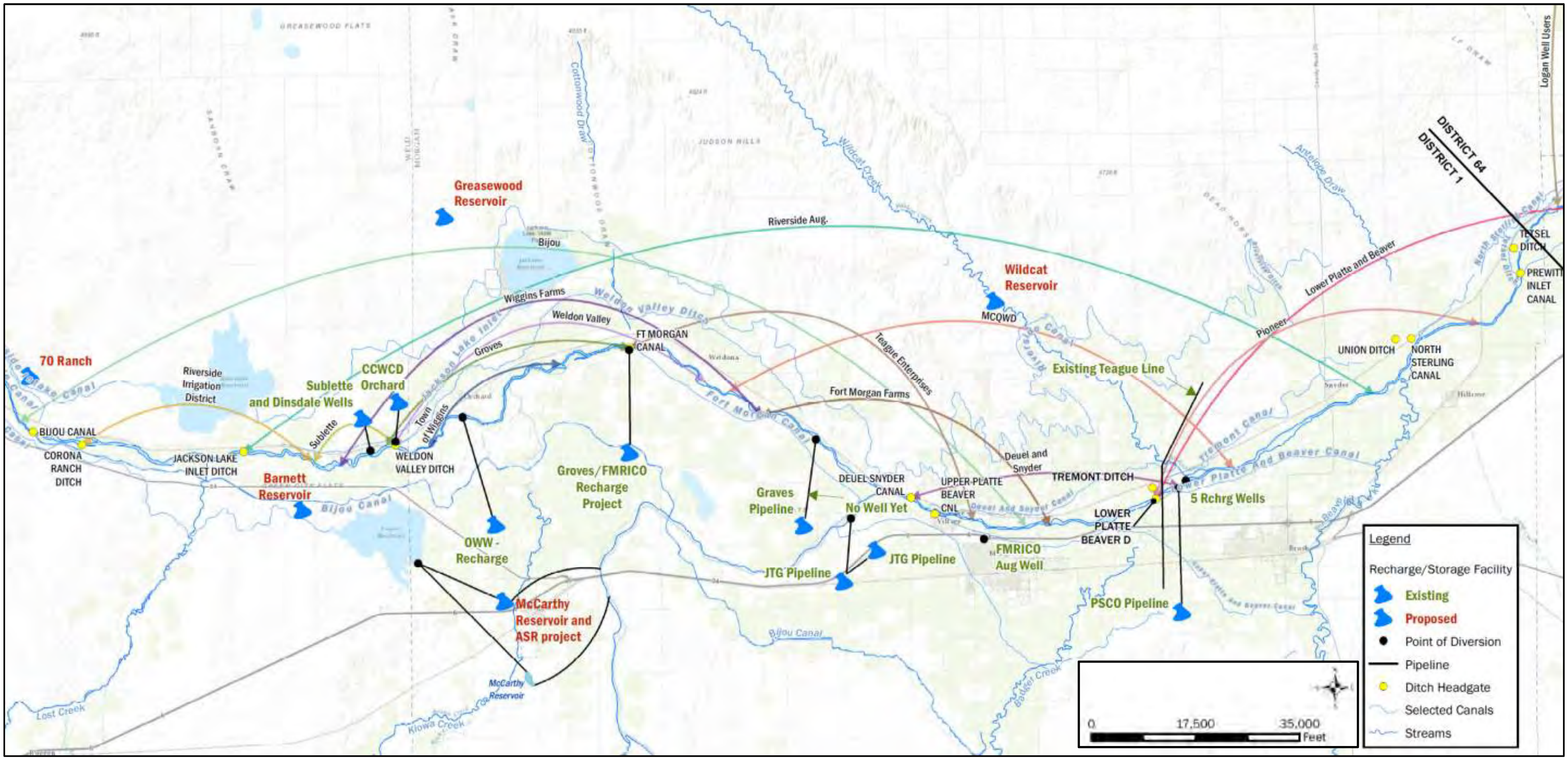


Figure 4-7. Existing and Proposed Infrastructure for Consideration by the NECWC in District 1

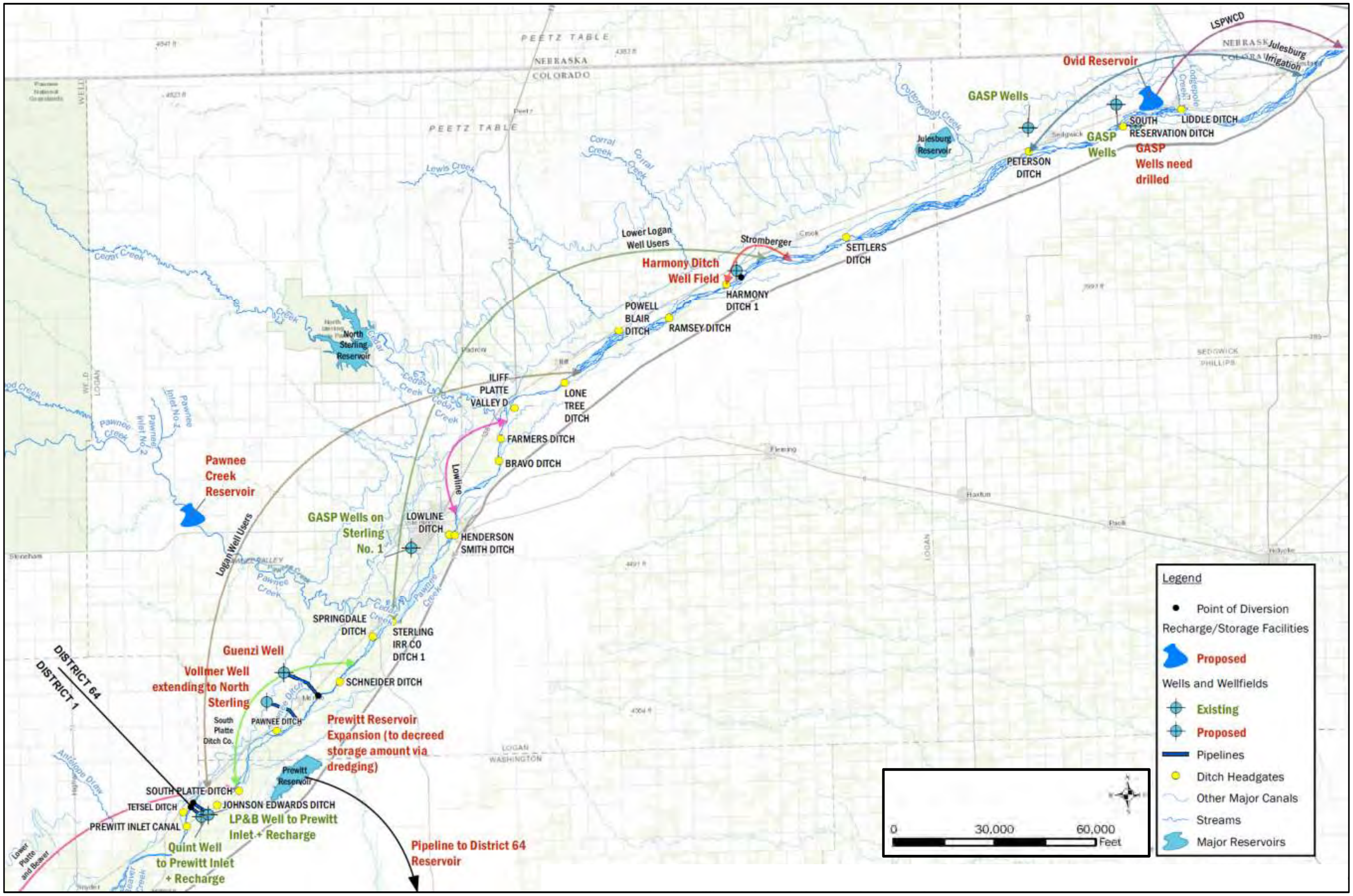


Figure 4-8. Existing and Proposed Infrastructure for Consideration by the NECWC in District 64

Section 5

Operational Planning and Modeling

Operational planning was a focus of this project from its initiation and was conducted using a variety of tools. Initial operational planning considered conceptual scenarios involving various types and amounts of infrastructure. The initial operational planning gave the NECWC a general understanding of the operational alternatives and possibilities that could be explored. After initial planning, more detailed planning was conducted in two phases. Phase 1 focused on member-to-member transactions of unused recharge credits. Phase 2 included the consideration of infrastructure. The objectives of operational planning analyses, tools used to conduct analyses, and results are described in this section.

5.1 Initial Operational Planning

A spreadsheet-based operational planning tool was developed to conduct initial operational planning. The spreadsheet was a high-level, multi-year operational planning tool developed to evaluate potential success and constraints in matching supplies with demands in the NECWC under different hydrologic scenarios and operational strategies.

The planning tool was run on a monthly time step and used input data describing exchange potential, transit losses, potential supplies, potential demands, and infrastructure (hypothetical and existing). The tool assessed supplies, demands, and deliveries and conducted a water balance in five reaches of the South Platte River in Districts 1 and 64. The South Platte River was divided into reaches in order to simplify the planning tool. The reaches were delineated based on exchange characteristics of different segments of the river. The reaches are shown in Figure 5-1.

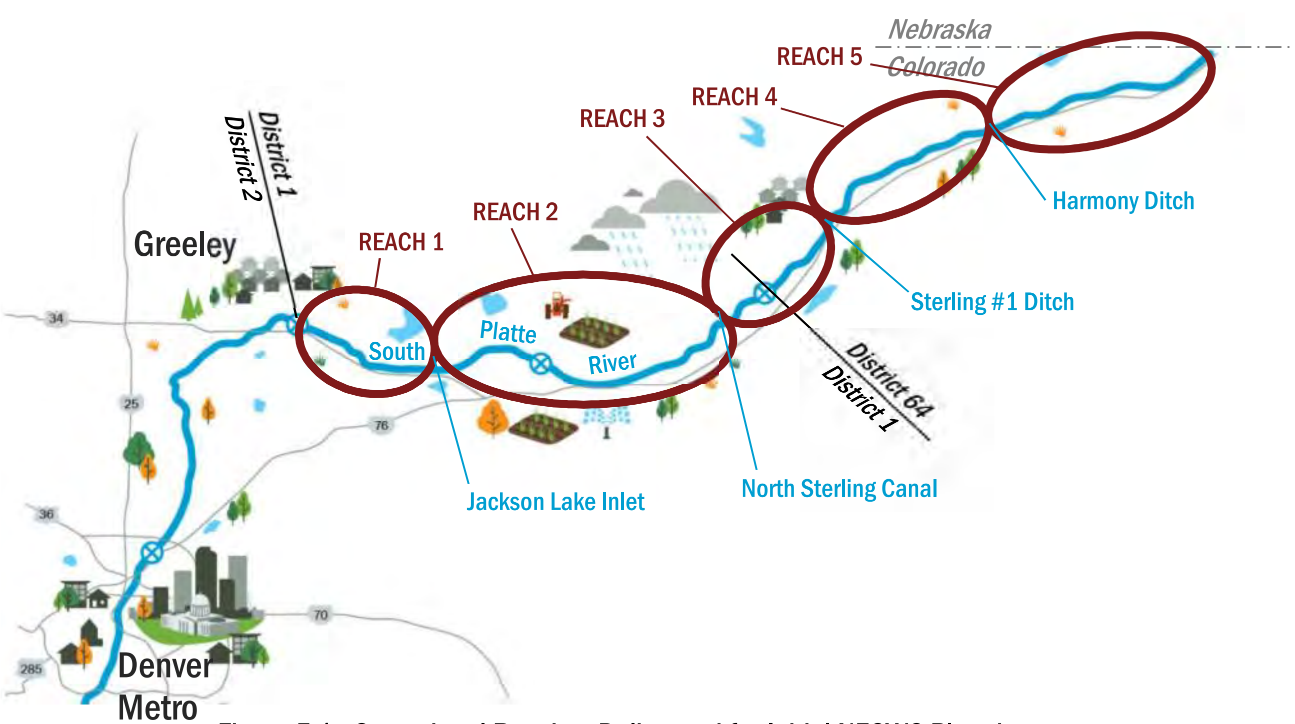


Figure 5-1. Operational Reaches Delineated for Initial NECWC Planning

The tool included the following components:

- A listing of potential supplies in each reach (including supplies passed down from upstream reaches or supplies exchanged from downstream reaches)
- A listing of demands in each reach
- A listing of storage reservoirs and recharge facilities in each reach
- Amounts of water targeted in each reach for exchange upstream or for delivery
- Estimates of transit loss for water passed to downstream reaches
- Functions to allow the user to prioritize the order of supplies used and the order of deliveries (for example, deliveries to in-reach demand were prioritized over deliveries to storage or recharge facilities)
- A summary to assess the amount of demand that was met in each reach

The planning tool was used to evaluate different hydrologic scenarios and operational strategies to successfully meet demands under the scenarios. Figure 5-2 shows an example of the output from the tool:

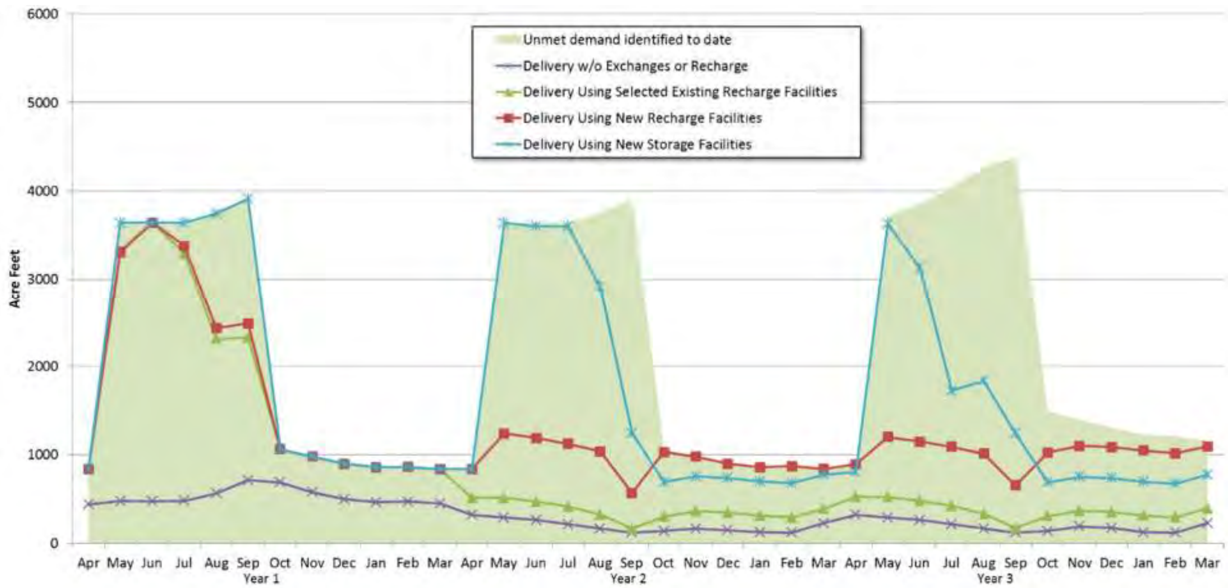


Figure 5-2. Output from Initial Operational Modeling of the NECWC

The modeling led to the following initial findings (which are indicated in Figure 5-2):

- Demands that are currently not being met could be partially satisfied with local member-to-member transactions.
- Demands cannot be fully met without the ability to exchange, store, or retime supplies.
- Demands increase and available supplies decrease during extended droughts. Infrastructure (either new or the ability to use existing) is needed to store or retime supplies during wetter conditions so that demands can be met during drier conditions.
- New recharge facilities with long lag times that retime supplies over several years would be useful for meeting demands during extended droughts.
- During prolonged droughts, unappropriated stream flows are not regularly available. Storage facilities will need to be adequately sized to store a few years of supply if unappropriated stream flows are depended upon to meet demands.

5.2 Phase 1 Operational Analyses

The findings of the initial planning analyses illuminated a range of possibilities and operational alternatives for the NECWC. The NECWC considered the operational alternatives in light of the infrastructure currently available to manage supplies, the legal issues and challenges that would need to be addressed to pursue various alternatives, and the relative benefits of different operational strategies to the NECWC members.

After considering the range of possibilities, the NECWC decided to conduct more detailed analyses of member-to-member transactions of unused recharge credits as a next step. These analyses were described as “Phase 1”. Member-to-member transactions were analyzed (absent infrastructure), because the NECWC anticipated these types of transactions could be more easily pursued in the short term from both an operational and legal perspective. For example, currently the NECWC does not own infrastructure, and it does not have agreements that allow for joint use of existing infrastructure. Member-to-member transactions could be conducted without the use of infrastructure. In addition, these types of transactions between augmentation plans currently occur throughout the basin, and the administrative approval process for these types of transactions is generally well-established.

The Phase 1 operational analysis evaluated the challenges and benefits of member-to-member transactions from the viewpoint of two different scenarios. The first scenario assumed that “Member 1” would lease projected unused recharge credits from “Member 2”, and Member 1 would use the leased credits in its augmentation plan’s April projection. The second scenario assumed that Member 1 would lease unused recharge credits from Member 2 after the April augmentation plan projection is submitted and on a spot market basis.

Phase 1 operational planning focused on the exchange potential analyses and discussions with Division 1 Engineer staff. Without new infrastructure or the ability to use existing infrastructure, supplies associated with member-to-member transactions would need to be delivered by exchange to upstream end users or by stream conveyance to downstream end users. The operational concept of the NECWC is to facilitate deliveries of supplies to an end user in a flexible manner from either upstream or downstream members depending on the members that have available supplies at a given time. As a result, it is important to understand the ability to implement exchanges and the reliability with which exchanges could be conducted. In addition, it is important to identify potential impediments to downstream delivery caused by ditches that may dry the river.

Downstream delivery

To evaluate potential impediments to downstream delivery, the Division Engineer’s Office was contacted, and a meeting was held to discuss the ability to bypass and deliver water through diversion structures along the river. The discussion and results of the meeting are described below:

- Water could be delivered through nearly every diversion structure on the mainstem of the South Platte River from the Burlington Ditch headgate to the state line. However, some improvements may be needed to efficiently conduct bypasses and measure flows.
- At several diversion structures, the bypass strategy with existing facilities would include diverting water intended for downstream delivery, conveying the water for a distance in the irrigation ditch, and returning the water to the river via a downstream spill. This method of bypass could likely result in relatively high losses compared to bypasses at structures that do not require in-ditch conveyance.
- Many diversion structures do not have adequate structures for measuring and administering bypasses. Measurement structures would be needed at these diversion locations to allow the

Division Engineer to administer the bypasses. Telemetry would be useful for monitoring and administering bypasses in real time.

- Some diversion structures already have adequate bypass and measurement structures that are owned by ditch companies. It is possible that the NECWC could use these structures in the future, but agreement terms and conditions and costs of using these structures would need to be negotiated with the owners.

Upstream Delivery

Delivery of supplies to upstream users would require exchanges. Exchange potential was examined in Section 4.3, and the results were described in Figures 4-3 through 4-5. The assessment suggested the following:

- Exchange potential exists throughout the South Platte River.
- Exchange potential is highly variable from year to year and differs geographically and seasonally.
- In nearly all segments of the South Platte River, exchange potential has historically been impacted periodically or regularly by ditches that place a call or otherwise dry the river.

Findings of Phase 1 Operational Analysis

The above conclusions regarding exchange potential and ability to deliver unused recharge credits informed the NECWC's view of Phase 1 scenarios and operations in several ways.

- A spot market may be feasible: The ability to deliver water upstream via exchange and downstream generally exists throughout the South Platte River. Opportunistic and short-term leases of unused recharge credits from a downstream member to an upstream member could occur when exchange potential is present. Leases of unused recharge credits from an upstream member to a downstream member could potentially occur more regularly, but bypass/measurement infrastructure would be needed. In addition, spot market use would depend on the relevant members' water court decrees and other legal use requirements.
- Spot market supplies may be limited in dry conditions: The availability of water on a spot market basis may be limited during extended dry conditions because 1) owners of recharge credits need to use their credits and therefore fewer unused credits are available; and 2) opportunities to divert to recharge and create new future recharge credits are reduced during extended dry periods. In addition, exchange potential tends to diminish during drier conditions, which would limit the ability to move available water from downstream locations of supply to upstream locations of demand for immediate use. This affirms the need for infrastructure that would allow for the diversion and/or exchange of unused recharge credits during average and wet conditions.
- Inclusion of unused recharge credits in a projection is difficult: While exchange potential is generally available, it has historically been interrupted periodically or regularly at nearly every diversion point on the South Platte River. As a result, it may be difficult to ensure that future projected unused recharge credits can be exchanged to a location of demand. Downstream delivery of unused recharge credits would potentially be more reliable, provided bypass and measurement structures are available to ensure that the water could be shepherded past diversions that may dry the river.
- Projectable supplies are more valuable than supplies available on a spot market: Many South Platte River augmentation plans have a projection requirement that balances lagged and projected well pumping depletions against available replacement supplies. Current year pumping is often limited by the ability to augment resulting lagged stream flow depletions that will occur in future years. However, if an augmentation plan can acquire long-term supplies that can be relied upon in future years, it would be possible to pump more in the current year.

Projected unused recharge credits could fulfill a long-term supply need and allow higher levels of current-year pumping if the user could ensure the credits can be delivered to the point of depletion in future years (or in future months during the initial year of the projection). Unless appropriate infrastructure is in place to ensure delivery, the use of available unused recharge credits and potential spot market transactions conducted during or after the irrigation season may not be available in an augmentation plan projection to help increase current-year pumping.

- A group augmentation plan covering Phase 1 operations may face legal/water court challenges: A concept that was evaluated by the NECWC and its consultants is some type of group augmentation plan for the NECWC members that would allow the use of unused recharge credits. Several legal challenges were identified when considering the Phase 1 member-to-member operations. These challenges include the ability to project either: 1) the downstream use of unused recharge credits or the upstream exchange of unused recharge credits, and 2) the notice and timing requirements included in many of the NECWC members' augmentation plan decrees. Based on these issues, the NECWC Board concluded that additional infrastructure and/or the ability to use existing infrastructure would benefit NECWC member operations.

The findings described above were considered by the NECWC Board and discussed with the membership. The group acknowledged that, while a spot market for unused recharge credits could fulfill a partial need, the more valuable types of transactions that include projectable, long-term unused recharge credits would be difficult to implement without infrastructure. The consensus of the NECWC Board and membership was that Phase 1 operations alone did not provide sufficient value given the potential legal challenges and potential risk and expense of pursuing a group Phase 1 operations decree in water court. As a result, the NECWC Board and members decided to investigate Phase 2 operational strategies.

5.3 Phase 2 Operational Analyses

Phase 2 operational analyses expanded the range of supplies considered and explored the potential benefits of infrastructure (either new or existing) to temporarily store or retime supplies and make them available to meet future demands. Phase 2 operational concepts included storing available supplies at a downstream location and exchanging those supplies to upstream storage when potential is available. Supplies located upstream could then be released and delivered to meet downstream demands. In addition to unused recharge credits, unappropriated stream flows and ATMs were evaluated as a source of supply that could potentially meet currently unmet demands in Districts 1 and 64.

The Phase 2 analyses considered a hypothetical operational concept that included storage and recharge infrastructure. The point flow and call analysis tool was adapted for use in Phase 2 operational analyses to evaluate the benefits of different alternatives with respect to infrastructure.

Several functions and inputs were incorporated into the tool to simulate Phase 2 operations. The new functions and inputs are summarized below:

- Unused recharge credits: Monthly time series of unused recharge credits quantified for NECWC members were included in the tool. Because only a few years of unused recharge credits have been quantified, representing only a snapshot of hydrologic conditions, the analysis incorporated variability of unused recharge credits based on variability of river flows. The analysis assumed that the amount of available unused recharge credits would generally correlate to flows in the South Platte River at Kersey. In dry years, which included 2002, 2004, 2006, and 2012, the analysis assumed no unused recharge credits were available. In average and wet years, the amount of available unused recharge credits was assumed to be proportional to the annual percentile of South Platte River flows at Kersey based on long-term flow records at that gage.

- Augmentation demands: Demands for augmentation supplies were incorporated into the tool. Demands were identified in Reaches 1 and 2 depicted in Figure 5-1. Demands were broken down on a monthly basis and varied in dry and average years. In wet years, which included 2007, 2010, and 2014, augmentation demands were assumed to be 0 AF.
- Reservoir operations: Reservoir operations and accounting were incorporated into the tool. Daily inflows, outflows, evaporation, and storage amounts were included.
- New recharge operations: Operations of new recharge facilities were incorporated into the tool. Daily inflows and lagging factors were included. It should be noted that these recharge facilities were assumed to divert primarily unappropriated supplies under a new water right and are in addition to recharge facilities currently owned and operated by augmentation plans and that periodically generate unused recharge credits.
- Exchange bypasses: The Sterling #1 and North Sterling Canal diversion structures frequently dry the river and prevent exchange. The tool assumed that at these locations, a pumping station and pipeline would be used to enable exchanges by pumping available supplies from below each of the diversions and into the respective ditches. The tool assumed that available supplies would be pumped into the ditches at a certain rate and a like amount of water could then be diverted via exchange farther upstream.
- Operational decision making: The tool was enhanced to allow the user to specify priorities for meeting demands and managing supplies. For example, if unused recharge credits were available to meet a local demand, the credits were used first. If all of the demand could not be met, supplies from storage were released to meet the demand.

The enhanced point flow and call analysis tool was used to simulate NECWC operations with the inclusion of hypothetical infrastructure described in Figure 5-3.

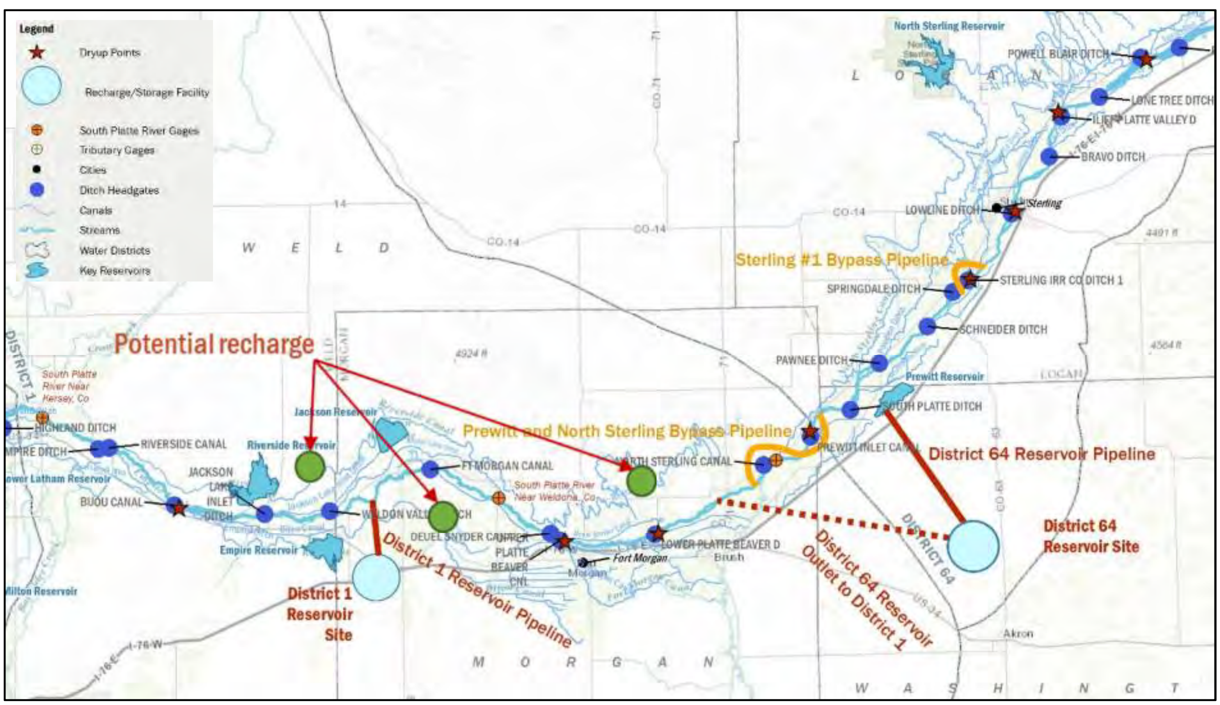


Figure 5-3. Assumed Infrastructure in Phase 2 Operational Analyses

Characteristics of the hypothetical infrastructure included in the operational concept described in Figure 5-3 are summarized below. It should be noted that the locations of infrastructure in Figure 5-3 are hypothetical, but the storage concepts are currently being studied. In fact, an application was recently filed by Parker Water and Sanitation District and the LSPWCD for water rights associated with a water supply project that includes components analogous to (but not the same as) the District 64 Reservoir Site shown in Figure 5-3.

- Storage facilities are located near the upstream ends of Districts 1 and 64. Each reservoir was assumed to have a storage capacity of 30,000 AF (for a total storage capacity of 60,000 AF). In the model simulations, releases from the District 1 reservoir were made first to meet demands, followed by releases from the District 64 reservoir.
- The intake capacity of each reservoir was assumed to be 150 cfs.
- Supplies stored in the District 64 storage facility could be released to District 64 or could be released upstream of the North Sterling Canal diversion structure and be exchanged to upstream demands, recharge facilities, or storage in District 1.
- New recharge facilities were located in District 1. The analysis considered intake capacities for recharge facilities of 100 cfs and 150 cfs.
- The new recharge facilities were assumed to be in locations that would create long-term recharge credits with SDFs of 1,470 days.
- The analysis assumes that, if recharge credits are available from the new recharge facilities, they would be used first, followed by unused recharge credits generated by member plans.

The operational concept was simulated using the enhanced point flow and call analysis tool under two scenarios. The first scenario did not consider recharge facilities and was only focused on the potential benefits of the District 1 and 64 reservoirs. The second scenario incorporated recharge facilities assuming both 100 cfs and 150 cfs diversion capacities.

Figure 5-4 shows the results of the first scenario. The figure shows simulation results for the years 2000 through 2014. It combines information on the total amount of demand, which is defined as the amount of augmentation water demands that are currently unmet or unmet in dry conditions. The total amount of demand is represented by the total height of the columns in each year. End of month storage in reservoirs is depicted with lines to provide an understanding of how reservoirs are used to meet demand. The source of supply used to meet demands is represented by the different segments of color on each column. The amounts of demand that were left unmet are indicated by the gray shading on each column.

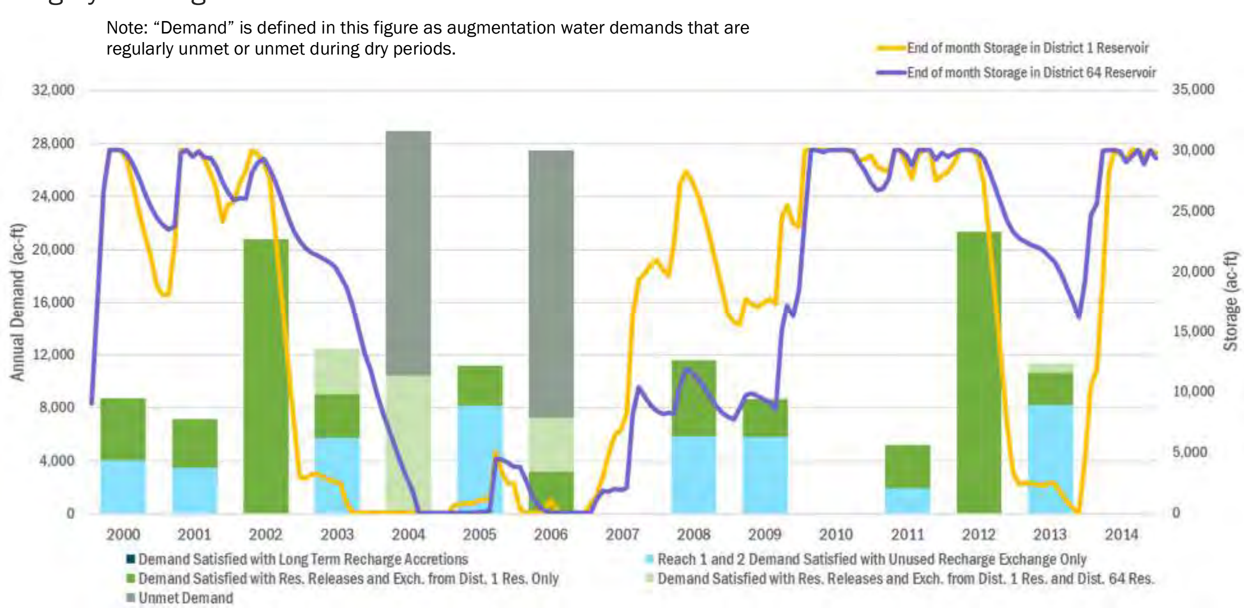


Figure 5-4. Simulation of Phase 2 Operational Concept with No Recharge Deliveries

The following are observations on the operational concept simulation shown in Figure 5-4:

- Years 2000 and 2001
  - Demands are fully met with a combination of unused recharge credits and reservoir releases.
  - Sufficient unappropriated supply and unused recharge credit was available to refill reservoirs each year.
- Years 2002 through 2006
  - Drought conditions during the early 2000s reduced the available unused recharge credits and unappropriated supply.
  - In 2002, no unused recharge credits were available, and demands were met solely from reservoir releases. Available supplies to refill storage were limited, and storage did not recover.
  - During the 2003 to 2006 timeframe, some unused recharge credits were periodically available and limited amounts of unappropriated supplies were stored, but the volume of demand was more than the amount of available supply. Water in storage was depleted, and not all of the demand could be met in 2004 and 2006.
  - The demands that were not met in 2004 and 2006 could potentially be met with ATMs. Using ATMs after other sources of supply are exhausted is consistent with the desired role of ATMs expressed by NECWC members and other agricultural water users along the South Platte River.
- Years 2007 through 2011
  - Hydrologic conditions turned wetter in 2007 through 2011, which lessened demand.
  - Wetter conditions and increased available unappropriated supplies and unused recharge credits allowed storage facilities to recover. All demands were met during this period.
- Years 2012 through 2014
  - Hydrologic conditions in 2012 turned very dry. Available supplies to meet demands were limited and demands were simulated to be relatively high.
  - Demands in 2012 were solely met from water in storage.
  - Much of 2013 was dry, and unappropriated supplies were generally unavailable for storage until flooding conditions occurred in September 2013. Unused recharge credit was simulated to be available to meet demands. Demands were also met from storage releases.
  - Hydrologic conditions were wetter in 2014, which allowed reservoirs to recover.
  - All demands were met. Storage releases were essential for meeting demands.

In summary, the infrastructure included in the first scenario of the operational concept was very useful in meeting demands under a variety of hydrologic conditions. However, in two years, demands were not fully met because the overall volume of demand during the drought of the early 2000s was greater than the amount of water that could be provided from available supplies, including water in storage.

The second scenario built on the first scenario by adding recharge facilities. Figure 5-5 shows the results of the second scenario. The data in Figure 5-5 represent results with 150 cfs of capacity to deliver water to recharge.

Results with 100 cfs of recharge diversion capacity were also generated, but the results were similar to those shown in Figure 5-5 but slightly less favorable due to smaller amounts of new long-term recharge credits available to meet demands. In the scenario with 100 cfs of recharge capacity, a slightly greater proportion of demand was met with new long-term recharge credits (as opposed to unused recharge credits available from member augmentation plans), and demands were not fully met in both 2004 and 2006.

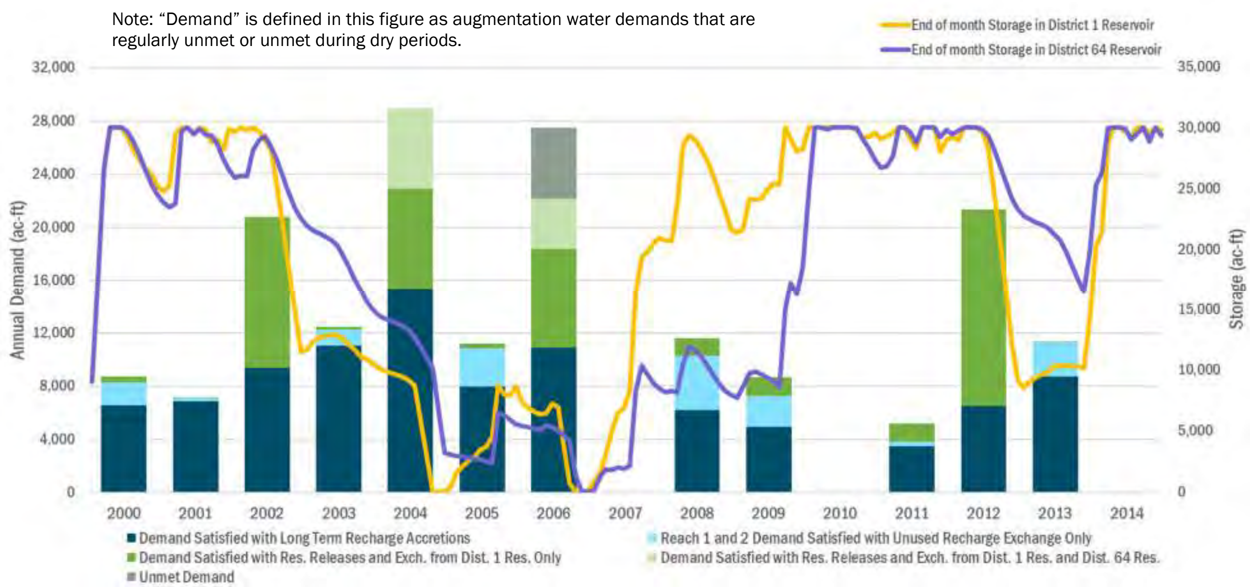


Figure 5-5. Simulation of Phase 2 Operational Concept With Recharge Deliveries

The following are observations on the operational concept simulation shown in Figure 5-5:

- Credits from new recharge facilities with long-term lags were a significant source of supply throughout the simulation.
- Stored supplies in reservoirs were important for meeting demands during drought periods when other supplies were not available and demands were higher.
- The drought of the early 2000s created conditions in which demands were greater than supplies, similar to the first scenario. However, unlike the first scenario, the availability of credits from new recharge facilities helped meet demands, and more water could remain in storage to meet higher demands in 2004 and 2006. Even with the additional supply from new recharge facilities, demand was not fully met in 2006.
- ATMs could be used to meet remaining demands when supplies from other sources are not available during drought years.
- An additional model simulation was conducted to evaluate the amount of storage needed to fully meet all demands in all years included in the study period. A total storage capacity of 85,000 AF split between the two assumed reservoirs in the second scenario was required to meet all of the demands shown in Figure 5-5.

5.4 Conclusions from Operational Analyses

The initial, Phase 1, and Phase 2 operational analyses were very valuable to the NECWC. Through the analyses and subsequent discussions, the NECWC determined that infrastructure is needed to better manage water supplies available to District 1 and 64 water users. While spot markets and member-to-member transactions can play a role in optimizing the use of available supplies during wet and normal times, the periods when supplies are most needed (dry times) are when no supplies are available. Infrastructure is critical for retiming supplies during wet and average hydrologic conditions so that they are available when demands are highest in dry times. ATMs could play a valuable role in meeting demands when available supplies in the river and from infrastructure are inadequate.

Section 6

Summary of ATM Evaluations by Colorado State University

Economic considerations with respect to ATMs were researched by Colorado State University (CSU) as a part of this project. The work focused on on-farm costs associated with ATMs, management programs for ATMs, and economic attractiveness of ATMs among ditch companies along the South Platte River. The work was envisioned to help agricultural producers understand how ATMs can, under certain circumstances, be to their financial benefit. The research was conducted by Larisa Serbina (graduate research assistant), James Pritchett (Professor) and Chris Goemans (Associated Professor), all in the Department of Agricultural and Resource Economics at CSU.

The research was originally proposed under a different grant application, but the CWCB suggested that it be added to the work under this project because the research goals would potentially be consistent with and inform the feasibility study for the NECWC. Specifically, if ATMs can be of financial benefit to producers, then the NECWC could help facilitate or otherwise participate in those transfers in a way that benefits all parties.

Overview of the Research

ATMs are a potential vehicle for creating mutually beneficial water supply arrangements between agricultural water owners and municipal providers or environmental interests. Economic sustainability and profitability of farming operations is a key factor in negotiating the terms of an ATM program. The economic research conducted by CSU focuses on how a producer's profit might change when adopting a crop rotation that includes reductions in consumptive use (CU) for the purpose of leasing the saved CU to another water user under an ATM. Producers need to know how their profits may change under a water-saving crop rotation so that mutually agreeable leases and levels of compensation can be successfully negotiated in an ATM.

The research focused on a representative farm in western Weld County and explored the following considerations:

- Characterization CU reductions under different crop rotations
- Quantification of the expected mean profits under the different crop rotations, the foregone profit compared to a "baseline" scenario (represented by irrigated corn), and the variability of foregone profits
- Comparison of crop rotation profit and opportunity cost frequencies to various risk criteria

The crop rotations considered in the research are illustrated in Figure 6-1 (taken from the project completion report from CSU).

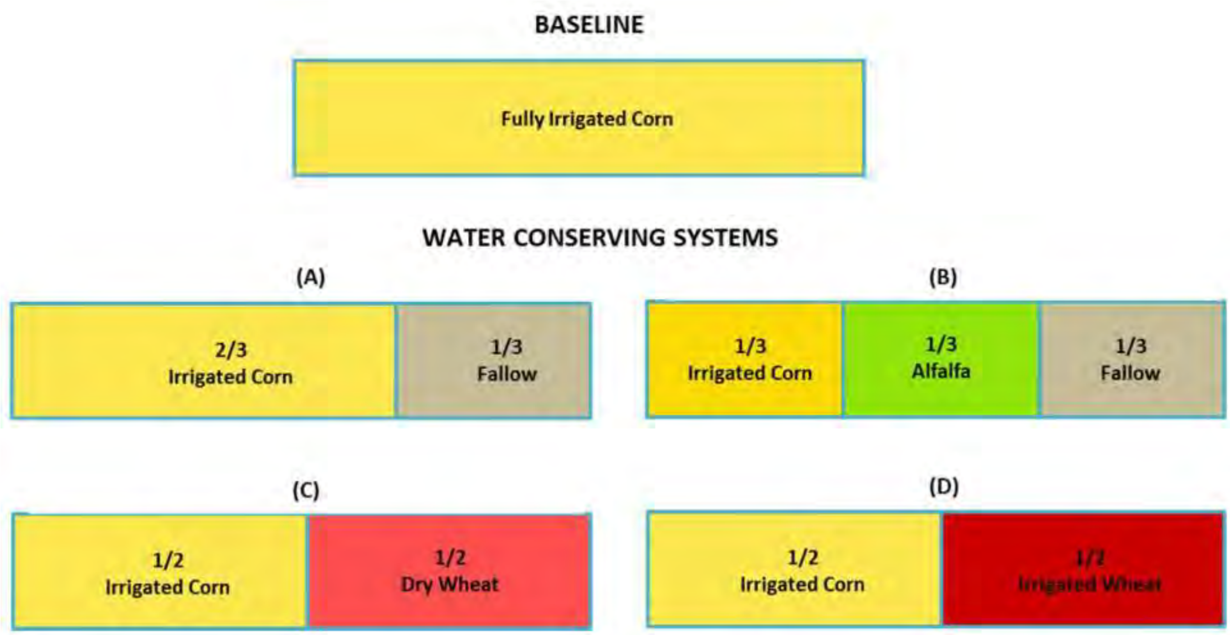


Figure 6-1. Baseline and Water Conserving Crop Rotations Considered by CSU

A summary of the research and results is included in the following abstract from the CSU project completion report. The Executive Summary of the full report is included in Appendix B, and the full report is included in Appendix C. Additional deliverables from this research project include:

- An article published in the May/June 2013 edition of *Colorado Water, Newsletter of the Water Center at Colorado State University* (Volume 30, Issue 3). The Colorado Water archives can be accessed using the following link: https://watercenter.colostate.edu/colorado-water-archive/
- The Master of Science thesis report of Larisa Serbina entitled "Describing and Quantifying Revenue Risk Producers Face When Adopting Water Conserving Cropping Systems", published in the Fall of 2012.

It should be noted that the research did not include a specific analysis of the legal and administrative requirements of the types of ATMs being evaluated. The report itself acknowledges this and says:

> *The legal verification of conserved CU is a thorny issue, and transaction costs associated with monitoring, diverting and transferring CU cannot exceed the surplus from leasing arrangements for this institution to exist. Further research and thought are needed in these areas.*

As a result, the reader should keep the above in mind when considering the results of the research. It should be noted that legal and administrative requirements have been the topic of many other research efforts and could be used in conjunction with the CSU research to develop a more comprehensive picture of successfully negotiating mutually beneficial ATM programs.

Abstract from "Completion Report: Opportunity Costs in Water Saving Crop Rotations"

Water leasing contracts may be a viable alternative to 'buy and dry' transactions in Colorado. The purpose of this research is to examine one aspect of leasing: the opportunity cost of farmers who adopt water conserving crop rotations that might be used for leases. Farmers seek an understanding of what crop rotations might be used to conserve CU, and how these rotations influence the farm's profitability and the variability of these profits. This understanding will inform the development of mutually agreeable leases and levels of compensation between farm managers and water suppliers. For those seeking to lease irrigation water, the information will inform their strategic planning for obtaining reliable water supplies.

From a farm manager's perspective, the opportunity cost of switching to a cropping system depends importantly on an expectation of profits, and the expectation includes the potential for low or high profits. In order to gain a better understanding of values that create an expectation, a simulation model is developed to measure the profits of a baseline, irrigated corn cropping system as well as for four other systems that conserve consumptive use water. Prices and yields are allowed to vary in a range and correlation consistent with the historical (1980-2010) data generation process. The simulation leads to a profit frequency for each cropping system that can be compared against one another. Likewise, an opportunity cost frequency is created by calculating the difference between an iteration's profit from the baseline system and the alternative cropping system.

Results suggest a combination of corn and wheat in a cropping system is almost always desirable compared to a fallow system or the corn-alfalfa-fallow system. The result is intuitive – from the crop manager's perspective it is almost always better to crop land than to have it sit idle. It is also true that the system provides some flexibility for the crop manager and the contracting leaser in a water conserving agreement – the wheat crop can be planted and irrigated as the water year unfolds. If water is needed, the crop remains non-irrigated, but if water is available it can be set to the wheat crop. The water conservation in this simulation ranges from 440 AF of conserved CU in an irrigated corn-wheat rotation to 1,195 AF of CU in an irrigated corn - dryland wheat rotation. In this type of an arrangement, the wheat can act as a drought "reservoir" for the leaser that is adjustable depending on circumstances.

Crop managers are concerned with both the upside and downside potential in alternative cropping systems. Upside potential is the inability to seize the profits in years during which prices are quite high and yields are above average.[1] Downside potential refers to years when profits are quite low because of low prices and/or poor yields. This analysis suggests little difference exists in the cropping systems for downside potential, but substantial differences occur on the upside, and this might make crop managers less likely to sign leases. Payment contingencies might help to alleviate the crop managers' concerns. One alternative is a two-step payment program: the initial, baseline payment, would be paid to the producer when cropping decisions are made in the Fall, and a second payment is made when harvest prices are realized.

Application to the NECWC

The above research will potentially be useful to the NECWC in the future if members seek to use the cooperative to facilitate one or more ATM programs with municipal water providers or other regional partners. Farming is a risky business. While ATMs could be a way to reduce risks associated with farm income variability, they are relatively untested in many parts of Colorado. The research provided by CSU could help quantify the economic risks of enrolling farms in an ATM program by setting compensation levels and developing payment strategies that will lessen the risks and increase the potential that an ATM program would provide an economic benefit to participating irrigators while providing critical water supplies to water providers and lessening the need for traditional "buy and dry" water transactions. As described earlier in this report, facilitating and accounting for leases conducted via ATMs is a service that the NECWC contemplates providing in the future.

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[1] The NECWC and the authors understand the meaning of this sentence is that alternative cropping patterns can negatively impact the ability of irrigators to seize profits when prices and yields are high.

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Section 7

Water Accounting

Accurate water accounting will be a critical short- and long-term need of the NECWC. Early in the project, the NECWC board and consultants discussed the type of data necessary to track and account for water transactions that could potentially be facilitated by the cooperative. Given the ever-changing nature of hydrology, river operations, water demands, and administration, the tool would need to be dynamic and include real-time data and information. The NECWC and consultants thought that, in addition to performing water accounting, an accounting tool could also provide operational insights and aid in decision-making. A list of data and accounting needs was developed and described in the Organizational Analysis report and is summarized below:

- **Call information:** The specific location and priority of calls will be important for evaluating the amount of unused recharge credit that is available and the ability to deliver water via exchange.
- **Locations of supplies and demands:** The specific locations of supplies and demands will be needed from both an operations and accounting perspective.
- **Administrative information:** When leases are conducted and water is “brought into” the NECWC, information on the member plan (or lessor), the type of water being leased (unused recharge credits, ATMs, water from senior irrigation rights, etc.), and other details will need to be provided and recorded.
- **Individual and collective information:** Information collected on individual leases will need to be aggregated for operational purposes.
- **Information on retimed or stored supplies:** If the NECWC leases water and retimes it by delivering water to a recharge or storage facility, the accounting will need to keep track of the amounts delivered, evaporative losses, the timing of future stream flow (in the case of recharge), amount in storage, and releases from storage.
- **Information on leases via ATMs:** If the NECWC facilitates leases of water by ATMs, the accounting will need to keep track of amounts of water available, the potential to deliver the water, and the amounts of water delivered via the temporary ATM transfer.
- **Operational scenario planning:** The NECWC manager or accountant may need to evaluate various alternative delivery scenarios if NECWC is trying to conjunctively manage multiple supplies and demands at a point in time.
- **Consumable, real-time data:** A “dashboard” of important, real-time information will provide the manager or accountant useful and consumable information to aid in decision-making.

A water accounting tool (or “Accounting Tool”) was created to meet the accounting and operational planning objectives described in the Organizational Analysis report. The tool was built in Microsoft Excel and uses a wide variety of macros to acquire web-based diversion and call data, perform calculations, and display data. It was updated several times during this project, and the NECWC anticipates that it will be updated in the future to reflect new types of transactions and the specific needs of members and other partners.

7.1 Accounting Tool Description

Figure 7-1 provides a high-level description of the data the Accounting Tool considers and the operations/transactions that it can track and facilitate. It is currently configured to track and manage member-to-member transactions of unused recharge credits or deliveries from storage or recharge facilitates. The Accounting Tool imports and considers real time data to enable the user to manage and track several different operations, as depicted in Figure 7-1.

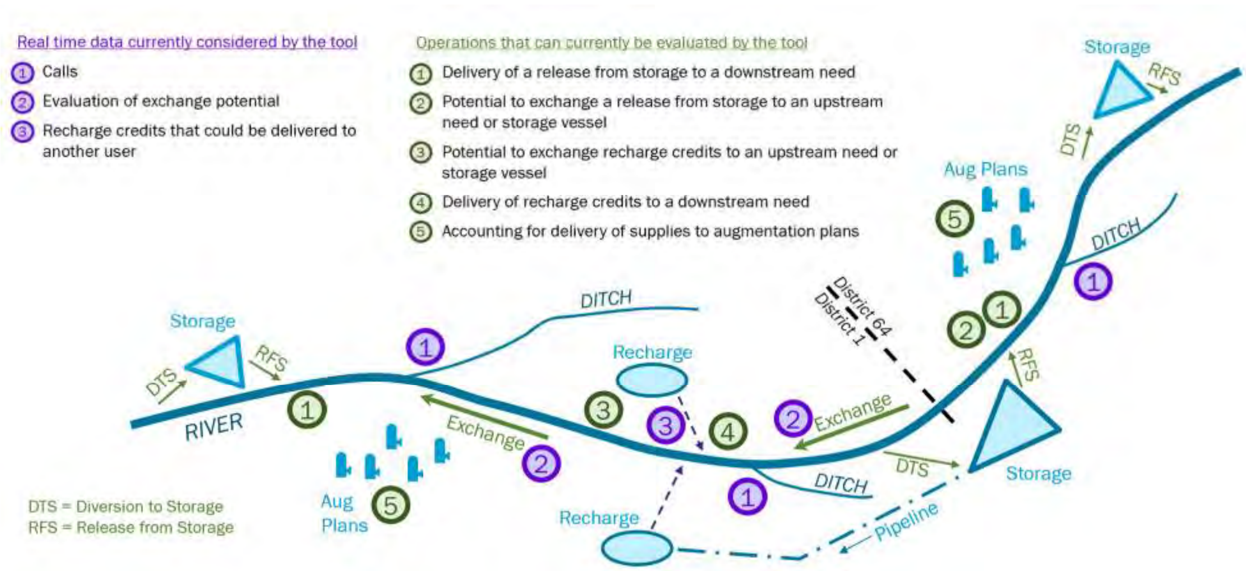

Figure 7-1. Schematic of Current Accounting Tool Functions

Available unused recharge credits and call data are key inputs to the Accounting Tool. Information describing the location and amount of water NECWC members or others would like to make available for lease would be provided by potential lessors, and information regarding potential water needs would be provided by potential lessees. Call information can be imported into the Accounting Tool on a real time basis and allows the tool to identify the ditch diversion structures that may be impeding exchange.

The tool uses call data to evaluate how far water supplies could be exchanged. It also evaluates how far down the river the supplies could be delivered based on the capacity to bypass flows past diversion structures that dry the river. For downstream deliveries, the Accounting Tool accounts for transit losses. While the current Accounting Tool has a focus on transactions involving unused recharge credits, it can manage and track deliveries from ATMs and storage or recharge facilities in similar ways.

The Accounting Tool identifies calls and dry up points on a real time basis giving the user the ability to make efficient and sound water management decisions

Additional features are being considered for the Accounting Tool, many of which are described later in this section.

7.2 Accounting Tool Structure and Functionality

As described previously, the Accounting Tool was created in Microsoft Excel. The tool uses macros to perform a wide variety of calculations and data management functions as well as obtaining on-line, real time call data. Input data, water transaction information, and water management information are organized in different series of tabs in the Excel workbook:

- Input data: Input data tabs allow the user to enter information that affect water management, such as bypasses, transit losses, exchanges, and calls (which can be updated automatically). A tab is also included for entering contact and other management-related data pertaining to augmentation plans and water users that conduct transactions through the NECWC.
- Operational data: The tool includes several tabs and data tables describing operational data such as the amount of water available for lease at various locations along the South Platte River, the potential to exchange water upstream, and summary operational information that is used by the Control Panel (see further description of the Control Panel later in this section).
- Transaction tracking: The tool includes a form for inputting data related to proposed water transactions and several tabs that track and account for water transactions for each augmentation plan or individual that leases water through the NECWC.

The user of the Accounting Tool can enter information on proposed water transactions from lessors as they are submitted. In addition, the user can enter information on the capacity of bypasses at diversion structures, known dry up points, and transit losses to evaluate delivery opportunities and constraints. Call data, as described previously, can be updated on a real time basis. With this information, the user can evaluate and make efficient decisions regarding the potential to exchange water upstream or deliver water downstream. If the tool indicates that water could be delivered from a lessor to a lessee, the transaction can be completed, and the tool would record the transaction. Daily operations and transactions can be saved by the user, and the resulting water accounting can be submitted to the Division Engineer.

7.3 Operations Control Panel

The Accounting Tool includes an operations Control Panel, which is a key decision-making aid for the user of the tool. Figure 7-2 shows the Control Panel. The Control Panel consolidates the real-time data in a display that can be used to manage operations and make decisions on potential water transactions. The Control Panel brings together the following information in dashboard format:

- River mile and structures: Diversion structures throughout the river (oriented from upstream to downstream) and the distance between structures.
- Exchange Capacity: The locations of calls and information describing the geographic constraints on exchange.
- Bypass Capacity: The locations and capacity of bypass structures available to deliver water past diversion structures that dry the river.
- Transit losses: The amount of transit loss applied to downstream deliveries.
- CO-OP diversions: The location and amount of water delivered to a lessee.
- CFS Available: The amount of NECWC-managed supply available for lease at each diversion structure along the river.

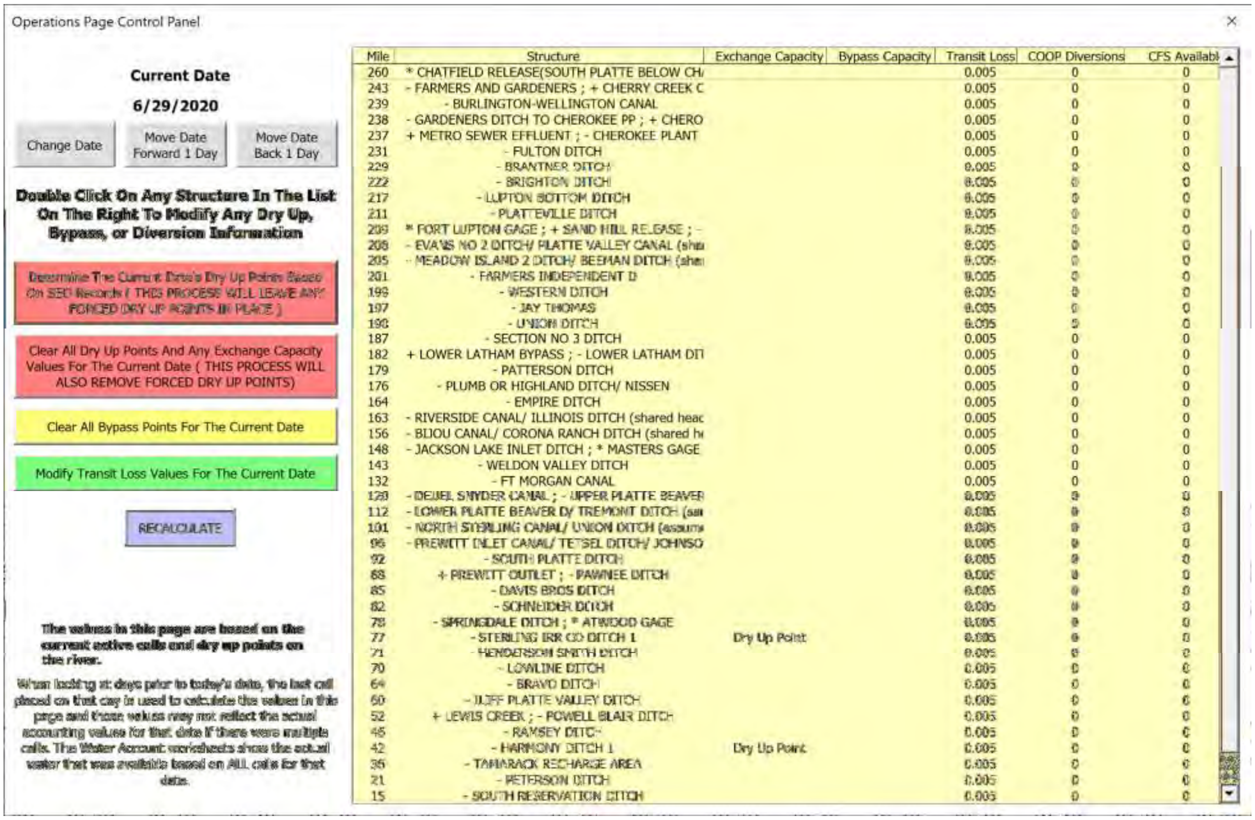

Figure 7-2. Accounting Tool Operations Control Panel

Figure 7-3. Parameter Modification Window

The operations Control Panel also allows the user to run hypothetical operational scenarios by altering some of the inputs without changing the underlying accounting data. The user can temporarily modify parameters such as dry-up status, exchange potential, bypass capacities, and delivery/diversions of cooperative supplies at each diversion structure in the river. The user can make these temporary changes easily by double clicking the diversion structure of interest on the Control Panel and entering the temporary input data (see Figure 7-3 for the parameter modification window). This functionality enables the user to explore a wide variety of delivery options. For example, the user could evaluate different options for delivering water to end users if river flows are diminishing and the user suspects a call will soon be administered at a certain diversion structure.

7.4 Potential Future Accounting Tool Modifications

As described previously, the Accounting Tool is currently configured to track and manage member-to-member transactions of unused recharge credits or releases of water from storage. However, in the future, it is possible that the tool could be expanded to account for the inclusion of recharge or storage infrastructure, owned by others and used by mutual agreement, that is used to retime water supplies and make them available for later delivery to members or other partners. As suggested, it is probable that recharge and infrastructure facilities used to retime supplies will be owned and operated by entities outside of the NECWC (i.e. partners) that will develop and manage their own water accounting data.

Figure 7-4 shows potential modifications that are being considered for the Accounting Tool to account for operations associated with infrastructure owned/operated by partners. The figure shows the same data as Figure 7-1 but adds potential modifications (see notes in red) that could be added to the Accounting Tool.

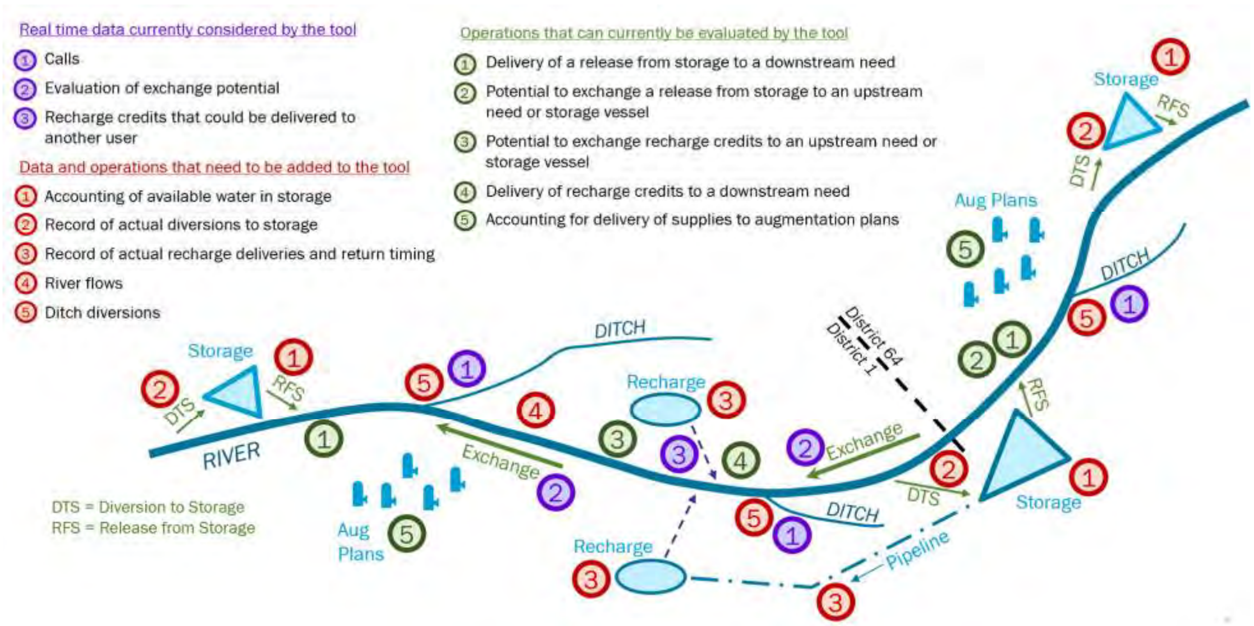

Figure 7-4. Schematic of Potential Modifications to the Accounting Tool

Below is a description of the modifications described in Figure 7-4.

- Accounting of available water in storage: The current Accounting Tool can monitor the ability to deliver water upstream and downstream and track/record transactions. However, the tool does not include information describing the amount of available water in storage that could be delivered to an NECWC member or other end user. The NECWC anticipates that storage facilities used to manage member supplies will likely be owned by others and will have separate accounting tools and requirements. An interface would need to be developed to link the Accounting Tool and the accounting conducted by the owner of the storage facility. With the interface, the Accounting Tool could be used to evaluate the amount of water available for release and the ability to deliver stored supplies to end users and record transactions.
- Record of actual diversions to storage: The current Accounting Tool can indicate how much member water is available for storage in various locations in the river. However, if some amount of available supply is diverted to storage, the tool does not have information describing the actual amount diverted. An interface between the Accounting Tool and accounting conducted by the reservoir owner would be needed to identify and record the actual amount of member supply diverted to storage for future use.

- **Record of actual recharge deliveries and return timing**: Similar to the additional functionality related to storage facilities described above, the Accounting Tool will need to link to accounting for recharge facilities (owned by others) if member supplies are retimed using alluvial aquifer recharge strategies. The Accounting Tool would need an interface with recharge accounting (conducted by others) that describes the actual amount of member water diverted to recharge, and the future timing of when resulting stream flow accretions may be available at the river for exchange or downstream delivery.
- **Real time point flow data:** The Accounting Tool and its Control Panel currently does not display real time diversions or river flows passing each diversion structure along the South Platte River. However, water administration tools have been developed for other purposes that include this type of functionality. The ability of the Accounting Tool to aid in efficient decision making and operational planning could be enhanced by incorporating a display of real time flow data at each diversion structure on the river. Incorporating this type of feature is an important future priority for the NECWC.

The modifications described above will require coordination and data exchange with partners who own and manage infrastructure. Implementing the modifications to the Accounting Tool will require additional functionality to facilitate data flow with potential partners. The potential needed functionality and data flow are illustrated in Figure 7-5.

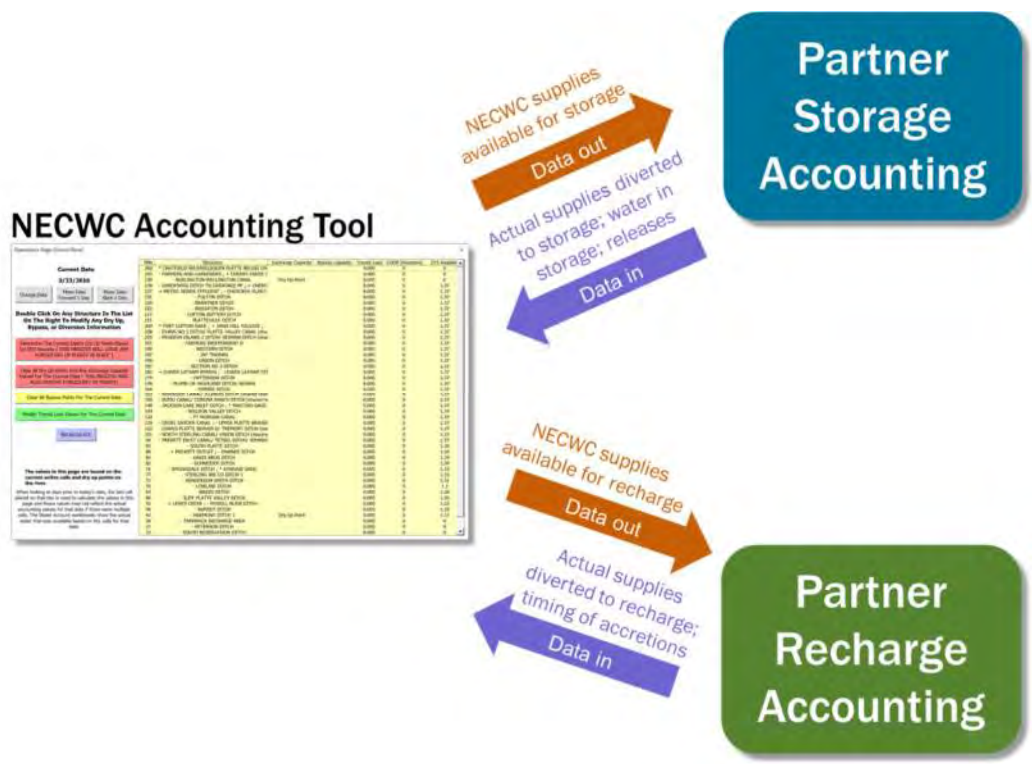

Figure 7-5. Illustration of Data Flow Associated with Potential Accounting Tool Modifications

As indicated in Figure 7-5, when working with partners, the NECWC Accounting Tool will be able to quantify and identify water supplies that could potentially be diverted into partner storage and recharge facilities. However, the partners would need to provide data to the NECWC that describe the actual amounts diverted to storage and recharge and the amount of water available for subsequent use by NECWC members. The Accounting Tool will need information from partner storage and recharge accounting that quantifies the amount of current and future water available to the NECWC that is either in storage or will be available from recharge as stream flow accretions at a future time.

The Accounting Tool will be an important resource for tracking river conditions and making operational decisions

Specific future modifications to the Accounting Tool are not currently known but will be determined through future collaborations with potential NECWC partners. The WaterSMART grant described in Section 1 includes scope and budget for collaborations with potential partners and modifications to the Accounting Tool that result from those discussions. A description of future Accounting Tool modifications (if any) will be provided in the final report for the WaterSMART grant that will be written at the project conclusion.

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Section 8

Implementation Activities

The NECWC has been focused on implementation throughout the course of this project. The focus of implementation activities and analyses evolved during the project based on the different phases of operational planning. Throughout the operational and implementation planning processes, the NECWC Board and consultants continued to meet to review analyses, consider the results and the needs of the membership, and identify next steps and opportunities to facilitate implementation.

8.1 Early Implementation Activities

Conceptual implementation processes were developed during the initial operational planning and formation of the NECWC. Template water sharing agreements were drafted for potential future use. Transactions that do not involve water court approval were identified and discussed with NECWC membership. Due to relatively wet hydrologic conditions that occurred just after the NECWC formed in 2014, no NECWC members proposed transactions during the early implementation phase.

8.2 Phase 1 Implementation Activities

As Phase 1 operational planning analyses were conducted, draft operational protocols were developed, and the Accounting Tool described in Section 7 was created.

The draft protocols for Phase 1 operations were described in a plan developed by the NECWC Board and consultants. The plan was a detailed evaluation of daily operations created to help identify questions that need to be answered, additional processes that need to be developed, and data that need to be acquired to ensure that the NECWC operates in a manner that meets the needs of both members and the Division Engineer, and that it has the appropriate information and ideas for terms and conditions to support a water court application, should the members decide to go that route.

The plan described daily operations by examining how the NECWC would facilitate various types of water transactions among the membership. The document focused on member-to-member transactions as opposed to transactions in which available supplies are stored or retimed for later use by members. The detailed operational processes described in the plan assumed that the NECWC would apply for and obtain a decree for NECWC operations that would authorize the use of member-owned unused recharge credits by other members.

A detailed description of transaction scenarios was provided in the plan to illustrate how the NECWC would operate and conduct water transactions. The contemplated operational plan for member-to-member transactions is summarized below.

1. The member submits a Water Transfer Order to the NECWC.
2. The NECWC sets up the potential transaction based on knowledge of members who could potentially use projected unused recharge credits or other available replacement water.
3. The transaction is included in pre-April 1 NECWC and relevant members' projections or in updated projections during the augmentation year (based on the timing of the request). The projections are provided to the Division Engineer.
4. The transaction takes place.

5. NECWC coordinates with members on their water accounting and provides NECWC water accounting to the Division Engineer.

The protocols included a proposal phase during which a potential transaction is contemplated between members, a verification phase when the NECWC confirms that the supplies are available and can be delivered to the end user, and an implementation phase when the transaction takes place and accounting is developed.

During the creation of the Phase 1 operational plan, several questions and unknowns were identified. For example, it is unknown what kinds of changes may be needed to member water rights and/or augmentation plan accounting. Physical and measurement limitations for delivering water on the South Platte River and internally would need to be identified and rectified. These questions led to some of the analyses that were described in Section 5 of this report.

As described in more detail in Section 5, the potential for successful Phase I operations is enhanced, and potentially relies on, additional infrastructure in the form of storage and recharge locations and in-stream headgate bypass facilities. Absent this infrastructure, the NECWC concluded that the challenges of a group water court application could be significant, and the costs and possible risks to NECWC and its members might outweigh the potential benefits of the Phase 1 operations. Based on its evaluation of the benefits and potential burdens of Phase 1 operational strategies, the NECWC Board of Directors determined that Phase 2 strategies should be investigated. As such, the operational plan for Phase 1 has been placed on hold.

8.3 Phase 2 Implementation Activities

Phase 2 operational analyses illuminated the need for and benefits of storage, recharge, and conveyance infrastructure, many of which were contemplated to be relatively large facilities. However, infrastructure is expensive to plan, construct, and operate. Based on these costs, the NECWC realized that it would benefit from the development of partnerships with entities that could help develop infrastructure projects that would serve multiple needs.

The NECWC pursued partnerships through a variety of means including evaluating the benefits that District 1 and 64 water users bring to partnerships, reaching out to specific partners to explore multi-benefit projects, and obtaining additional funding to further develop local and regional partnerships.

Benefits of a representative organization

The NECWC identified a wide variety of benefits that other water users could derive from a partnership with the NECWC or other organization representing District 1 and 64 water users (or "representative organization"). The benefits are summarized below:

1. **Unified Public Relations and Representation:** The representative organization can reflect the views and interests of agricultural water users in the lower South Platte River. It provides a respected voice for agricultural interests. It can act as a representative liaison between local agricultural water users/managers and potential regional partners, thus assisting and enhancing the important and necessary process of establishing regional partnerships with other water users.

2. **Knowledge of River Operations:** Local water users have firsthand and in-depth knowledge of the complicated hydrology and operations of the lower South Platte River. This knowledge is beneficial in developing and optimizing the use of new and existing infrastructure projects and water management strategies. This knowledge can also be used to build good working relationships and trust between local water users and regional partners.

3. **Potential Use of Unused Recharge Credits:** At times, water users have unused recharge credits that make up a portion of river flow. When not utilized under their existing decrees, these unused recharge credits would supply river flow that is captured and stored under new appropriations. A representative organization would provide a framework for aggregating unused credits, thereby providing greater recognition and importance of these supplies to other water users. In addition, the representative organization could provide a framework for leasing of unused recharge credits. Infrastructure (storage capacity, bypass structures, etc.) is needed for this to be successful.
4. **Additional Member Utilization of Conditional Water Rights:** Local water users also own conditional water rights that would be senior to new river appropriations. These assets could potentially be utilized through the representative organization to help meet the needs of a regional partner or to collaborate on the joint use of a new facility.
5. **Facilitation of Alternative Transfer Methods:** Local ATM agreements have recently been established by individual water users, but they have not been implemented on a large scale. Infrastructure is needed to solve problems related to location and timing of water supplies vs demands and to open ATM opportunities to a wider variety of willing participants. The representative organization could facilitate and manage a regional ATM program, which would ease administrative burdens for both water lessors and lessees. If regional infrastructure partnerships with municipal providers are established, the representative organization could help members utilize a resulting new ATM market and could work to ensure the use of ATM water in these projects rather than senior water rights obtained via "buy and dry."
6. **Potential Use and/or Development of Needed Infrastructure:** Local and regional water users/providers will almost certainly have an increased need for both exchanges and bypasses of water in the future, which will require the use of existing infrastructure and possible development of new or larger diversion and bypass structures as plans for capturing and moving water are developed and implemented. In addition, new infrastructure may need to be developed at existing diversion points. The representative organization could provide a framework for coordinating and facilitating the use and development of infrastructure for regional water management strategies.
7. **Realtime Accounting and Management of Water:** A real-time water accounting system has been developed through this project that can be used by the representative organization to precisely track and manage water supplies and demands along the mainstem of the South Platte River. Additional accounting and water management tools can be developed that could be utilized by local water users and by regional partners in cooperative projects.
8. **Facilitation of New Infrastructure:** The representative organization can work with other water users and regional partners to fund new reservoirs or other infrastructure that would be beneficial to members.
9. **Organizational Flexibility:** The representative organization could add members with varying uses of water and from different geographic areas. This flexibility allows the representative organization to consider new operational goals and bring in new types of members to achieve those goals.

Outreach to potential partners

The NECWC has been actively working with potential regional partners and has been involved in studies that could potentially result in future regional partnerships that would lead to the development of infrastructure necessary to implement some of the operational strategies described in Section 5.

Parker Water and Sanitation District (PWSD) provides water to Parker, Colorado, which is a municipality along the Front Range. PWSD is a member of the NECWC and has been collaborating with the NECWC for several years on strategies that could help meet the needs of agricultural water users in Districts 1 and 64 while providing municipal water supplies for Parker. The collaboration has led to a proposed municipal and agricultural water supply project in District 1 and 64 that would benefit both Parker and agricultural water users. The collaboration is described in more detail in Section 8 of this report.

The NECWC has also been participating in discussions and a feasibility study focused on the South Platte Regional Opportunities Water Group Concept (or SPROWG Concept). The SPROWG feasibility study explored infrastructure needed to meet municipal, agricultural, and environmental water needs in the areas where the NECWC will operate. The work of the study highlighted the importance of infrastructure to providing water supplies for a wide range of end users and also emphasized the importance of ATMs in providing a reliable source of firming supply when unappropriated and stored supplies are scarce. SPROWG Concept is described as follows:

> The SPROWG Concept is a regional vision to develop water supply and delivery ahead of future growth to fulfill a significant portion of the South Platte basin's water needs. To realize that potential, work must be done to recruit potential partners and answer important questions regarding water demands, governance structure, water treatment strategies, and project costs.
>
> The SPROWG Concept envisions multiple storage facilities and additional conveyance capacity strategically positioned throughout the basin and operationally linked. The infrastructure network would store unappropriated native flow, reusable supplies, water derived from ATMs, and unused recharge credits in portions of the basin where water is most available. This "Concept water" then would be delivered, either directly or by exchange, to specified "demand gateways" to meet diverse municipal, agricultural, environmental and recreational demands.

The NECWC and LSPWCD continue to participate in ongoing discussions regarding SPROWG Concept development.

Additional funding to develop partnerships

The NECWC realized that to fully implement the operational concepts that would be most beneficial to the members, it would need to do more work to create partnerships that could help construct infrastructure. To that end, the NECWC, through the LSPWCD, applied for and was awarded a grant under the WaterSMART, Water Marketing Strategy Grants program to conduct outreach/partnership building and scoping/planning activities to broaden its membership and marketing opportunities both locally and regionally. The overall objective of the WaterSMART grant is to collaborate with a broader set of potential members, both locally and regionally, and thereby enhance operations to provide benefits to agricultural water users in Districts 1 and 64 and also municipal water users in a broader geographic region.

The objectives of the WaterSMART grant work are as follows:

- Develop an Outreach and Partnership Building Plan: The NECWC will engage local and regional stakeholders to encourage participation in the NECWC.
- Conduct Scoping and Planning Activities Related to Local and Regional Partnerships: Numerous technical and legal research and planning efforts will be needed to support incorporation of new partners and integration with existing NECWC membership.

- Enhance Administrative and Management Tools: Existing contract templates, corporate bylaws, and water accounting tools will be reviewed and enhanced, and new tools will be developed to accommodate additional stakeholders and to make the tools scalable.
- Develop Financial and Funding Strategies: Research will be conducted on the financial structure of water transactions that encourage market activity, and strategies will be developed for enhancing the long-term financial sustainability of the NECWC.
- Develop a Water Marketing Strategy: Consistent with the requirements of this WaterSMART grant funding opportunity, a water marketing strategy will be developed that incorporates the results of outreach and research and integrates the water marketing and implementation strategies developed during the course of the work.

As described in Section 1, the WaterSMART grant will build upon the work conducted through the WSRF and ATM grant work described in this report. The WaterSMART grant contract extends through December of 2021. Through the WaterSMART grant, additional partnerships benefiting water users in the lower South Platte basin will be pursued and additional technical, legal, and organizational issues will be investigated. The final report for the WaterSMART grant, when issued in 2021, will provide additional information on operational strategies, partnerships, and organizational considerations.

8.4 Summary of Implementation Activities

The implementation activities identified and undertaken by the NECWC have been guided by the results of technical and legal analysis and by the NECWC Board and membership. The evolution of the NECWC and its operational planning started with evaluating the resources available to the members in the form of unused recharge credits and the benefits that could be derived from transacting those credits. Subsequent analyses pointed to the need for infrastructure to fully realize the benefits that could be derived from additional resources to manage water supplies. Upon reaching this conclusion the NECWC began and has continued to pursue partnerships with entities that could help them develop water supply projects that benefit all participants. The pursuit of partnerships has resulted in the application for water rights associated with a water supply project being pursued by PWSD and LSPWCD that will benefit agricultural water users in Districts 1 and 64.

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Section 9

Next Steps

The NECWC is currently pursuing implementation and development in three specific areas. First, it is actively supporting the LSPWCD in its efforts to partner with PWSD on a water supply project in the lower South Platte River. Second, it is actively participating in the development of the SPROWG Concept. Third, it is continuing to build partnerships with local and regional water users and providers using the funding provided by the WaterSMART grant. This section describes the activities that will be taking place in the near future in these three areas.

Partnership with PWSD

As mentioned earlier in this report, PWSD is a member of the NECWC and has been actively working with the NECWC on strategies to develop water supplies for municipal and agricultural water users in Parker and in the lower South Platte basin. When the project development entered a stage in which water rights would be sought, the NECWC Board of Directors and membership determined that the LSPWCD would be a more appropriate entity to partner with PWSD on the water rights application for several reasons. The LSPWCD is an established conservancy district and represents a wider array of water users with additional demands in the lower South Platte basin.

Given the LSPWCD's role in this significant infrastructure project that could benefit a large number of water users in Districts 1 and 64, including NECWC members, it is possible that the LSPWCD could take on some of the water management objectives that the NECWC has pursued for several years. The NECWC will continue to monitor the progress of the Parker/LSPWCD water supply project and support the LSPWCD in its participation. The NECWC is also continuing to evaluate its role, in conjunction with LSPWCD, in helping provide water supply security for the membership and water users in Districts 1 and 64.

Involvement in SPROWG

The NECWC will continue its involvement in the SPROWG Concept. It is likely that the SPROWG Concept will be a focal point of the upcoming South Platte Basin Implementation Plan (SPBIP) update. NECWC's continued involvement in the SPROWG Concept, and subsequently the SPBIP, will help it identify potential partners, continue discussions regarding potential infrastructure that could serve its members' and other water users' needs, and pursue ways to conduct ATMs that are valuable to District 1 and 64 water users.

WaterSMART Grant

The funding provided by the WaterSMART grant will allow the NECWC and the LSPWCD to participate in the SPROWG Concept and with PWSD in a meaningful way. It will allow the NECWC to conduct technical analyses of the SPROWG Concept and help identify strategies for District 1 and 64 water users to benefit from the potential infrastructure and partnerships. Strategies can be pursued for obtaining long term recharge credits and identifying ideal locations for recharge facilities. Outreach can be conducted to identify and pursue additional partnerships or ways to enhance the current partnership with PWSD.

Future Implementation and Evolution of the NECWC

The NECWC has evolved since its formation and will continue to evolve in the future as new analyses are conducted, new partners are engaged, and new opportunities arise. Its past evolution occurred as operational analyses were performed, legal topics were evaluated (both water and corporate), and potential partnerships were considered. The NECWC Board and membership oversaw and considered each step of the evolutionary process and recommended next steps that focused on meeting the needs of members. The NECWC is a flexible organization that can add additional and new types of members and conduct organizational adaptations (with the help of corporate counsel) to meet the needs of existing and potential new members. With this organizational flexibility, it will be capable of capitalizing on future partnerships and opportunities to enhance the water supply security of its members and water users in Districts 1 and 64.

Summary and long-term benefits of CWCB grant funds

The funding provided by the CWCB via the WSRF and ATM grant programs resulted in the creation of a first-of-its-kind cooperative focused on water management. Through the creation of this organization, water users in Districts 1 and 64 have had a voice and representation in several important efforts to develop strategies for meeting future water supply gaps while preserving water supplies for irrigated agriculture in the lower South Platte basin. In addition, the funding from the CWCB provided assistance in obtaining the additional funding from the WaterSMART grant program, which will help the NECWC and LSPWCD continue pursuing projects to provide water security for water users in the lower South Platte basin. The CWCB funds catalyzed the benefits that the NECWC has already created for water users in the lower South Platte basin and the benefits that will be realized in the next stages of development.

Section 10

Limitations

This document was prepared solely for Lower South Platte Water Conservancy District, the Northeast Colorado Water Cooperative, and the Colorado Water Conservation Board in accordance with professional standards at the time the services were performed and in accordance with the contracts between Lower South Platte Water Conservancy District and Brown and Caldwell dated November 17, 2011 and December 9, 2013. This document is governed by the specific scope of work authorized by Lower South Platte Water Conservancy District; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the Northeast Colorado Water Cooperative, Lower South Platte Water Conservancy District, and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information. This report was not prepared in contemplation of, or for the purpose of supporting, litigation in any water court or administrative matter.

Further, Brown and Caldwell makes no warranties, express or implied, with respect to this document, except for those, if any, contained in the agreement pursuant to which the document was prepared.

All data, drawings, documents, or information contained this report have been prepared exclusively for the person or entity to whom it was addressed and may not be relied upon by any other person or entity without the prior written consent of Brown and Caldwell unless otherwise provided by the Agreement pursuant to which these services were provided.

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Section 11

References

Colorado Corn Growers Association, et al. "Completion Report: Development of Practical Alternative Agricultural Water Transfer Measures for Preservation of Colorado Irrigated Agriculture." Colorado Water Conservation Board Competitive Grant Program, May, 2011.

Lower South Platte Water Conservancy District, Vranesh and Raisch, Phillips Law Offices, and Brown and Caldwell. "WSRA Grant Completion Report: Organizational Analysis for the Northeast Colorado Water Cooperative", Colorado Water Conservation Board, Water Supply Reserve Account Grant Program, June 30, 2015.

Serbina, Larisa. "Describing and Quantifying Profit Risk Producers Face When Adopting Water Conserving Cropping Systems". *Colorado Water, Newsletter of the Water Center of Colorado State University.* Volume 30, Issue 3. May/June 2013, pp 5-7.

Serbina, Larisa. *Describing and Quantifying Revenue Risk Producers Face When Adopting Water Conserving Cropping System*. Master of Science Thesis. Colorado State University. Fort Collins, Colorado. 2012.

Serbina, Larisa, J. Pritchett, C Goemans. *Completion Report: Opportunity Costs in Water Saving Crop Rotations.* Department of Agricultural and Resource Economics, Colorado State University.

Serbina, Larisa, J. Pritchett, C Goemans. *Executive Summary: Opportunity Costs in Water Saving Crop Rotations.* Department of Agricultural and Resource Economics, Colorado State University.

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Appendix A: Business Plan for the Northeast Colorado Water Cooperative

December 4, 2013

BUSINESS PLAN
NORTHEAST COLORADO WATER COOPERATIVE

1. EXECUTIVE SUMMARY:

The Northeast Colorado Water Cooperative (Water Cooperative) is a cooperative organization that will be made up of entities or persons within Water Districts 1 and 64 who own decreed or pending decrees for augmentation. The Water Cooperative is being formed for the purpose of facilitating the maximum beneficial use of certain water rights along the lower South Platte River in northeastern Colorado, especially in District 1 and 64.

The Water Cooperative has many purposes and objectives revolving around maximizing beneficial use of water supplies. Initially, the Water Cooperative will strive to lease, exchange and retime excess augmentation water between members through a coordinated process to provide notice, account for and execute leases, exchanges and retiming of excess augmentation water. Within five years it is anticipated that either the Water Cooperative would develop an overarching water court decree or that individual augmentation plans would amend or give notice under their existing decrees to list available augmentation plans in their decree(s) as a source from which replacement water can be used in their plan(s). This could allow the members of the cooperative to develop a flexible and efficient movement of excess recharge credits among individual augmentation plans. In the future, the Water Cooperative may also be able to provide a means to more flexibly use other water rights to benefit its members and potentially non-members including both the facilitation of leasing, exchanging and retiming decreed changed senior water rights and developing new water rights to use currently unappropriated water. These changed senior water rights and newly appropriated water rights could be leased, exchanged and retimed to both members and non-members via the Water Cooperative organization.

The Water Cooperative's governing board of directors is designed to be representative of multiple geographic areas within Districts 1 and 64 as well as representative of various water uses throughout the service area. Financing of the Water Cooperative is planned based on various funding sources such as grants, loans, membership dues, and water transaction fees based upon numerous operating scenarios such as number of members, variations in hydrology, short and long term operational plans, and types of water supplies and demands.

There are multiple potential benefits to Water Cooperative members and non-members outlined in this business plan. In addition, there are several risks such as financial costs and support, water rights and legal constraints, management performance, community support, and other risks that potential members should be aware of.

Detailed descriptions of the Water Cooperative’s planned services, membership qualifications, organizational management team, personnel requirements, financing plans, risk analysis, and financial estimates are outlined in the following sections.

2. COOPERATIVE SERVICES:

The following is a discussion of the services the Water Cooperative is planning to offer members in the near future and long term. Once the cooperative is formed and operating, the need for particular services may change and will be determined by the members and the board of directors.

Short Term:

Over the last ten years of augmentation plan operations within Districts 1 and 64 it has become apparent that, due to the variability of groundwater recharge (see attached Exhibit A - V*ariability of Groundwater Recharge*), numerous augmentation plans have periodic amounts of both excess augmentation supplies and shortages of augmentation supplies, depending on annual, monthly and daily operating conditions. The Water Cooperative plans to provide its members with several services in the short term to coordinate the lease, exchange and retiming of excess augmentation supplies from members who at times have excesses to members who at times have shortages. Note that all of the excess augmentation supplies occur from the normal operating conditions of existing individual augmentation plans. These excesses occur as a result of the differences in timing of recharge accretions in comparison to well depletions and as a result of the uncertainty in future hydrology within the basin.

The Water Cooperative plans to track and coordinate annual, monthly and daily water excesses and shortages between its members, within existing decreed augmentation plans. The Water Cooperative does not plan to provide separate augmentation accounting but will instead rely on member-supplied information to track water supplies and shortages. The Water Cooperative will also work with its members to develop real time telemetry for wells and other infrastructure that have short term impacts on the stream, and will pursue financial assistance for such telemetry. However, ultimate data acquisition on a real time basis (if needed) is up to either the augmentation plan or individual landowner. The Water Cooperative will use all available information from its members and will coordinate with the Division of Water Resources to ensure that all leases, administrative exchanges, and re-diversions occur in the proper time, location and amount to avoid injury to other water rights. In addition, the Water Cooperative plans to coordinate and assist in meeting any accounting and notice requirements set up by the existing terms and conditions within individual augmentation plans to allow for such use. Members will provide timely accounting information to the Water Cooperative with respect to their individual augmentation plans.

Most augmentation plan decrees that require a notice to use excess augmentation supplies also have a provision that require any augmentation plan which uses such excess augmentation supplies for more than five years to obtain or amend an existing decree to allow for such continued use. The Water Cooperative anticipates that within the first five years of operations, it would either file an application in water court to develop an overall augmentation plan which allows for such continued use or assist its member augmentation plans to amend their existing plans to continue such use.

It is anticipated that the short term goals of optimizing existing excess augmentation supplies would occur within Districts 1 and 64 and between agricultural, municipal, commercial and industrial members of the Water Cooperative.

Long Term:

The Water Cooperative plans to explore other ideas to further maximize water uses and supplies within Water Districts 1 and 64 and possibly within other parts of the South Platte Basin.

First, the Water Cooperative plans to research and potentially coordinate various means to lease, exchange and re-divert the transferrable portion of historic consumptive use water from both senior direct flow and reservoir water rights, while maintaining ownership of the ag water rights, and to find alternatives to the traditional "buy and dry" approach to changed uses of senior water rights. These leased water rights would be potentially coordinated and exchanged via the Water Cooperative; however the water court adjudication of such a change of use would be the responsibility of individual members. Senior water rights exchanged and leased through the Water Cooperative could be used to firm up long term water supply commitments to both members and non-members.

Second, the Water Cooperative will investigate the need for utilizing existing infrastructure and building additional infrastructure to help improve water use efficiency by its members both for the short term and long term operations of the Water Cooperative. The Water Cooperative will research and analyze the costs and benefits of such infrastructure and the financing options for building feasible infrastructure. If Water Cooperative members deem feasible infrastructure projects warrant construction and adequate financing is available, the Water Cooperative will pursue such construction. It is anticipated from initial planning and engineering that new and existing infrastructure such as pumping stations, pipelines, long-term recharge areas, storage reservoirs and other infrastructure could significantly improve the optimization of using excess augmentation water, changed direct flow and storage water rights, exchange potential, and development of unappropriated waters within Water Districts 1 and 64.

Finally, the Water Cooperative plans to research the historical timing and amount of unappropriated waters in Water Districts 1 and 64 and to utilize existing and new infrastructure to strategically divert and beneficially use such water to meet existing agricultural, municipal, industrial and non-consumptive shortages for both members and non-members. The Water Cooperative would analyze the un-met demands or water shortages for both its members and non-members who contract with the Water Cooperative for possible water supplies. Water allocations and deliveries of newly developed water supplies to and from the Water Cooperative would be determined annually, monthly and daily by board of director policies and management execution of such policies.

It is anticipated that the long term operation scenarios outlined above would require court approved adjudication for such use. The Water Cooperative anticipates that extensive legal and engineering work would need to be done to adjudicate any new water rights associated with the above operating scenarios (as noted above, historic changes of use would be the responsibility of individual ditch and reservoir companies). Financial estimates and financing options would be presented to Water Cooperative members. Pursuit of newly adjudicated water rights would commence if found feasible.

3. COOPERATIVE MEMBERSHIP: Membership in the Cooperative will be available to the following persons or entities who have a principal office or residence in either Water District 1 or 64 in northeastern Colorado: any person who owns a decreed or pending application for a water right or augmentation plan or water recharge facility authorized by decree from a recognized Colorado Water Court (not including persons who are individual shareholders, members or users of an entity with such a right, plan or facility)

Persons or entities interested in membership may apply for either a voting or non-voting membership and pay the requisite membership fee for one membership interest. Membership fees have initially been set for both voting and non-voting members and are detailed in the financial section below. Members with voting rights will have the authority to elect the board of directors and participate as a board member, as well as vote on other issues that come before the membership. The bylaws of the cooperative will govern the voting and other rights of the members and the directors. Because of the cooperative structure, each voting member will have one vote.

All members, whether voting or non-voting, will execute a patronage agreement with the cooperative which will provide the terms and conditions for patronizing the cooperative. To patronize the cooperative will mean a member will supply water and/or request water in exchange transactions between the members that are tracked and governed by cooperative management as outlined above.

Besides one-time membership fees to join the cooperative, there is a likelihood that there will be an annual assessment of some form that will be needed to cover the annual operating costs of the cooperative. Financial information is provided below. However, other forms of assessments could be used that include, for example, a percentage or specific dollar amount that is added to transactions between members for the exchange of water credits, or some combination of annual assessment and a transaction fee. Other than the membership fee to join the Coop, other fees will be determined at least annually and perhaps more often by the Board of Directors.

4. ORGANIZATION/MANAGEMENT TEAM :

Management of the Coop will be conducted by a volunteer Board of Directors and a small staff. The Board of Directors will consist of persons who are members or representatives of members having a strong working knowledge of water matters. A short biography of each of the initial directors is shown on Exhibit B attached to this business plan. The directors will be elected by the members of the Coop. Initially, the Board will hire a manager who will also have extensive experience with water matters and who will be able to process the water accounting necessary to move water from suppliers to users.

The Board of Directors will set policy for the operation of the enterprise, while the manager will execute the policies. These policies will include:

- Reviewing and approving or denying applications for membership in the Cooperative.
- Hiring, firing and supervising the manager. The manager will report directly to the Board and provide the Board at least monthly operational and financial updates.
- Additional staff positions may be needed. The Board, with advice of the manager, will determine when a position needs to be created or deleted.
- The lease rates for acquiring member water, unless conducted by bid.
- The lease rates for the use of member water by other members, unless conducted by bid.
- The lease rates for the use of member water by non-members for short term use (less than a year).
- If a bid process is used for the transfer of water, the Board will establish the method of bidding to be used and so guide the manager in establishing the process.
- Upon the recommendation of the manager, reviewing and approving the hiring of outside consultants for the Coop, such as engineering firms, accountants or attorneys.

The manager will be responsible for the routine hiring and firing of employees for any additional positions. The manager and employees will operate the Coop including accounting for all water exchanges, communications with members, hiring outside consultants as approved by the Board, and appropriate government reporting.

There will be an annual meeting of the members of the Water Cooperative at which time the members will elect directors and be given reports by the management and Board on the prior year's operations of the cooperative. Throughout the year, the management and Board will maintain an open and transparent relationship by and between the members and management.

Members will be required to execute a patronage agreement in which they agree to terms and conditions for supply and/or use of water within the Coop. Water suppliers will notify the Coop of how much water they have available for the Coop’s use. This will enable the supplier to retain the volume of water that they deem necessary to prevent a shortage or potential shortage in their plan.

Water supplies that have been acquired by the Coop may be made available to any member. (There could be a bidding process during times of limited supply, or as an alternative). When water is made available to the Coop it may be necessary to establish protocols or restrictions as to which users may acquire the water and under what terms (e.g., there may be limitations on how much a single purchaser may acquire, geographically where it can be used, a hierarchy of types of uses, prices for those uses, etc.). These policies and protocols will be determined by the Board of Directors and executed by the manager.

5. <u>RISK ANALYSIS</u>:

There will be various risks associated with the operations and administration of the Water Cooperative. While a number of risks are outlined below, there may be other unforeseen risks that could occur for members of the Water Cooperative.

Generally, the Water Cooperative has been considered by the communities within Water Districts 1 and 64 as a positive organization set up to address water supply issues by a wide range of water users. However, the risk of a negative community perception and corresponding lack of some community support may arise, should people believe that the Water Cooperative creates certain negative impacts to the community. While not all issues can be addressed, the Water Cooperative will strive to have dialogues with both members and non-members within the South Platte Basin to understand and address negative issues perceived from Water Cooperative operations and to look for ways to positively impact members and non-members.

Potential members of the Water Cooperative have from the beginning stressed that any operations of a new organization should be 1) open, transparent and fair and 2) work within the existing water rights system to prevent injury to water rights owners in the basin. The Water Cooperative will focus on accomplishing both of these goals through organizational policies and necessary water court proceedings.

There are a wide range of risks associated with the water court process. These include but are not limited to:

1) extensive engineering analyses may be required for long term operational plans and the use of such data and findings by third parties,

2) extensive legal research and documentation may be required to file and adjudicate water rights needed for the long term operational plans, along with the legal bases of such work,

3) potential high costs associated with the engineering and legal work needed to adjudicate water rights for the Water Cooperative, and

4) settlement and/or court decisions that may restrict planned Water Cooperative operations.

These risks are common in adjudicating any water rights in Colorado but may be higher with this organization due to the potential magnitude of operations by the Water Cooperative. Also, potentially high financial outlays by members seems to be the biggest risk associated with water court proceedings; however, other issues such as water user support within the basin, potential impacts to existing water rights and constraints on short and long term operations are additional risks that Water Cooperative members should be aware of as a result of the adjudication process.

The Water Cooperative will strive to keep administrative, operating, legal, engineering and other costs at a minimum, but risks of high financial costs do exist for members. Short and long term financial estimates are outlined in detail below; however, there are various factors that could increase these estimates in the future such as possible increased engineering and legal costs for new services to be provided to members in the future. The Water Cooperative has researched and will continue to both research and seek financing options for administering and operating the organization for its members such as grants, loans, membership dues, water transaction fees, issuance of preferred stock, other investments, etc. There are risks that some of these financing options may not be available in the future, forcing a larger amount of the financial burden upon members of the Water Cooperative. As an example, it should be noted that State grant funds can't be used for the water court adjudication process.

Administering and operating the Water Cooperative in a productive, efficient and competent manner will be a primary focus of the board of directors and management team of this organization. There will be numerous short term and long term policies and guidelines set up to run the organization at a professional level. Legal, engineering and financial consultants will assist with the structure, planning, administration and operations of the Water Cooperative. However, the board of directors and management team will have a significant responsibility and role in setting policies and guidelines as well as implementing and enacting policies and guidelines through the daily administration and operation of the Water Cooperative. Organizational tasks such as staffing personnel, financial accounting, executing consultant contracts, etc., will need to be undertaken by the management team and board of directors. Operational needs such as water tracking, contract execution, telemetry development, membership communications, pricing structures, future planning, implementation of projects, water court adjudications, etc. are also tasks that the management team and board of directors will need to undertake. There are inherent risks associated with all of the administrative and operational work performed by the management team, board of directors and consultants of the Water Cooperative, such as errors, omissions, lack of knowledge or inexperience in operating this type of organization, personnel conflicts, dishonesty, fraud and other risks. The Water Cooperative board of directors, management team and consultants will strive to minimize such risks with open, transparent and fair policies and guidelines for administration and operations. Safeguard policies and oversight will be put into place to avoid and/or reduce these risks.

In general, the most significant risk to Water Cooperative members is the financial risk of surrendering large amounts of capital outlays with a reduced or negative return. Other risks such as negative public perception, reductions in water deliveries and other matters should be considered by Water Cooperative members. In both the short term and long term, the board of directors believes that the benefits of the Water Cooperative from both a financial and water supply aspect to its members will be greater than the costs and risks of the operations of this organization.

6. USE AND EFFECT OF FINANCING:

The Water Cooperative will require some type of financing for the initial start-up, the water court activity which will be required, and for any infrastructure that would assist in making the cooperative more efficient. The methods used to finance these individual items may be the same or could be set up separately.

The Water Cooperative has been successful in the past acquiring grants to gather information necessary to determine the feasibility of the initial idea. There is still favorable interest in the Water Cooperative among the water community and funds may be available to facilitate a portion of the start-up. Grants from third parties may be available from government agencies, private funding, or agricultural associations. These grants and sources of funding should be pursued; however these funds may not be available for water court activity, which will most likely be the most expensive portion of the start-up. However, grant funding may be used to further develop engineering studies or to develop an accounting model for tracking water credits by and between the members in the cooperative. In order for the Water Cooperative to be successful, there must be buy in from the members, therefore, an initial start-up fee for members that, at a minimum, offsets the projected costs of operation seems prudent.

The requirement for funds to conduct water court proceedings could be financed by the individual members and/or investor members, or the cooperative could pursue direct financing. An initial discussion with Cobank, a national cooperative lender, yielded a possibility of a grant and/or financing for this part of the start-up. Further discussions are pending.

After the Water Cooperative begins to operate, the need for infrastructure may arise. Funding for these projects could be accomplished through any of the above mentioned sources. Members could contribute equally if it benefits all, or an individual member could build the infrastructure for the cooperative if they see a direct benefit for the member. Investor members, bank financing, and State grants or financing could be used.

7. FINANCIAL DATA:

A pro forma budget for the first three years of operation is presented below. Income that could be generated in the initial start-up stages as well as the expenses incurred are purely estimates and are not figures determined by actual operations. The proposed budget assumes that there would be 15 voting members and 10 non-voting members who would each be assessed no annual fees for the first two years and $5,000 for the following year. If the Coop is able to generate more revenue through the lease of water than assumed in this budget then the annual fees could be less. Purchase of a share of a voting or non-voting membership interest is not included in the spreadsheet; however, it has been projected that the cost of a voting membership will be $2,000 and $1,000 for a non-voting membership interest. For purposes of the pro forma information, it was anticipated that the cooperative would exchange 2,000 acre-feet between its members and the Coop would receive an administrative charge of $10 per acre foot exchanged in the first year.

Most of the Water Cooperative operational expenses for the first three years were assumed to be staff services and professional contracting services. It is anticipated that a general manager hired by the Water Cooperative will handle all of the staffing tasks required by the cooperative operations with the remainder of work being accomplished by designated consultants. The general manager of the Water Cooperative could also be contracted to provide services to the Lower South Platte Water Conservancy District which would help to offset the cost of overhead expenses for the cooperative. Expenses are an estimate based on current employment and contractor costs for similar activities. Consulting expenses include an administration fee from LSPWCD to assist with the development of the Water Cooperative organization, staffing and operations. There are no water court costs or significant engineering costs included in the operational budget. The initial costs for engineering and legal costs to obtain a blanket augmentation plan for the cooperative and for development of an accounting model have yet to be determined. Preliminary engineering and accounting model costs will be funded by grant funds. In addition, grant funding will fund a significant portion of the initial start-up costs for administration, management and legal and financial consulting.

CONCLUSION:

The Northeast Water Cooperative is being formed for the purpose of maximizing the beneficial use of water resources along the South Platte River in northeastern Colorado, specifically in Districts 1 and 64 while maintaining current individual ownership of water rights. It is anticipated that by joining the cooperative, members will have the ability to more easily and efficiently transfer water credits between the members. Membership in the cooperative will offer the following benefits:

- Coordination of and a market for the lease, exchange and retiming of excess augmentation supplies between cooperative members.
- Accounting models developed for the tracking and coordination of annual, monthly and daily water excesses and shortages between members, within existing decreed augmentation plans.
- Development of real time telemetry for wells and other infrastructure that have short term impacts on the stream, and potential financial assistance for such telemetry.
- Utilization of available information from members for coordination with the Division of Water Resources to ensure that all leases, administrative exchanges, and re-diversions occur in the proper time, location and amount to avoid injury to other water rights.
- Coordination and assistance in meeting any accounting and notice requirements set up by the existing terms and conditions of current member augmentation plans.
- During the first five years of operations, establishment of an overall augmentation plan or assistance with members to amend their existing augmentation plans for the efficient use of excess augmentation supplies.
- Possible creation of diverse methods to lease, exchange and re-divert the transferrable portion of historic consumptive use water from senior direct flow and reservoir water rights, while maintaining individual ownership of the ag water rights, and to find alternatives to the traditional “buy and dry” approach to changed uses of senior water rights.
- Investigation of the need to utilize existing infrastructure and build additional infrastructure to help improve water use efficiency by members, both for the short term and long term operations of the Water Cooperative.
- Research and potential development of historical un-appropriated waters in Water Districts 1 and 64 to utilize existing and new infrastructure strategically to divert and beneficially use such water to meet existing agricultural, municipal, industrial and non-consumptive shortages for both members and non-members.
- Pursuit of newly adjudicated water rights would commence if found feasible.
- Access to the water cooperative may create positive individual, local and regional economic development and financial benefit.
- Anticipated improvements to individual and regional water supplies.

Variability of Ground Water Recharge

in the Lower South Platte River

Augmentation plans allow junior water rights (usually wells) to create out-of-priority depletions to stream flows as long as replacement water is provided to “augment” streamflows by offsetting the stream depletions and preventing injury to senior water rights. Most agricultural augmentation plans rely on managed recharge as the main source of water supply to offset their pumping depletions. Managed recharge is commonly done by diverting or pumping water from a river or stream and allowing the water to percolate into the alluvial aquifer through recharge ponds or unlined irrigation ditches. Augmentation plans will usually have other sources of water available as well, such as shares in a more senior ditch or reservoir company. In general, plans with senior sources of supply use them only when recharge credits cannot cover all of their out of priority depletions.

Water rights for recharge are relatively junior. As a result, when there is a senior call on the river, recharge rights are not in priority and cannot be diverted. In drier years, the opportunities to divert junior recharge rights might be few and far between and in short windows of time. In normal years, there may only be certain seasons when recharge rights are in priority – like the spring for example. However, even in dry years, the delayed accretions (credits) from previous diversions will be used in the augmentation plans.

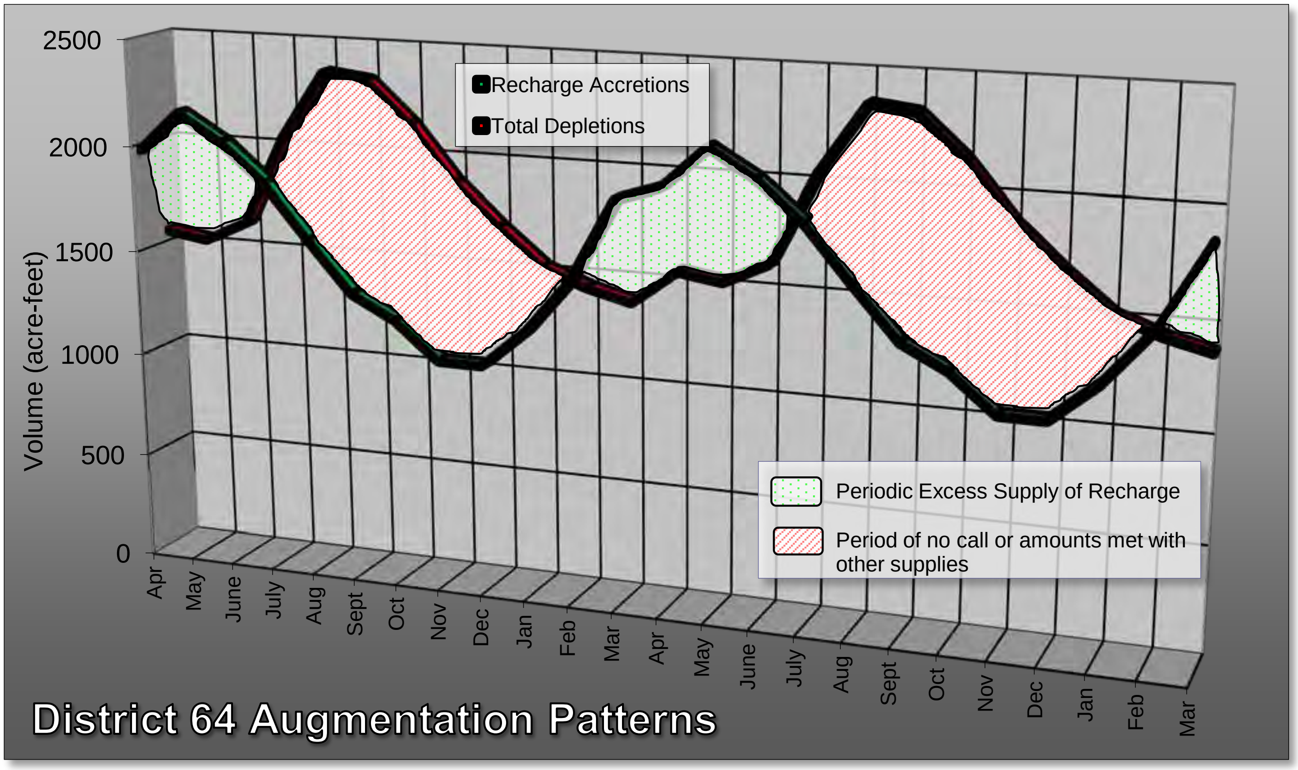
Because junior recharge rights will only be in priority intermittently or in short windows of time, augmentation plan operators must recharge as much as possible when they are in priority, because they do not know when they will be able to recharge again. And, the timing of when the recharge rights are in priority seldom matches the timing of when water is needed from the wells to irrigate crops.

Locations of recharge ponds and other recharge facilities relative to irrigation wells also present timing difficulties for augmentation plans. For example, if recharge ponds are located closer to the river than the irrigation wells in an augmentation plan, the recharge credits reach the river more quickly than the depletions. Augmentation plans need to have adequate water supplies to fully cover their pumping depletions at all times that they are out of priority. However, on the days that the junior recharge rights are in priority for diversion, it is impossible to know what the river call will be on the days that the recharge accretions and the well depletions will reach the river, which will be months, years, and decades into the future.

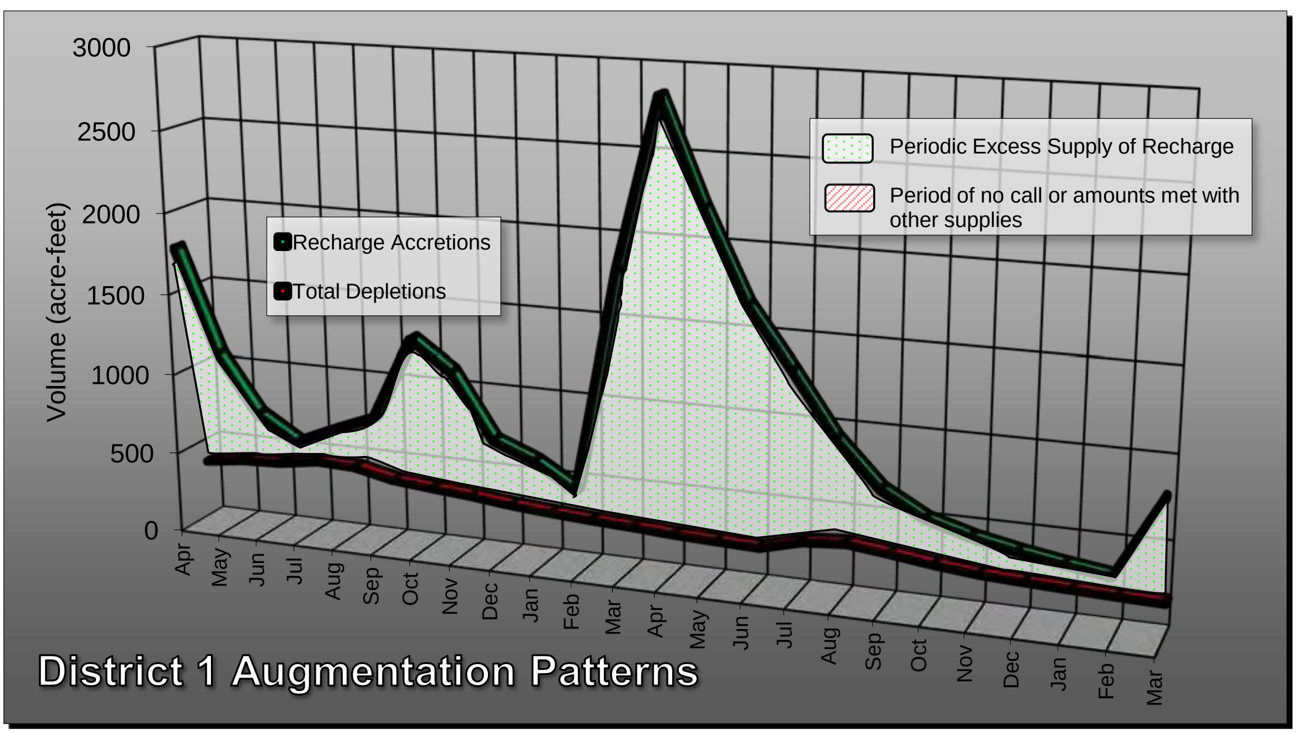
These variabilities in recharge mean that it is impossible to divert and recharge only the amount of water ultimately needed to offset the well depletions. As a result, most augmentation plans will have some extra recharge credits from time to time so that they can provide adequate supplies to cover depletions year round. But, this does not mean that the plans “have more than they need.” Any plan can have surplus credits at some times, and be barely adequate or short of credits at other times during the same year. Patterns of recharge and depletion are shown for two actual plans in the graphs that follow. These graphs depict the unavoidable variability in the timing between when recharge credits reach the river compared to when well depletions reach it.

When added up, the many augmentation plans between Kersey and the stateline can periodically generate significant amounts of excess recharge credits, usually in normal to wetter years. Much, if not all, of this excess can go away in drier times because of the factors described above.

There is a need to find a way to make good use of these excess recharge credits when they do occur, since they are a necessary and unavoidable result of running the existing augmentation plans. This is one of the primary goals of the group trying to organize the lower South Platte water cooperative.



This figure illustrates the variability in patterns of depletions and recharge in District 64. In late winter and spring, recharge exceeds depletions. However in the summer and fall, depletions are more then recharge credits, and augmentation plans need to rely on other sources of water for augmentation supply.



In District 1, augmentation plans frequently need to recharge as much water as they can in the spring so that the lagged accretions last through the summer, fall, and early winter when the opportunity to recharge using junior water rights may not be available.

EXHIBIT B
BOARD OF DIRECTORS
NORTHEAST COLORADO WATER COOPERATIVE

Don Chapman

Don Chapman is the superintendent of the Riverside Irrigation District, located in Fort Morgan. He has been superintendent of the Riverside system since 1999. He has also served on the boards of the Lower Platte and Beaver Canal Company, the Morgan Prewitt Reservoir Company and the Irrigationists' Association.

Larry Frame

Larry Frame is the Superintendent of the Julesburg Irrigation District. Larry began his employment with the District in 1994 and was appointed Superintendent in 1995. The Julesburg Irrigation District provides water to 21,500 acres in Sedgwick County Colorado and Deuel County Nebraska. The District not only utilizes the Julesburg Reservoir rights, but has multiple direct flow decrees to provide irrigation water. Larry also serves as a Board Member on the Sedgwick Sand Draws Board of Directors and has been the Secretary-Treasurer of the Colorado Division of National Pony Express Association since 1998.

Ken Fritzler

Ken Fritzler is currently in his seventh year as Board President of the Lower South Platte Water Conservancy District and has also served as Vice President for two years in his ten years serving District. Other duties include plan administrator for Logan Well Users, an augmentation plan including 360 wells and numerous recharge water rights along with being Vice President of District 64 Reservoir Company which owns the water rights for Ovid Reservoir near Ovid Colorado.

Mike Groves

Mike Groves bought his first farm along with his twin brother when they were 17 years old. They still farm together in the Orchard/Weldona area. Along with the farm ground, Mike also has a cow/calf operation and a feedlot. Mike has been a member of the Bijou Irrigation District and Company Boards for 16 + years. He has been the President of the District for the last 3 years.

Chris Kraft

Chris is a dairy farmer in Morgan County. He is a director on the Fort Morgan Reservoir and Irrigation Company and the Jackson Lake Company. He and his wife Mary also have a dairy farming operation. Chris was appointed to the Colorado Water Quality Control Commission by Governor Bill Owens and served two terms from 2000 to 2006. He is very interested in Colorado's water and collects old water books and maps.

Ron Quint

Ron Quint operates a small farm and cattle operation near Merino. He is the ditch superintendent and also sits on the board of directors for the South Platte Ditch Company which delivers water for irrigation and recharge to farms in the Merino area. In addition, he serves as President and plan manager for the South Platte Ditch Well Users augmentation plan.

Larry Mowery

Larry Mowery is a graduate of CU at Boulder with a B.S. in business. After college he worked for a financial institution and started a catalog agribusness. In the 1970's he was an office manager for a major petroleum distributor. In 1978 he started the first of three dairies, the last one was sold in 1985 . After the dairy, he started a cow-calf operation which is ongoing today. The present operation around the Crook area consists of up to 600 cows running on about 4000 acres with about 800 acres irrigated. Larry has been president of four small corporations, on four ditch company boards as president and/or secretary and/or director. He was also a member of the startup committee for the District 64 Reservoir Company.

John Rusch

John Rusch does the augmentation accounting for the Bijou Irrigation Company and several other NE Colorado augmentation plans and substitute water supply plans. In the past he has served on various water and community service boards. He is currently serving as a director for the Northern Colorado Water Conservancy District and Morgan County Quality Water District.

Jim Yahn

Jim Yahn is the manager of the North Sterling and Prewitt Reservoirs, a position that he has held for 21 years. He is responsible for overseeing the diversion and distribution of water to over 350 farmers. Together the reservoirs are a source of irrigation water for approximately 70,000 acres. Jim received his B.S. in Agricultural Engineering from Colorado State University and worked as a consulting engineer in Fort Collins for 5 years prior to his current employment. He is a native of Colorado growing up on a family ranch, which used water from the North Sterling Reservoir System. Jim was the past Chairman of the South Platte Basin Roundtable (SPBRT) and currently serves as the SPBRT representative to the Interbasin Compact Committee.

Appendix B: Executive Summary: Opportunity Costs in Water Saving Crop Rotations

Executive Summary: Opportunity Costs in Water Saving Crop Rotations

Larisa Serbina, James Pritchett and Chris Goemans

Authors are former Graduate Research Assistant, Professor and Associate Professor all in the Department of Agricultural and Resource Economics, Colorado State University.
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The authors gratefully acknowledge the funding of the Colorado State University Agriculture Experiment Station and the Colorado Water Conservation Board's Alternatives to Agriculture Transfer Grant Program.

Abstract: Water leasing contracts may be a viable alternative to 'buy and dry' transactions in Colorado. The purpose of this research is to examine one aspect of leasing: the opportunity cost of farmers who adopt water conserving crop rotations that might be used for leases. Farmers seek an understanding of what crop rotations might be used to conserve consumptive use (CU), and how these rotations influence the farm's profitability and the variability of these profits. This understanding will inform the development of mutually agreeable leases and levels of compensation between farm managers and water suppliers. For those seeking to lease irrigation water, the information will inform their strategic planning for obtaining reliable water supplies.

From a farm manager's perspective, the opportunity cost of switching to a cropping system depends importantly on an expectation of profits, and the expectation includes the potential for low or high profits. In order to gain a better understanding of values that create an expectation, a simulation model is developed to measure the profits of a baseline, irrigated corn cropping system as well as for four other systems that conserve consumptive use water. Prices and yields are allowed to vary in a range and correlation consistent with the historical (1980-2010) data generation process. The simulation leads to a profit frequency for each cropping system that can be compared against one another. Likewise, an opportunity cost frequency is created by calculating the difference between an iteration's profit from the baseline system and the alternative cropping system.

Results suggest a combination of corn and wheat in a cropping system is almost always desirable compared to a fallow system or the corn-alfalfa-fallow system. The result is intuitive – from the crop manager's perspective it is almost always better to crop land than to have it sit idle. It is also true that the system provides some flexibility for the crop manager and the contracting leaser in a water conserving agreement – the wheat crop can be planted and irrigated as the water year unfolds. If water is needed, the crop remains non-irrigated, but if water is available it can be set to the wheat crop. The water conservation in this simulation ranges from 440 AF of conserved CU in an irrigated corn-wheat rotation to 1,195 AF of CU in an irrigated corn - dryland wheat rotation. In this type of an arrangement, the wheat can act as a drought "reservoir" for the leaser that is adjustable depending on circumstances.

Crop managers are concerned with both the upside and downside potential in alternative cropping systems. Upside potential is the inability to seize the profits in years during which prices are quite high and yields are above average. Downside potential refers to years when profits are quite low because of low prices and/or poor yields. This analysis suggests little difference exists in the cropping systems for downside potential, but substantial differences occur on the upside, and this might make crop managers less likely to sign leases. Payment contingencies might help to alleviate the crop managers' concerns. One alternative is a two-step payment program: the initial, baseline payment, would be paid to the producer when cropping decisions are made in the Fall, and a second payment is made when harvest prices are realized.

Executive Summary: Opportunity Cost in Water Conserving Cropping Systems

Water leases may be a viable alternative to 'buy and dry' transactions. These water leases require crop rotations that conserve crop consumptive use (CU), such as the fallowing of a crop or planting of a non-irrigated crop in lieu of full irrigation. The conserved CU is transferred to other users via storage or used as a credit in some form of exchange with other water users.

A host of issues -- legal, political, environmental, and scientific -- need be resolved in order for water leases to be a successful instrument for meeting reallocation objectives. The purpose of this report is to explore one facet of these issues -- how a farmer's profit might change when adopting the water conserving crop rotation. The profit change is called an 'opportunity cost' because it measures the foregone profits of full irrigation.

Farmers want to know how much profit is given up when adopting crop conserving rotations and how this changes with yields and prices. This knowledge will inform the development of mutually agreeable leases and levels of compensation between farm managers and water suppliers. For those seeking to lease irrigation water, the information will inform their strategic planning for obtaining reliable water supplies.

It's useful to think about these questions in a specific farm context, so this report focuses a representative farm located in western Weld County and

(a) characterizes CU water conservation in various crop rotations;

(b) quantifies the mean expected profits for these rotations, the foregone profit relative to the irrigated baseline (known as an opportunity cost) and the dispersion of foregone profits about the mean expected profit level; and

(c) compares crop rotation profit and opportunity cost frequencies according to various risk criteria.

Data and Simulation Procedure

Our simulation calculates the financial tradeoffs that exist when adopting different cropping systems under uncertain price and yield conditions. Profits stemming from a "baseline" cropping system (e.g., 100% irrigated corn) are calculated and compared to CU water conserving systems (e.g, 50% corn, 50% fallow) that are illustrated in Figure 1. Serbina (2012) explains the details of how the crop systems wwere determined, and also some other systems, in her thesis.

The *Baseline Cropping System* is a 100% irrigated corn system typical in the South Platte River Basin where as much as 70% of irrigated farm acres are comprised of corn that is either harvested for grain or silage (USDA-NASS).

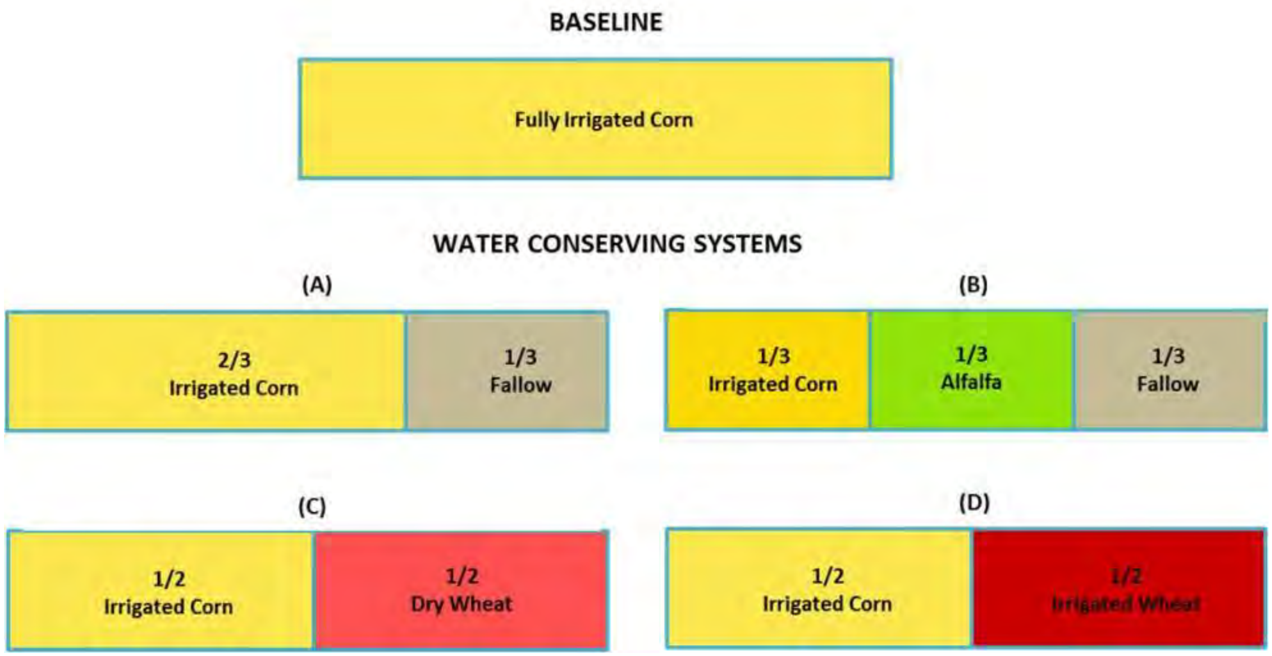
Water Conserving System A is a slight adjustment to the *Baseline Cropping System*, as irrigated corn is planted on 2/3 of the farm acres and 1/3 is fallowed. This system is also consistent with a farm planted entirely to irrigated corn in two of three years, but the farm is fallowed in the other year. Presumably, the conserved water from the fallow period is available for lease.

Water Conserving System B includes two crops that are of particular importance in the basin, irrigated corn and irrigated alfalfa, and these are often used in rotation with one another. System B also includes a fallow portion on one-third of its acres. While the water conservation in system A and B are similar, the introduction of different crops may influence the potential distribution of farm profits.

Water Conserving System C is comprised of one-half irrigated corn and the rest in dryland (non-irrigated) wheat. The introduction of wheat is likely to improve returns relative to a fallow system such as *Water Conserving System A.* It should be noted that while some farms in the South Platte River Basin are able to grow dryland wheat with their soils, equipment and managerial expertise, this not universally true, so system C is not an option for all farms.

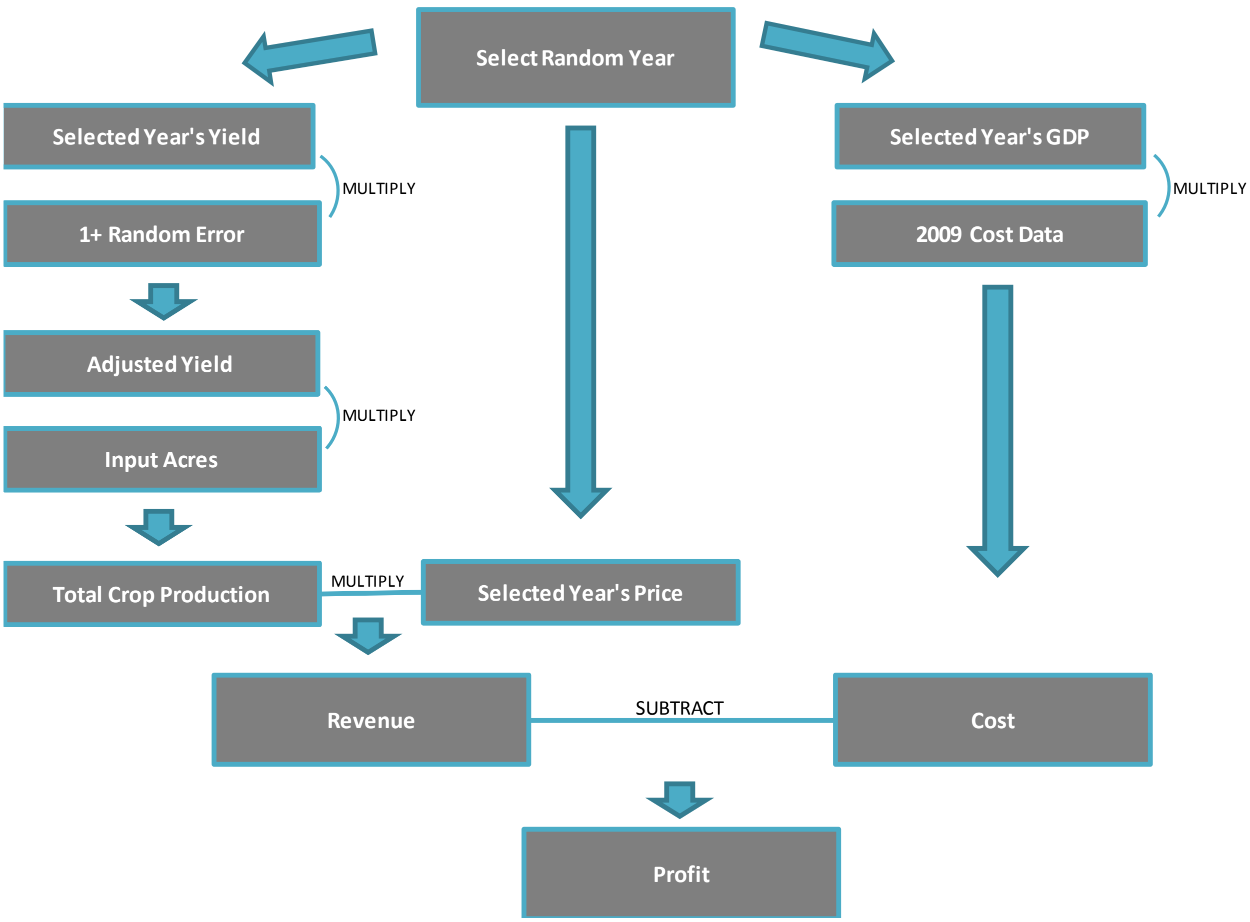
Water Conserving System D replaces non-irrigated wheat in *Water Conserving System C* with irrigated wheat, and retains the same amount of irrigated corn. Irrigated wheat yields are substantially better than non-irrigated wheat yields, suggesting an increase in profits compared to dryland wheat. However, the CU water conservation of this system us not as large as that found in System C.

Figure 1: Cropping Systems



The systems represented in Figure 1 are applied to a 2,000 acre irrigated farm, which is of sufficient size to be attractive for water leases. The profits of the farm are calculated for each of the systems illustrated in Figure 1, and this calculation is iteratively repeated for a variety of potential yield and price outcomes. Profits are collected for the iterations so that an empirical frequency can be characterized. Figure 2 illustrates the iteration process.

Figure 2: Illustration of the Iteration of Water Conserving System Profits



The iterative process begins with the selection of a random year from an historical dataset that ranges from 1980 to 2010. (Later on, we focus on recent years 2006 to 2010 to capture recent high price conditions). The dataset includes a time series for local harvest prices and county average yields. The selected year (e.g., 1985) becomes the base year for that iteration. Commodity prices for the base year are used directly in the calculation, but the yield from that year is adjusted with a random component to simulate farm level yield variation. This adjusted yield is calculated by adding a random percent error term to the selected base yield. The percent error term is selected from a de-trended, simulated percent error distribution derived from county-level, historical yields, a process described more fully in Serbina, 2012 and that has been used in other farm level simulations. The procedure ensures a potential variation in yields that have been demonstrated historically, while preserving the correlation between local production conditions and national/local prices. Without the random error term the sample would be drawn from a simpler historical distribution of yields, thus, the result would be the same distribution as that of the historical data meaning the potential risk of adopting a cropping system may be understated.

The production acres are multiplied by the adjusted yield to calculate total production for the farm. Total production is multiplied by the commodity price and summed across crops to equal the total farm revenue. The production cost associated with the specific crop are adjusted to be in selected year dollars using the GDP ratio. In this way current cost structures are represented, but adjusted for inflation. The cost are then subtracted from revenue to obtain profit.

The difference between revenue and cost represents the potential profit obtained from producing a particular crop under that iteration's conditions. For a given iteration, the differences between the profit under the baseline system and the alternative systems represent potential foregone profits for the irrigator if they were to switch to the water conserving alternative. These opportunity costs are collected in sum, but also converted to opportunity costs per conserved CU.

It is important to note that profits do not include a payment for leased water associated with the conserved CU, and so it is hypothesized that profits for the alternative cropping systems are expected to be less than the baseline system. The farm profit calculation includes deficiency payments but omits the receipt of direct government payments, crop insurance premiums and indemnities.

Data

Yearly yield data for each crop is collected at the county level from 1980-2010. Yearly irrigated corn yields, irrigated and dry-land winter wheat yields, and irrigated alfalfa hay yields are collected via United States Department of Agriculture (USDA) Quick Stats and Colorado Agricultural Statistical Service Publications.

The price data for corn and wheat are acquired from the USDA Colorado Department of Agricultural Market and News Service from Greeley, Colorado. The price per bushel of corn is obtained using the averages of the prices in the month of November from 1981 to 2011 to represent a typical cash price received at harvest. The price per bushel of winter wheat is obtained using the averages of the prices in the month of August from 1981 to 2010. Target prices for these crops (used in the calculation of deficiency payments) are taken from USDA-ERS publications. The price for alfalfa hay per ton is given by the average of the prices in the month of July from 1980-2010.

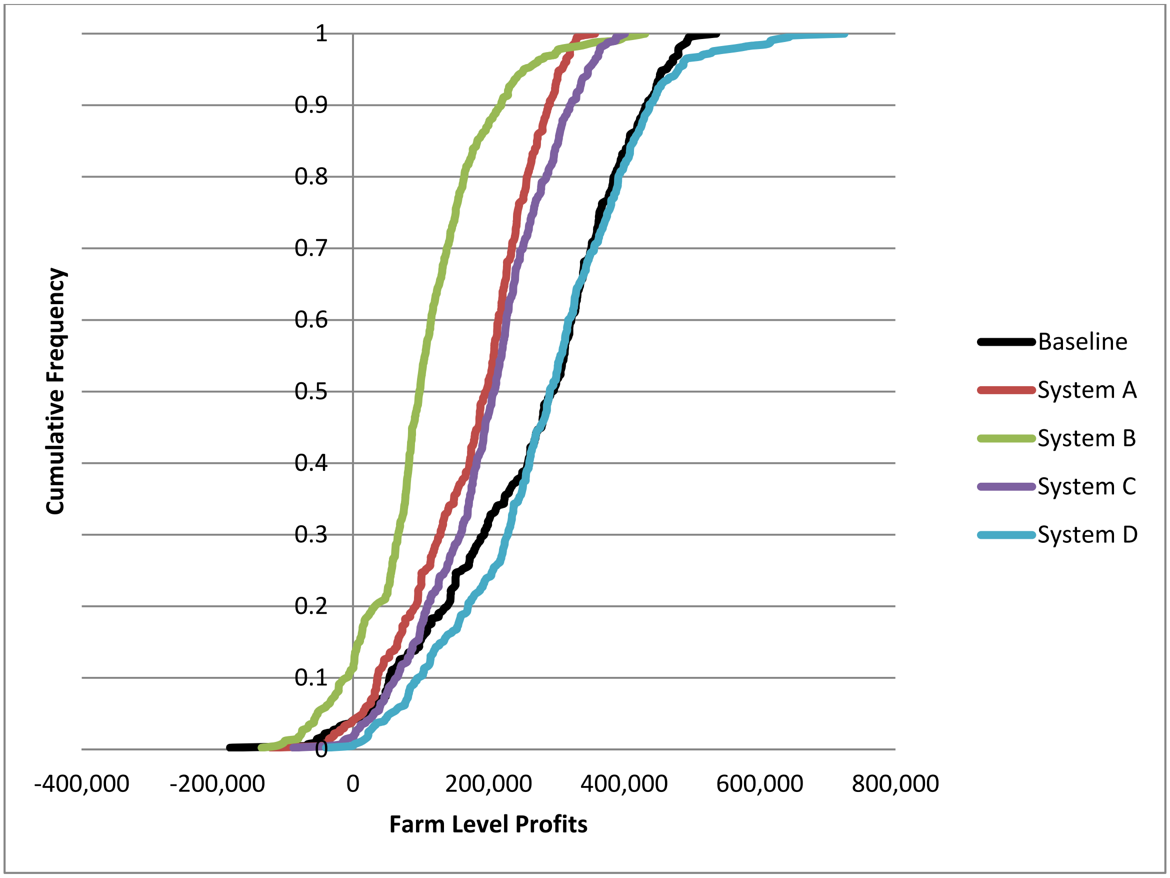
Results

Profits in each frequency are sorted from lowest to highest to produce the cumulative historical frequencies illustrated in Figure 3. It is clear that *Water Conserving System B* has the highest cumulative frequency of negative returns for the cropping system at 11.4%. The cumulative frequency of negative returns is observed where the green curve (System B) crosses the vertical axis that intersects the horizontal axis at $0 profits. The lower the crossing of the vertical axis, the less frequent are negative returns in the simulation. Farm managers are often concerned with negative profits when contemplating alternative cropping systems, so system B may be one of the least preferred as it crosses the axis higher than all other cropping systems.

Less separation is found among the remaining cropping systems when negative returns are considered – nearly all of the systems cross the vertical axis at the same cumulative frequency. A slight preference exists for systems D (0.5% cumulative frequency for negative profits) and system C (1% cumulative frequency for negative profits). The *Baseline System* receives negative profits 3% of the iterations.

Examining the left hand side of the graph illustrates the "downside risk" of a cropping system where the downside is a negative profit outcome. Also relevant is the "upside potential" of the frequency that can be judged by the right-hand side. Upside potential refers to the frequency of achieving very high profits and these years are the ones in which significant farm equity is generated. Inspecting Figure 3 suggests substantial differences between the highest upside potential of cropping systems (*System D and Baseline*) compared to the others. In fact, *System D* is preferred to the other systems over the entire range of positive profits.

Figure 3. Cumulative Frequency of Profits for Simulated CU Conserving Systems (500 iterations)



Summary statistics for the simulated returns are reported in Table 1, and these results reinforce the preference for *Water Conserving System D* relative to the other alternatives. System D exhibits the greatest mean profit level, the lowest standard deviation, the greatest minimum profit level and the greatest maximum profit level. This system's use of irrigated corn tends to enhance profits in most years, and the use of irrigated wheat improves its performance over dryland wheat (*System C*) and fallowing (*Systems A and B*). It also performs well relative to the baseline, in no small part because of higher wheat prices relative to wheat costs in recent years. However, this rotation does not conserve the most CU (bottom row of Table 1), and its standard deviation of profits is among the highest representing a potentially significant source of cash flow risk to the farm manager.

Table 1: Summary Statistics of Profits for Cropping Systems (1980 – 2010 Data Foundation)

	Baseline ($)	***System A ($)***	***System B ($)***	***System C ($)***	***System D ($)***
Mean Profit	$265,240	$176,836	$103,044	$199,517	$285,354
Standard Dev.	$138,641	$92,432	$90,638	$94,707	$130,797
Coefficient of Variation	52	52	88	47	46
Minimum Profit	$-181,317	$-120,884	$-134,725	$-87,893	$-39,825
Maximum Profit	$535,758	$357,190	$431,053	$401,131	$724,882
AF of Conserved CU	0	797	285	1,195	440
No. Of Acres Changed from Irrigated Corn	0	667	667	1,000	1,000

An important tradeoff exists – the most profitable system may not conserve the most CU. As an example, *Water Conserving System D's* mean profit is the highest among cropping systems, but only conserves 440 AF relative to the irrigated corn baseline (second to last row in Table 1). The CU is conserved by reducing the number of acres of irrigated corn by 1,000, which is also a large change relative to system A and B. The opportunity cost per unit of CU and/or per acre is an important metric for farm managers and leasers alike, so the results are also tabulated on these bases in Table 2 and Table 3.

Table 2: Opportunity Cost of Switching to a CU Conserving System as Measured on a Per Acre Basis

	System A ($/ac)	***System B ($/ac)***	***System C ($/ac)***	***System D ($/ac)***
Mean Opportunity Cost	$ 132	$238	$65	$-24
Standard Deviation	$72	$160	$70	$90
Coefficient of Variation	55	67	107	-384
Minimum Opportunity Cost	$-91	$-222	$-126	$-466
Maximum Opportunity Cost	$268	$643	$247	$256
No. of Acres Changed from Irrigated Corn	667	667	1,000	1,000

In Table 2, the mean of the opportunity cost frequencies ranges from $-24 per acre (*Cropping System D*) to $238 per acre (*Cropping System A*). Recall that the opportunity cost is the difference between an iteration's profit of the *Baseline Cropping System* and an alternative cropping system, so that a smaller opportunity cost implies less difference relative to the baseline and negative numbers imply the alternative system generated greater profits compared to the baseline. The alternative with both the greatest mean and standard deviation is *Cropping System B* – the corn-alfalfa-fallow rotation. Farm managers adopting this system may demand more compensation on a per acre basis than those adopting *Cropping System D*. Interestingly, the mean opportunity cost value for *Cropping System B* is similar, but generally lower to than that surveyed by Pritchett, Thorvaldson, and Frasier (2008) who found a mean willingness to accept of respondents comprised an interval between $150 to $383 per acre. Anecdotally, payment amounts of up to $500 per fallowed acre are found in the South Platte River Basin.

Farmers may also receive payment based on the acre-feet (AF) of conserved CU. Table 3 summarizes the opportunity costs of adopting a cropping system, but with a focus on amount of conserved CU.

Table 3: Opportunity Cost of Switching to a CU Conserving System per Acre Foot of Consumptive Use (CU) Conserved

	System A (\$/AF of CU)	***System B (\$/AF of CU)***	***System C (\$/AF of CU)***	***System D (\$/AF of CU)***
Mean Opportunity Cost	\$111	\$569	\$55	\$-46
Standard Deviation	\$58	\$363	\$56	\$199
Coefficient of Variation	52	64	102	-435
Minimum Opportunity Cost	\$-76	\$-519	\$-106	\$-1,060
Maximum Opportunity Cost	\$224	\$1,504	\$206	\$583
Acre Feet of CU Conserved on Farm	797	285	1,195	440

Water Conserving System C provides interesting results for opportunity cost per AF of conserved CU. The system is a combination of irrigated corn on 1/2 of its acres and dryland (non-irrigated) wheat on the remaining acres. The introduction of dryland wheat gives it a substantial CU conservation total relative to *Water Conserving System D* – 1,195 AF of conserved CU versus 440 AF of conserved CU respectively. The mean opportunity cost of \$55 per AF is slight compared to systems A and B, and it exhibits a lower cash flow risk (\$56 standard deviation) and a modest coefficient of variation. The addition of dryland wheat provides an improved level of profitability relative to fallowing in *Water Conserving System A*, and does not increase cash flow risk as measured by standard deviation.

Sensitivity Analysis: Examining Price Conditions for 2006 through 2010

The results reported in the previous table are derived via random draws from an historical dataset that ranges from 1980 to 2010. These draws are pertinent so long as the structural and biophysical relationships for crop farming resemble that of the past. Yet, structural changes have occurred during the time period including improved plant genetics, increasing international market interdependence, a changing farm policy, etc. As a sensitivity analysis, the simulation process of Figure 2 is repeated, but only for a data foundation that consists of the five years 2006 through 2010. It may be the case that these more recent years are a better representation of future activity compared to the larger data set. Table 4 provides a results summary of simulating from the smaller, more recent dataset.

Table 4. Summary Statistics of Profits for Water Conserving Systems (2006 – 2010 Data)

	Baseline ($)	***System A ($)***	***System B ($)***	***System C ($)***	***System D ($)***
Mean Profit	$687,453	$458,325	$363,902	$448,384	$584,570
Standard Deviation	$637,671	$425,135	$331,122	$394,814	$386,631
Coefficient of Variation	93	93	91	88	66
Minimum Profit	$30,975	$20,651	-$53,377	$5,467	$66,727
Maximum Profit	$2,063,254	$1,375,572	$1,147,951	$1,355,433	$1,465,667
Acre Feet of CU Conserved on Farm	0	797	285	1,195	440
No. Of Acres Changed from Irrigated Corn	0	667	667	1,000	1,000

At first glance, it’s clear that favorable prices and yields increase the mean profits of every cropping system. The *Baseline Cropping System* generates the highest profits on average (second row of Table 4) followed by *Water Conserving System D* and *Water Conserving System A.* The *Baseline Cropping System* is able to reap the benefits of relatively high corn prices and improved corn yields in 2006 – 2010. *Water Conserving System D* is preferred as an alternative given its higher mean, and relatively less risk as measured with the coefficient of variation. *Water Conserving System B* remains the least preferred alternative.

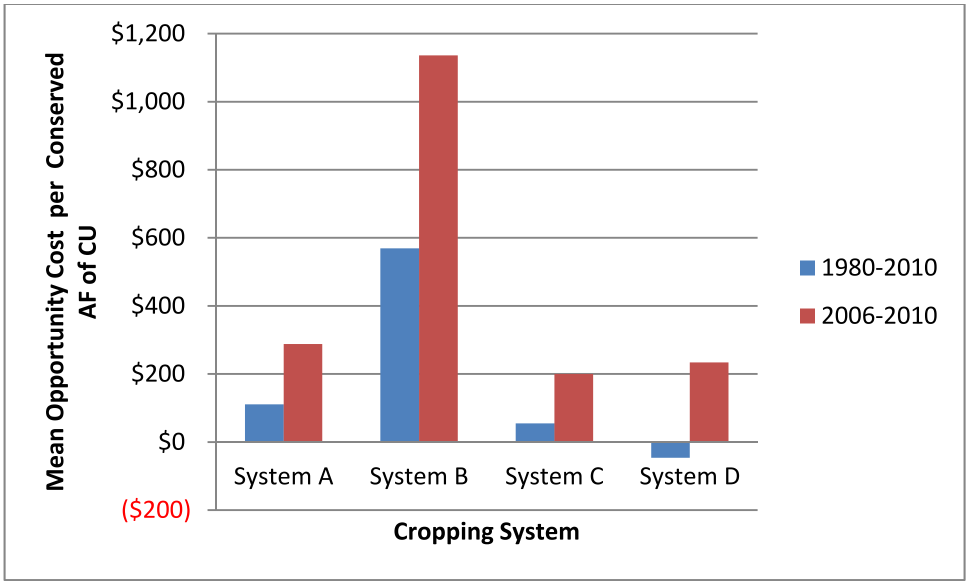
The changing profitability of the smaller, recent data foundation suggest greater opportunity cost for adopting CU conserving cropping systems. Results of the opportunity cost calculation per AF of conserved CU are summarized in Table 5.

Table 5: Opportunity Cost of Switching to a CU Conserving System per Acre Foot of Water Conserved (2006 to 2010 Data)

	System A ($/AF of CU)	***System B ($/AF of CU)***	***System C ($/AF of CU)***	***System D ($/AF of CU)***
Mean Opportunity Cost	$288	$1,136	$200	$234
Standard Deviation	$267	$1,153	$210	$691
Coefficient of Variation	93	101	105	295
Minimum Opportunity Cost	$13	$697	$95	$1,225
Maximum Opportunity Cost	$863	$3,977	$698	$1,847
Acre Feet of CU Conserved on Farm	797	285	1,195	440

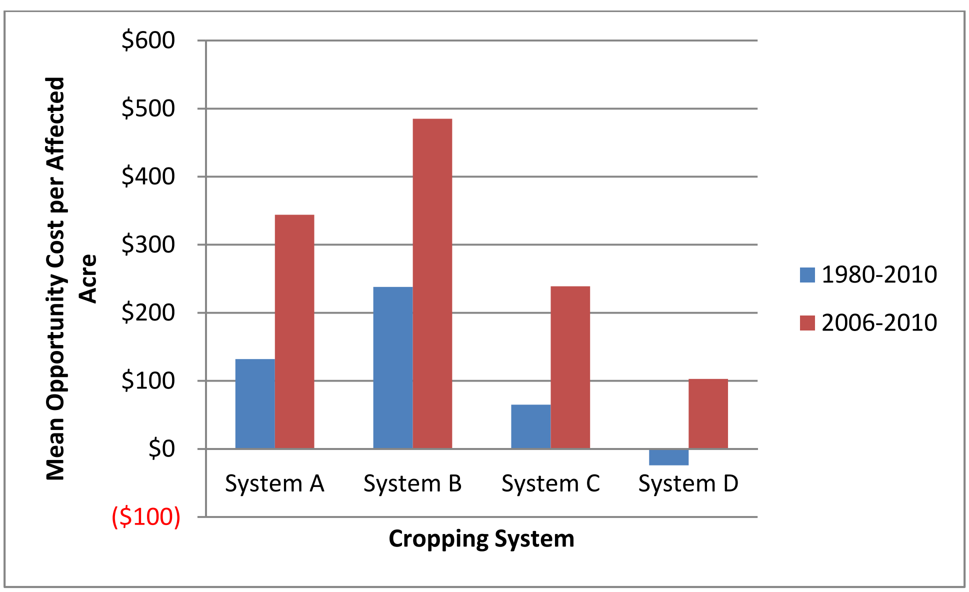
The mean opportunity cost per AF of conserved CU is reported in the second row of Table 5, and as might be expected, the values are substantially larger than in Table 3. The range of values is from $200 per AF of conserved CU for *Water Conserving System C* to more than $1,000 per conserved CU for *Water Conserving System B.* The rank ordering by mean opportunity cost is slightly different – *Water Conserving System C* supplants *Water Conserving System D* while still conserving the most CU. Figure 4 charts the mean opportunity cost values for the cropping systems in both the smaller and larger datasets indicating the differences both between systems and across the different time periods.

Figure 4. Mean Opportunity Costs per AF of Conserved CU of Cropping Systems (2006-2010 Data)



A similar figure illustrates the opportunity cost for the smaller data set on a per affected acre basis. As the case with the previous figure, using the latter years as a data foundation increases the opportunity cost relative to the full dataset. The range of opportunity cost is closely aligned with the range of surveyed willingness to accept from Thorvaldson, Pritchett and Frasier (2008) and is illustrated in Figure 5.

Figure 5. Mean Opportunity Costs per Acre of Cropping Systems (2006-2010 Data)



Water Conserving System D has the smallest mean opportunity cost per acre, suggesting that it is desirable for the crop manager as it provides the smallest profit decline. It is also (potentially) desirable for the leaser, who might choose to compensate the crop manager for adopting a system in place of the *Baseline Cropping System*. In this type of lease, both parties are interested in the size and frequency of payments that will make the difference. Table 6 summarizes this information. Perhaps most significantly, *Water Conserving System D* exhibits the greatest frequency of small payments using the recent years' data, but also demonstrates the greatest frequency of large payments because of difference in 'upside potential' when profits are very high for corn. The 'upside potential' is similar to the right hand side divergence of the cumulative frequencies first illustrated in Figure 3.

Table 6. Frequency of Compensation Payment ($/AF of CU) in a Certain Range in Order to Achieve Baseline Cropping System Profits (2006-2010)

	System A	**System B**	**System C**	**System D**
Less than $100/AF of CU	10%	10%	40%	47%
Between $100 and $200 / AF of CU	60%	3%	37%	9%
Between $200 and $600/ AF of CU	8%	25%	15%	22%
Greater than $600/ AF of CU	22%	62%	9%	22%

Water Conserving System C generates compensation payments of $200 or less 77% of the time, compared to System D's payments of $200 or less 56% of the time. *Water Conserving System* D receives large payments (greater than $600) 22% of the time compared to just 9% of the time for System C. In this sense, System D is more susceptible to loss of upside potential compared to System C.

Conclusions and Discussion

Temporary leases are one instrument receiving attention for replacing 'buy and dry' transactions. The purpose of this article is to explore one facet of water leases -- a farmer's opportunity cost for adopting water conserving crop rotations when entering leasing arrangements.

From a farm manager's perspective, the opportunity cost of switching to a cropping system depends importantly on an expectation of profits, and the expectation includes the potential for low or high profits. In order to gain a better understanding of values that create an expectation, a simulation model is developed to measure the profits of a baseline, irrigated corn cropping system as well as for four other systems that conserve consumptive use water. Prices and yields are allowed to vary in a range and correlation consistent with the historical (1980-2010) data generation process. The simulation leads to a profit frequency for each cropping system that can be compared against one another. Likewise, an opportunity cost frequency is created by calculating the difference between an iteration's profit from the baseline system and the alternative cropping system.

The profit frequency comparison suggests that *Water Conserving System D*, which is comprised of irrigated corn and irrigated wheat, is a system with the highest mean profits and smallest likelihood of negative profits. *Water Conserving System B*, which contains equal parts of corn, alfalfa and fallow, is the least favorable. When illustrated as a cumulative frequency (Figure 1), it is clear that small differences exist between the systems when profits are low, but large differences distinguish one cropping system from another when profits are high. Put more simply, the cropping systems have a similar downside potential, but very different upside potential, and it is the potential "loss" of high profits that may be most concerning to farm managers.

The opportunity cost of adopting cropping systems varies according to the profits – a higher opportunity cost exists for *Water Conserving System B* because its profits are substantially lower than the *Baseline Cropping System.* As might be expected, *Water Conserving System D* has lowest opportunity cost and often outperforms the *Baseline Cropping System* over the 1980 – 2010 historical data foundation.

From a crop manager's perspective, *Water Conserving System D* generates the most profitable outcome for CU conservation if payment is not made. This system removes 440 acre feet of water from production, and alters ½ of the corn acreage to wheat. From a leaser's perspective, *Water Conserving System D* likely requires the least amount of compensation per unit of water removed from production because it has the lowest opportunity cost. However, in the case that the leaser is interested in a largest quantity of water, *Water Conserving System C* would be the best alternative, requiring a minimum compensation of at least $55 per acre foot of CU with potential of acquiring 1,195 AF of CU.

Recent years have seen an increase in the local harvest cash price received for commodities such as corn and wheat, at the same time improved yields are realized for these irrigated field crops compared to previous decades. As a result, a sensitivity analysis is performed focusing on a 2006 to 2010 data foundation for a new set of iterations. In this simulation, the *Baseline System* is easily the most profitable cropping system, and the opportunity cost of switching from a 100% irrigated corn crop is substantial. The mean opportunity cost ranges from $103 per acre to $485 per acre, which is similar to previous surveys of farmer willingness to accept for fallowing (Thorvaldson, Pritchett and Frasier, 2008.)

A limitation of this study is its focus on specific conditions – the irrigated farm is representative of the South Platte River Basin. Different farms may experience differing yields and prices depending on biophysical and marketing circumstances. The results are also limited by the historical dataset – results will be generalizable only to the extent that the future was like the past.

Having written that, common elements do emerge from the results that can be extended to other cases. First, a combination of corn and wheat in a cropping system is almost always desirable compared to a fallow system or the corn-alfalfa-fallow system. The result is intuitive – from the crop manager's perspective it is almost always better to crop land than to have it sit idle. It is also true that the system provides some flexibility for the crop manager and the contracting leaser in a water conserving agreement – the wheat crop can be planted and irrigated as the water year unfolds. If water is needed, the crop remains non-irrigated, but if water is available it can be set to the wheat crop. The water conservation in this simulation ranges from 440 AF of conserved CU in *Water Conserving System D* to 1,195 AF of CU in *Water Conserving System D*. In this type of an arrangement, the wheat can act as a drought "reservoir" for the leaser that is adjustable depending on circumstances.

Crop managers are concerned with both the upside and downside potential in alternative cropping systems. Upside potential is the inability to seize the profits in years during which prices are quite high and yields are above average. Downside potential refers to years when profits are quite low because of low prices and/or poor yields. This analysis suggests little difference exists in the cropping systems for downside potential, but substantial differences occur on the upside, and this might make crop managers less likely to sign leases. Payment contingencies might help to alleviate the crop managers' concerns. One alternative is a two-step payment program: the initial, baseline payment, would be paid to the producer when cropping decisions are made in the Fall, and a second payment is made when harvest prices are realized. These prices can be a fixed interval above/below a publicly reported price such as the Chicago Board of Trade.

This research focuses on a narrow face of leasing CU from cropping systems. The legal verification of conserved CU is a thorny issue, and transactions costs associated with monitoring, diverting and transferring CU cannot exceed the surplus from leasing arrangements for this institution to exist. Further research and thought are needed in these areas.

Works Cited

Pritchett, J., J. Thorvaldson and M. Frasier. 2008. "Water as a Crop: Limited Irrigation and Water Leasing in Colorado." Review of Agricultural Economics. Vol 30. No. 3. pp. 435-444.

Serbina, L. 2012. Describing and Quantifying Revenue Risk Producers Face When Adopting Water Conserving Cropping System. Unpublished Master of Science Thesis. Colorado State University. Fort Collins, Colorado.

Appendix C: Completion Report: Opportunity Costs in Water Saving Crop Rotations

Completion Report: Opportunity Costs in Water Saving Crop Rotations

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Abstract: Water leasing contracts may be a viable alternative to ‘buy and dry’ transactions in Colorado. The purpose of this research is to examine one aspect of leasing: the opportunity cost of farmers who adopt water conserving crop rotations that might be used for leases. Farmers seek an understanding of what crop rotations might be used to conserve consumptive use (CU), and how these rotations influence the farm’s profitability and the variability of these profits. This understanding will inform the development of mutually agreeable leases and levels of compensation between farm managers and water suppliers. For those seeking to lease irrigation water, the information will inform their strategic planning for obtaining reliable water supplies.

From a farm manager’s perspective, the opportunity cost of switching to a cropping system depends importantly on an expectation of profits, and the expectation includes the potential for low or high profits. In order to gain a better understanding of values that create an expectation, a simulation model is developed to measure the profits of a baseline, irrigated corn cropping system as well as for four other systems that conserve consumptive use water. Prices and yields are allowed to vary in a range and correlation consistent with the historical (1980-2010) data generation process. The simulation leads to a profit frequency for each cropping system that can be compared against one another. Likewise, an opportunity cost frequency is created by calculating the difference between an iteration’s profit from the baseline system and the alternative cropping system.

Results suggest a combination of corn and wheat in a cropping system is almost always desirable compared to a fallow system or the corn-alfalfa-fallow system. The result is intuitive – from the crop manager’s perspective it is almost always better to crop land than to have it sit

idle. It is also true that the system provides some flexibility for the crop manager and the contracting leaser in a water conserving agreement – the wheat crop can be planted and irrigated as the water year unfolds. If water is needed, the crop remains non-irrigated, but if water is available it can be set to the wheat crop. The water conservation in this simulation ranges from 440 AF of conserved CU in an irrigated corn-wheat rotation to 1,195 AF of CU in an irrigated corn - dryland wheat rotation. In this type of an arrangement, the wheat can act as a drought “reservoir” for the leaser that is adjustable depending on circumstances.

Crop managers are concerned with both the upside and downside potential in alternative cropping systems. Upside potential is the inability to seize the profits in years during which prices are quite high and yields are above average. Downside potential refers to years when profits are quite low because of low prices and/or poor yields. This analysis suggests little difference exists in the cropping systems for downside potential, but substantial differences occur on the upside, and this might make crop managers less likely to sign leases. Payment contingencies might help to alleviate the crop managers’ concerns. One alternative is a two-step payment program: the initial, baseline payment, would be paid to the producer when cropping decisions are made in the Fall, and a second payment is made when harvest prices are realized.

Opportunity Cost in Water Conserving Cropping Systems

Colorado's population is expected to double in the next twenty years substantially increasing municipal and industrial water demand (SWSI, 2010). As population grows in urban centers, additional households' water needs will be met via storage, improved efficiency and reallocation away from agriculture. Reallocating is often cited as a low cost alternative, and state agencies forecast that up to 1 million acre feet (AF) will shift use.

In Colorado's decentralized water system, the de facto method of reallocating water is an outright sale of water from agricultural interests to municipal water providers in a voluntary exchange. The good being exchanged is a consumptive use (CU) amount of water, and the calculation of CU is based on historical cropping patterns. The water sale is generally accompanied by a dry-up of the formerly irrigated lands, and this activity is broadly known as 'buy and dry[1].'

'Buy and dry' activity can be politically contentious and undesirable to many stakeholders in Colorado, urban and rural alike. Significant momentum and investment is being made in alternative forms of transactions, such as water leases, that still meet the needs of water users without creating concentrated, permanent fallowing of irrigated acres. These water leases require crop rotations that conserve CU, such as the fallowing of a crop or planting of a non-irrigated crop in lieu of full irrigation. The conserved CU is transferred to other users via storage or used as a credit in some form of exchange with other water users.

A host of issues -- legal, political, environmental, and scientific -- need be resolved in order for water leases to be a successful instrument for meeting reallocation objectives. The purpose of this report is to explore one facet of these issues -- a farmer's opportunity cost of

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[1] Permanent fallowing of land provides a simple means for verifying that irrigation water has been removed from the land and consumptive use is no longer occurring.

adopting water conserving crop rotations when entering leasing agreements. In this case, the opportunity cost is what farmers give up when adopting the water conserving crop rotation

Farmers seek an understanding of what crop rotations might be used to conserve CU, and how these rotations influence the farm's profitability and the variability of these profits. This understanding will inform the development of mutually agreeable leases and levels of compensation between farm managers and water suppliers. For those seeking to lease irrigation water, the information will inform their strategic planning for obtaining reliable water supplies.

It's useful to think about these questions in a specific farm contest, so this report focuses a representative farm located in western Weld County and

(a) characterizes CU water conservation in various crop rotations;

(b) quantifies the mean expected profits for these rotations, the foregone profit relative to the irrigated baseline (known as an opportunity cost) and the dispersion of foregone profits about the mean expected profit level; and

(c) compares crop rotation profit and opportunity cost frequencies according to various risk criteria.

Risk analysis is often used when comparing farm level marketing strategies (Tomek and Peterson, 2001), but very little literature considers risk assessment of irrigated cropping systems. The only two examples appear to be Karagiaannis et al. (2003) who examine irrigation efficiency using a stochastic production frontier of Greek crops, and the Taylor et al. (1993) case study of irrigation in the Arkansas River Basin of Colorado. It should be noted that dry-land cropping systems have been the subject of risk analysis (Fathelrahaman, 2010; Elder, 2004; Williams, 1988; Williams et al., 1990), but economic research in irrigation more often involves assessment of water pricing (Goodman and Howe, 1997; Shuck and Green, 2002) or allocative efficiency and technology adoption (Carey and Zilberman, 2002) rather than a comparison of cropping systems. To the authors' knowledge, this is the first research to compare deficit irrigation crop rotations in the context of water leasing, and the first to perform a risk analysis of the opportunity cost of these rotations vis a vis a fully irrigated baseline.

In the text that follows, an analytical model characterizes profits for various crop systems and describes the opportunity cost of CU conserving systems relative to a fully irrigated baseline. A specific example is developed for a representative farm. Profit distributions are empirically generated for representative cropping systems by allowing yields and prices to vary. Interpretation of results, discussion of relevant issues and limitations follows.

Analytical Description of CU Conserving Crop Rotations and Opportunity Cost

This section poses an analytical framework for measuring the profits of an irrigated cropping system and then introduces risk to the system by allowing for variation in prices and yields. The framework's focus is a farm manager's view of the opportunity cost when choosing among cropping systems. Let farm level profits, π , for an irrigated cropping system *i* be defined as:

(1) $\pi^i = \pi^i(p, v, y_i, x_i)$

where y_i is a vector of output quantities produced with cropping system i and sold competitively at price vector p, x_i is the vector of input quantities purchased competitively at price vector v . In this simple formulation, all prices and quantities are known with certainty. The output and input are indexed by the cropping system type i as some cropping systems will produce differing amounts of output using different input levels.

The irrigated crop manager prefers the i^{th} cropping system to an alternative system *j* when

(2) $\pi^i(p, v, y_i, x_i) \geq \pi^j(p, v, y_j, x_j)$

If the irrigated crop manager signs a lease to produce a less profitable rotation, the least payment,φ, must be at least as large as the difference in profits. The opportunity cost of producing an alternative cropping system is defined as:

$$(3)\quad \varphi\left(\pi^{i},\pi^{j}\right) \equiv \pi^{i}(p,v,y_{i},x_{i}) - \pi^{j}\left(p,v,y_{j},x_{j}\right)$$

and may be generalized to create a pairwise comparison of many different systems. The difference φ may not be the actual lease price signed by a farm manager, as factors such as limited information, market power, the relative strength of demand, transactions costs and other factors come into play.

The farm manager is concerned not only in the level of φ when considering the type of cropping system to adopt, but how it might vary from expectations in any given year, and perhaps what are perceived to be the extreme highs and lows -- φ_u and φ_l respectively. In general, leases are signed before uncertain harvest time prices and yields are realized, and it's not always the case that the *i*th cropping system will maintain a profit advantage over the *j*th cropping system when the harvest is realized. As result, the manager must develop expectations on the potential distribution of φ as in:

$$(4)\ \emptyset = \int_{\varphi_l}^{\varphi_u} \varphi\left(\pi^{i},\pi^{j}\right)\, d\varphi$$

An important objective of this research is to characterize ∅ by simulating profits when output prices (*p*) and yields (*y*) are drawn via a historical bootstrapping process. The empirical ∅ is characterized by risk criteria that mimic a farm manager's concerns. Risk criteria includes mean profit levels, standard deviation of profit, coefficient of variation, and illustration of the cumulative frequency. The empirical formulation of the cropping system model is found in the next sub-section.

Empirical Formulation: water input, yields, conserved water and profits

An empirical model is needed that calculates a cropping system's profits when prices and yields are stochastically determined. Consider a formulation of the profit for the i^{th} cropping system represented in equation (1) as:

(5) $\pi = R\ (y, p) - C(\text{x,v})$

where π represents profit, R is revenue and C is cost. Revenues can be disaggregated into outputs and their associated prices:

(6) $R = \sum_{l=1}^{L} p_l * y_l$

where l= 1…L for any given crop . The cost of production is the product of input prices and quantities, in the absence of fixed costs:

(7) C = $\sum_{n=1}^{N} v_n * x_n$

where n= 1…N. In the case of crop production, such inputs would be fuel, fertilizer, seed, herbicide, labor, hauling and irrigation costs.

The amount of crop produced, y_l , is assumed to be an outcome of its inputs according to a production relationship. Separating the water input (*w)* from all others (*z*), the production relationship is written as:

(8) $y_l = f\left(w_{l,}, z_l \mid A\right)$

In equation 8, $w_{l,}$ is the amount of water input associated with its l^{th} output measured on net CU basis. A is an exogenous variable for a fixed number of acres in system. Inserting variables from equations 6 through 8 into equation 5 creates a more detailed profit function for the i^{th} crop rotation:

(9) $\pi^i\ (w, y) = \sum_{l=1}^{L} p_l * y_l - w_l * v_l - \sum_{n=1}^{N} v_n * z_{n,l}$

where revenue $(p_l * y_l)$ is offset by the cost of water ($w_l * v_l$) and the cost other inputs $\sum_{n=1}^{N} v_n * z_{n,l}$

Importantly, equation (9) treats prices and yields as deterministic. In the simulation procedure described below, yields and prices are randomly selected in a way that preserves the underlying historical data generation process. Simply put, local harvest prices are determined by national supply and demand conditions, transactions costs and local supply and demand. Local prices and local yields are often correlated, but not perfectly. For example, seldom do high prices and high yields persist at the same time unless there is a national shortfall in supply that is not experienced locally. Data limitations make it difficult to quantify this relationship structurally, hence why an historical data generation process is used.

Indeed, an iteration of the model will include calculating profit as depicted in equation (9) for various cropping systems once crop prices and yields are drawn randomly. The baseline system is an irrigated continuous corn system. The opportunity cost of switching to another system is calculated according a combination of equation (3) and (9):

$$(10) \quad \varphi\left(\pi^{i}, \pi^{B}\right) \equiv \pi^{i}(p, v, y_{i}, z_{i}, w_{i}) - \pi^{B}(p, v, y_{B}, z_{B}, w_{B})$$

where B denotes the baseline rotation. Equations (9) and (10) are solved in every model iteration, and the profits and opportunity costs are collected as two different frequencies. The cropping system CU is also calculated and is subtracted from that of the baseline rotation in order to determine the CU conservation of adopting a new system:

$$(11) \; CU_{CON} = CU_{B} - CU_{j} = \sum_{l=1}^{L} w_{l}^{B} - \sum_{l=1}^{L} w_{l}^{j}$$

where CU for the l^{th} crop is determined in the j^{th} system from a known yield and CU relationship (Serbina, 2012). CU_{CON} is useful when comparisons of cropping systems are made in terms of the opportunity cost per acre foot (AF) of water conserved, i.e. $\frac{\varphi(\pi^{i},\pi^{B})}{CU_{CON}}$. Increasing the amount of conserved CU may make a cropping system more attractive to leasers, but will reduce profits for crop managers.

Data and Simulation Procedure

A simulation calculates the financial tradeoffs that exist when adopting different cropping systems under uncertain price and yield conditions. The model has been characterized in the previous equations, but the simulation approach and data used to populate the model needs be described.

Due to the physical limits, data deficiencies and time constraints in research, a simulation procedure is the most practical approach to the current research problem, and has been used in similar work. In 2010, Fathelrahaman et. al conducted an economic and stochastic efficiency comparison of tillage systems. When comparing the various tillage systems, gross margin and profits distributions are simulated. Distributions are compared using mean, median, standard deviation, and stochastic efficiency with respect to a function (SERF). The current research is similar in that the net profit and opportunity cost frequencies are generated and compared using criteria similar to that posited by Fathelrahaman et al.

Using a simulation approach, Calatrava and Garrido (2005) simulate farm profits with deterministic profit functions and stochastic water supplies. Profit distributions for alternative cropping systems are quantified and compared. The authors note that producers have a lower probability of profits that reach their lowest levels when water leasing or trading options are available. Results suggest that mean and median profits are always greater in a scenario with a water market as opposed to no-trade situation. The unit of analysis is at a water market level, while the current research focuses on farm level assessment of profits and risks.

In this research, profits stemming from a “baseline” cropping system (e.g., 100% irrigated corn) are calculated and compared to CU water conserving systems (e.g, 50% corn, 50% fallow) that are illustrated in Figure 1.

The *Baseline Cropping System* is a 100% irrigated corn system typical in the South Platte River Basin where as much as 70% of irrigated farm acres are comprised of corn that is either harvested for grain or silage (USDA-NASS).

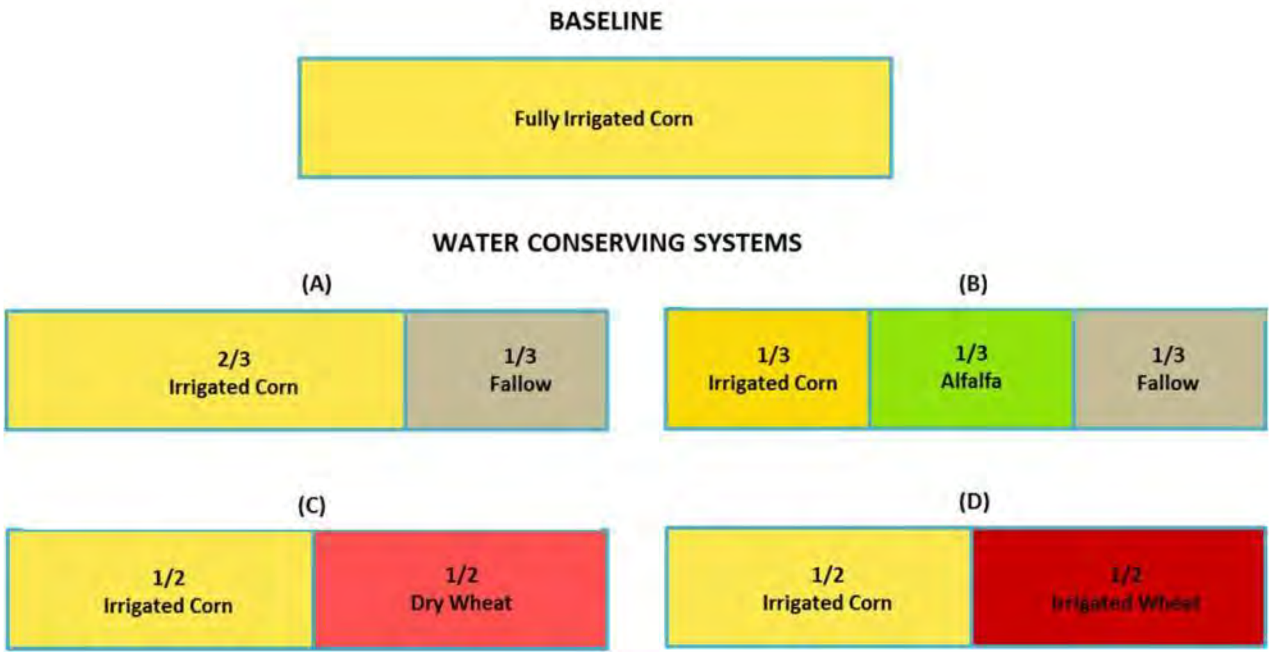
Water Conserving System A is a slight adjustment to the *Baseline Cropping System*, as irrigated corn is planted on 2/3 of the farm acres and 1/3 is fallowed. This system is also consistent with a farm planted entirely to irrigated corn in two of three years, but the farm is fallowed in the other year. Presumably, the conserved water from the fallow period is available for lease.

Water Conserving System B includes two crops that are of particular importance in the basin, irrigated corn and irrigated alfalfa, and these are often used in rotation with one another. System B also includes a fallow portion on one-third of its acres. While the water conservation in system A and B are similar, the introduction of different crops may influence the potential distribution of farm profits.

Water Conserving System C is comprised of one-half irrigated corn and the rest in dryland (non-irrigated) wheat. The introduction of wheat is likely to improve returns relative to a fallow system such as *Water Conserving System A.* It should be noted that while some farms in the South Platte River Basin are able to grow dryland wheat with their soils, equipment and managerial expertise, this not universally true, so system C is not an option for all farms.

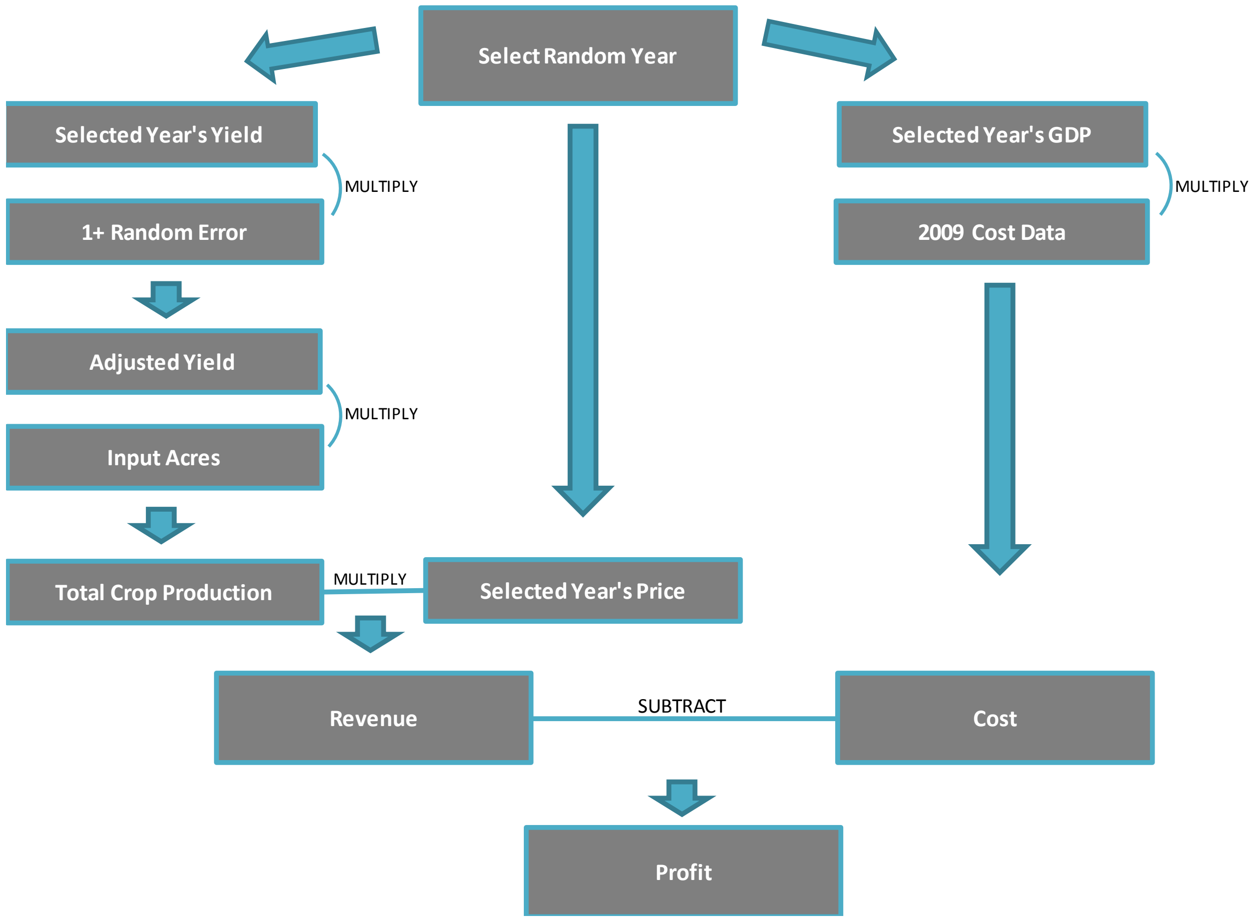
Water Conserving System D replaces non-irrigated wheat in *Water Conserving System C* with irrigated wheat, and retains the same amount of irrigated corn. Irrigated wheat yields are substantially better than non-irrigated wheat yields, suggesting an increase in profits compared to dryland wheat. However, the CU water conservation of this system us not as large as that found in System C.

Figure 1: Cropping Systems



The systems represented in Figure 1 are applied to a 2,000 acre irrigated farm, which is of sufficient size to be attractive for water leases. The profits of the farm are calculated according to equation (5) for each of the systems illustrated in Figure 1, and this calculation is iteratively repeated for a variety of potential yield and price outcomes. Profits are collected for the iterations so that an empirical frequency can be characterized. Figure 2 illustrates the iteration process.

Figure 2: Illustration of the Iteration of Water Conserving System Profits



The iterative process begins with the selection of a random year from an historical dataset that ranges from 1980 to 2010. The dataset includes a time series for local harvest prices and county average yields. The selected year (e.g., 1985) becomes the base year for that iteration. Commodity prices for the base year are used directly in the calculation, but the yield from that year is adjusted with a random component to simulate farm level yield variation. This adjusted yield is calculated by adding a random percent error term to the selected base yield. The percent error term is selected from a de-trended, simulated percent error distribution derived from county-level, historical yields, a process described more fully in Serbina, 2012 and that has been used in other farm level simulations (e.g., Pritchett et al, 2004). The procedure ensures a potential variation in yields that have been demonstrated historically, while preserving the correlation between local production conditions and national/local prices. Without the random error term the sample would be drawn from a simpler historical distribution of yields, thus, the result would be the same distribution as that of the historical data meaning the potential risk of adopting a cropping system may be understated.

The number of acres in production is multiplied by the adjusted yield to calculate total production for the farm. Total production is multiplied by the commodity price and summed across crops to equal the total farm revenue. The production cost associated with the specific crop are adjusted to be in selected year dollars using the GDP ratio. The cost are then subtracted from revenue to obtain profit.

The difference between revenue and cost represents the potential profit obtained from producing a particular crop under that iteration's conditions. For a given iteration, the differences between the profit under the baseline system and the alternative systems represent potential foregone profits for the irrigator if they were to switch to the water conserving alternative. These opportunity costs are collected in sum, but also converted to opportunity costs per conserved CU as per equation 11.

It is important to note that profits do not include a payment for leased water associated with the conserved CU, and so it is hypothesized that profits for the alternative cropping systems are expected to be less than the baseline system. The farm profit calculation includes deficiency payments but omits the receipt of direct government payments,crop insurance premiums and indemnities.

Data

Yearly yield data for each crop is collected at the county level from 1980-2010. Yearly irrigated corn yields, irrigated and dry-land winter wheat yields, and irrigated alfalfa hay yields are collected via United States Department of Agriculture (USDA) Quick Stats and Colorado Agricultural Statistical Service Publications.

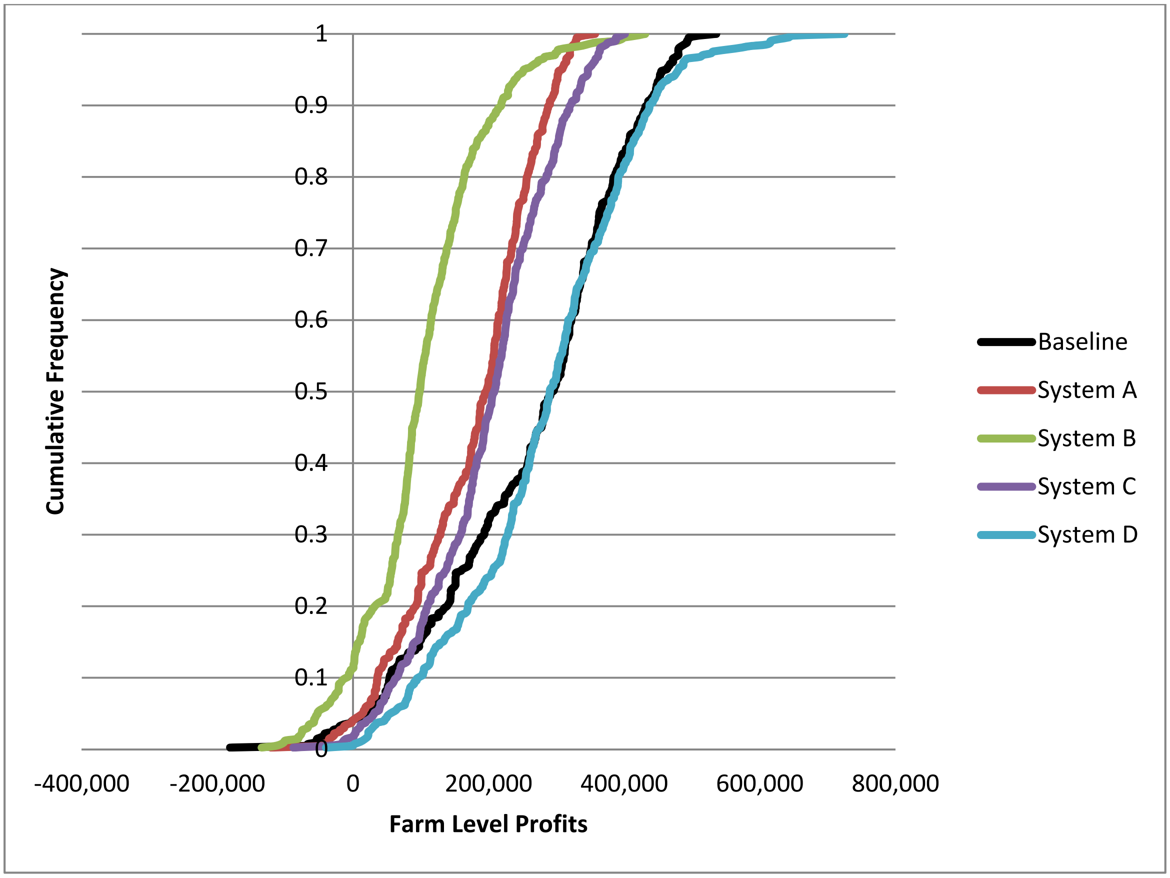
The price data for corn and wheat are acquired from the USDA Colorado Department of Agricultural Market and News Service from Greeley, Colorado. The price per bushel of corn is obtained using the averages of the prices in the month of November from 1981 to 2011 to represent a typical cash price received at harvest. The price per bushel of winter wheat is obtained using the averages of the prices in the month of August from 1981 to 2010. Target prices for these crops (used in the calculation of deficiency payments) are taken from USDA-ERS publications. The price for alfalfa hay per ton is given by the average of the prices in the month of July from 1980-2010.

Results

The overall objective of this study is to examine the opportunity cost to farmers of adopting CU water conserving cropping systems that are labeled *Water Conserving System A, B, C and D.* Profits are calculated according to equation 5, and these profits are compared to a *Baseline System* of continuous corn according to equation 10. The results of equation 10 are the opportunity cost of adopting the system as it is defined in this study. The uncertainty of prices and yields is characterized by the iterative process described in Figure 2. The model is iterated 500 times and the profits/opportunity costs are collected into empirical frequencies.

Profits in each frequency are sorted from lowest to highest to produce the cumulative historical frequencies illustrated in Figure 3. It is clear that *Water Conserving System B* has the highest cumulative frequency of negative returns for the cropping system at 11.4%. The cumulative frequency of negative returns is observed where the green curve (System B) crosses the vertical axis that intersects the horizontal axis at $0 profits. The lower the crossing of the vertical axis, the less frequent are negative returns in the simulation. Farm managers are often concerned with negative profits when contemplating alternative cropping systems, so system B may be one of the least preferred as it crosses the axis higher than all other cropping systems.

Figure 3. Cumulative Frequency of Profits for Simulated CU Conserving Systems (500 iterations)



Less separation is found among the remaining cropping systems when negative returns are considered – nearly all of the systems cross the vertical axis at the same cumulative frequency. A slight preference exists for systems D (0.5% cumulative frequency for negative profits) and system C (1% cumulative frequency for negative profits). The *Baseline System* receives negative profits 3% of the iterations.

Examining the left hand side of the graph illustrates the “downside risk” of a cropping system where the downside is a negative profit outcome. Also relevant is the “upside potential” of the frequency that can be judged by the right-hand side. Upside potential refers to the frequency of achieving very high profits. Farm managers are concerned with the upside potential of a system, as these years are the ones in which significant farm equity is generated. These years might also represent the highest opportunity cost of leasing conserved CU. Inspecting Figure 3 suggests substantial differences between the highest upside potential of cropping systems (*System D and Baseline*) compared to the others. In fact, *System D* is preferred to the other systems over the entire range of positive profits.

Summary statistics for the simulated returns are reported in Table 1, and these results reinforce the preference for *Water Conserving System D* relative to the other alternatives. System D exhibits the greatest mean profit level, the lowest standard deviation, the greatest minimum profit level and the greatest maximum profit level. This system’s use of irrigated corn tends to enhance profits in most years, and the use of irrigated wheat improves its performance over dryland wheat (*System C*) and fallowing (*Systems A and B*). It also performs well relative to the baseline, in no small part because of higher wheat prices relative to wheat costs in recent years. However, this rotation does not conserve the most CU (bottom row of Table 1), and its standard deviation of profits is among the highest representing a potentially significant source of cash flow risk to the farm manager.

Table 1: Summary Statistics of Profits for Cropping Systems (1980 – 2010 Data Foundation)

	Baseline ($)	***System A ($)***	***System B ($)***	***System C ($)***	***System D ($)***
Mean Profit	$265,240	$176,836	$103,044	$199,517	$285,354
Standard Deviation	$138,641	$92,432	$90,638	$94,707	$130,797
Coefficient of Variation	52	52	88	47	46
Minimum Profit	$-181,317	$-120,884	$-134,725	$-87,893	$-39,825
Maximum Profit	$535,758	$357,190	$431,053	$401,131	$724,882
Acre Feet of CU Conserved on Farm	0	797	285	1,195	440
No. Of Acres Changed from Irrigated Corn	0	667	667	1,000	1,000

An important tradeoff exists – the most profitable system may not conserve the most CU. As an example, *Water Conserving System D's* mean profit is the highest among cropping systems, but only conserves 440 AF relative to the irrigated corn baseline (second to last row in Table 1). The CU is conserved by reducing the number of acres of irrigated corn by 1,000, which is also a large change relative to system A and B. The opportunity cost per unit of CU and/or per acre is an important metric for farm managers and leasers alike, so the results are also tabulated on these bases in Table 2 and Table 3.

Table 2: Opportunity Cost of Switching to a CU Conserving System as Measured on a Per Acre Basis

	System A ($/ac)	***System B ($/ac)***	***System C ($/ac)***	***System D ($/ac)***
Mean Opportunity Cost	$132	$238	$65	$-24
Standard Deviation	$72	$160	$70	$90
Coefficient of Variation	55	67	107	-384
Minimum Opportunity Cost	$-91	$-222	$-126	$-466
Maximum Opportunity Cost	$268	$643	$247	$256
No. of Acres Changed from Irrigated Corn	667	667	1,000	1,000

In Table 2, the mean of the opportunity cost frequencies ranges from $-24 per acre (*Cropping System D*) to $238 per acre (*Cropping System A*). Recall that the opportunity cost is the difference between an iteration's profit of the *Baseline Cropping System* and an alternative cropping system, so that a smaller opportunity cost implies less difference relative to the baseline and negative numbers imply the alternative system generated greater profits compared to the baseline. The alternative with both the greatest mean and standard deviation is *Cropping System B* – the corn-alfalfa-fallow rotation. Farm managers adopting this system may demand more compensation on a per acre basis than those adopting *Cropping System D*. Interestingly, the mean opportunity cost value for *Cropping System B* is similar, but generally lower to than that surveyed by Pritchett, Thorvaldson, and Frasier (2008) who found a mean willingness to accept of respondents comprised an interval between $150 to $383 per acre. Anecdotally, payment amounts of up to $500 per fallowed acre are found in the South Platte River Basin.

Farmers may also receive payment based on the acre-feet (AF) of conserved CU. Table 3 summarizes the opportunity costs of adopting a cropping system, but with a focus on amount of conserved CU.

Table 3: Opportunity Cost of Switching to a CU Conserving System per Acre Foot of Consumptive Use (CU) Conserved

	System A ($/AF of CU)	***System B ($/AF of CU)***	***System C ($/AF of CU)***	***System D ($/AF of CU)***
Mean Opportunity Cost	$111	$569	$55	$-46
Standard Deviation	$58	$363	$56	$199
Coefficient of Variation	52	64	102	-435
Minimum Opportunity Cost	$-76	$-519	$-106	$-1,060
Maximum Opportunity Cost	$224	$1,504	$206	$583
Acre Feet of CU Conserved on Farm	797	285	1,195	440

Water Conserving System C provides interesting results for opportunity cost per AF of conserved CU. The system is a combination of irrigated corn on 1/2 of its acres and dryland (non-irrigated) wheat on the remaining acres. The introduction of dryland wheat gives it a substantial CU conservation total relative to *Water Conserving System D* – 1,195 AF of conserved CU versus 440 AF of conserved CU respectively. The mean opportunity cost of $55 per AF is slight compared to systems A and B, and it exhibits a lower cash flow risk ($56 standard deviation) and a modest coefficient of variation. The addition of dryland wheat provides an improved level of profitability relative to fallowing in *Water Conserving System A*, and does not increase cash flow risk as measured by standard deviation.

Sensitivity Analysis: Examining Price Conditions for 2006 through 2010

The results reported in the previous table are derived via random draws from an historical dataset that ranges from 1980 to 2010. These draws are pertinent so long as the structural and biophysical relationships for crop farming resemble that of the past. Yet, structural changes have occurred during the time period including improved plant genetics, increasing international market interdependence, a changing farm policy, etc. As a sensitivity analysis, the simulation process of Figure 2 is repeated, but only for a data foundation that consists of the five years 2006 through 2010. It may be the case that these more recent years are a better representation of future activity compared to the larger data set. Table 4 provides a results summary of simulating from the smaller, more recent dataset.

Table 4. Summary Statistics of Profits for Water Conserving Systems (2006 – 2010 Data)

	Baseline ($)	***System A ($)***	***System B ($)***	***System C ($)***	***System D ($)***
Mean Profit	$687,453	$458,325	$363,902	$448,384	$584,570
Standard Deviation	$637,671	$425,135	$331,122	$394,814	$386,631
Coefficient of Variation	93	93	91	88	66
Minimum Profit	$30,975	$20,651	-$53,377	$5,467	$66,727
Maximum Profit	$2,063,254	$1,375,572	$1,147,951	$1,355,433	$1,465,667
Acre Feet of CU Conserved on Farm	0	797	285	1,195	440
No. Of Acres	0	667	667	1,000	1,000

Changed from Irrigated Corn					

At first glance, it's clear that favorable prices and yields increase the mean profits of every cropping system. The *Baseline Cropping System* generates the highest profits on average (second row of Table 4) followed by *Water Conserving System D* and *Water Conserving System A.* The *Baseline Cropping System* is able to reap the benefits of relatively high corn prices and improved corn yields in 2006 – 2010. *Water Conserving System D* is preferred as an alternative given its higher mean, and relatively less risk as measured with the coefficient of variation. *Water Conserving System B* remains the least preferred alternative.

The changing profitability of the smaller, recent data foundation suggest greater opportunity cost for adopting CU conserving cropping systems. Results of the opportunity cost calculation per AF of conserved CU are summarized in Table 5.

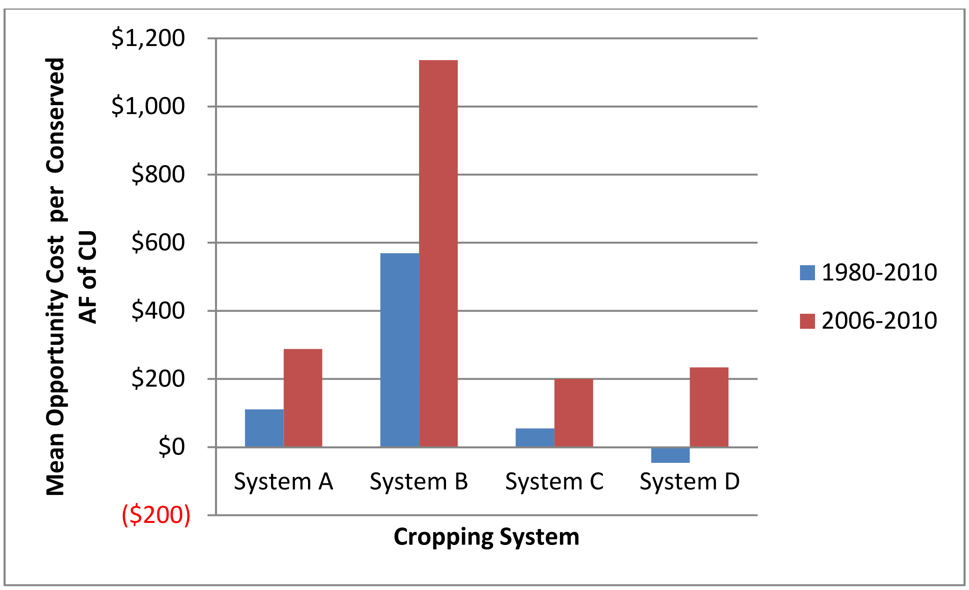
Table 5: Opportunity Cost of Switching to a CU Conserving System per Acre Foot of Water Conserved (2006 to 2010 Data)

	System A ($/AF of CU)	***System B ($/AF of CU)***	***System C ($/AF of CU)***	***System D ($/AF of CU)***
Mean Opportunity Cost	$288	$1,136	$200	$234
Standard Deviation	$267	$1,153	$210	$691
Coefficient of Variation	93	101	105	295
Minimum Opportunity Cost	$13	$697	$95	$1,225
Maximum Opportunity Cost	$863	$3,977	$698	$1,847

Acre Feet of CU Conserved on Farm	797	285	1,195	440

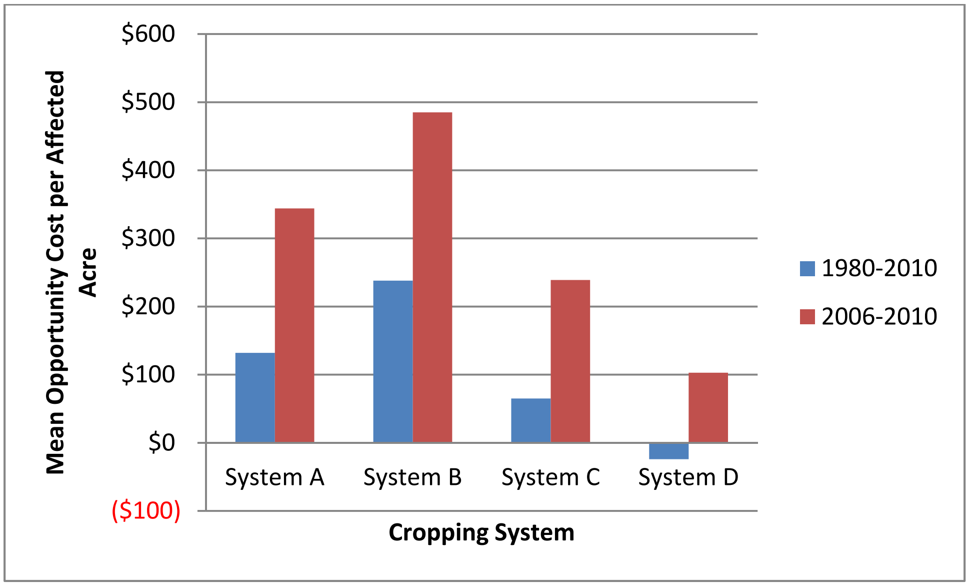
The mean opportunity cost per AF of conserved CU is reported in the second row of Table 5, and as might be expected, the values are substantially larger than in Table 3. The range of values is from $200 per AF of conserved CU for *Water Conserving System C* to more than $1,000 per conserved CU for *Water Conserving System B.* The rank ordering by mean opportunity cost is slightly different – *Water Conserving System C* supplants *Water Conserving System D* while still conserving the most CU. Figure 4 charts the mean opportunity cost values for the cropping systems in both the smaller and larger datasets indicating the differences both between systems and across the different time periods.

Figure 4. Mean Opportunity Costs per AF of Conserved CU of Cropping Systems (2006-2010 Data)



A similar figure illustrates the opportunity cost for the smaller data set on a per affected acre basis. As the case with the previous figure, using the latter years as a data foundation increases the opportunity cost relative to the full dataset. The range of opportunity cost is closely aligned with the range of surveyed willingness to accept from Thorvaldson, Pritchett and Frasier (2008) and is illustrated in Figure 5.

Figure 5. Mean Opportunity Costs per Acre of Cropping Systems (2006-2010 Data)



Water Conserving System D has the smallest mean opportunity cost per acre, suggesting that it is desirable for the crop manager as it provides the smallest profit decline. It is also (potentially) desirable for the leaser, who might choose to compensate the crop manager for adopting a system in place of the *Baseline Cropping System*. In this type of lease, both parties are interested in the size and frequency of payments that will make the difference. Table 6 summarizes this information. Perhaps most significantly, *Water Conserving System D* exhibits the greatest frequency of small payments using the recent years' data, but also demonstrates the greatest frequency of large payments because of difference in 'upside potential' when profits are very high for corn. The 'upside potential' is similar to the right hand side divergence of the cumulative frequencies first illustrated in Figure 3.

Table 6. Frequency of Compensation Payment ($/AF of CU) in a Certain Range in Order to Achieve Baseline Cropping System Profits (2006-2010)

	System A	**System B**	**System C**	**System D**
Less than $100/AF of CU	10%	10%	40%	47%
Between $100 and $200 / AF of CU	60%	3%	37%	9%
Between $200 and $600/ AF of CU	8%	25%	15%	22%
Greater than $600/ AF of CU	22%	62%	9%	22%

Water Conserving System C generates compensation payments of $200 or less 77% of the time, compared to System D's payments of $200 or less 56% of the time. *Water Conserving System* D receives large payments (greater than $600) 22% of the time compared to just 9% of the time for System C. In this sense, System D is more susceptible to loss of upside potential compared to System C.

Conclusions and Discussion

As populations grow worldwide, increasing demands are being placed on freshwater for food, energy, municipal, industry and environmental uses. In many areas, water will need to be re-allocated between uses to meet demands. Shifting water is likely to be controversial and may cause unintended consequences to third parties.

Colorado shares many of the complex interactions that come with reallocating water between sectors. Stakeholders in Colorado seek pathways for re-allocating water from agriculture to municipal use in a way that mitigates damages. Temporary leases are one instrument receiving attention for replacing 'buy and dry' transactions. The purpose of this article is to explore one facet of water leases -- a farmer's opportunity cost for adopting water conserving crop rotations when entering leasing arrangements.

From a farm manager's perspective, the opportunity cost of switching to a cropping system depends importantly on an expectation of profits, and the expectation includes the potential for low or high profits. In order to gain a better understanding of values that create an expectation, a simulation model is developed to measure the profits of a baseline, irrigated corn cropping system as well as for four other systems that conserve consumptive use water. Prices and yields are allowed to vary in a range and correlation consistent with the historical (1980-2010) data generation process. The simulation leads to a profit frequency for each cropping system that can be compared against one another. Likewise, an opportunity cost frequency is created by calculating the difference between an iteration's profit from the baseline system and the alternative cropping system.

The profit frequency comparison suggests that *Water Conserving System D*, which is comprised of irrigated corn and irrigated wheat, is a system with the highest mean profits and least number of negative profits. *Water Conserving System B*, which contains equal parts of corn, alfalfa and fallow, is the least favorable. When illustrated as a cumulative frequency (Figure 1), it is clear that small differences exist between the systems when profits are low, but large differences distinguish one cropping system from another when profits are high. Put more simply, the cropping systems have a similar downside potential, but very different upside potential, and it is the potential "loss" of high profits that may be most concerning to farm managers.

The opportunity cost of adopting cropping systems varies according to the profits – a higher opportunity cost exists for *Water Conserving System B* because its profits are substantially lower than the *Baseline Cropping System.* As might be expected, *Water Conserving System D* has lowest opportunity cost and often outperforms the *Baseline Cropping System* over the 1980 – 2010 historical data foundation.

From a crop manager's perspective, *Water Conserving System D* generates the most profitable outcome for CU conservation if payment is not made. This system removes 440 acre feet of water from production, and alters ½ of the corn acreage to wheat. From a leaser's perspective, *Water Conserving System D* likely requires the least amount of compensation per unit of water removed from production because it has the lowest opportunity cost. However, in the case that the leaser is interested in a largest quantity of water, *Water Conserving System C* would be the best alternative, requiring a minimum compensation of at least $55 per acre foot of CU with potential of acquiring 1,195 AF of CU.

Recent years have seen an increase in the local harvest cash price received for commodities such as corn and wheat, at the same time improved yields are realized for these irrigated field crops compared to previous decades. As a result, a sensitivity analysis is performed focusing on a 2006 to 2010 data foundation for a new set of iterations. In this simulation, the *Baseline System* is easily the most profitable cropping system, and the opportunity cost of switching from a 100% irrigated corn crop is substantial. The mean opportunity cost ranges from $103 per acre to $485 per acre, which is similar to previous surveys of farmer willingness to accept for fallowing (Thorvaldson, Pritchett and Frasier, 2008.)

A limitation of this study is its focus on specific conditions – the irrigated farm is representative of the South Platte River Basin. Different farms may experience differing yields and prices depending on biophysical and marketing circumstances. The results are also limited by the historical dataset – results will be generalizable only to the extent that the future was like the past.

Having written that, common elements do emerge from the results that can be extended to other cases. First, a combination of corn and wheat in a cropping system is almost always desirable compared to a fallow system or the corn-alfalfa-fallow system. The result is intuitive – from the crop manager's perspective it is almost always better to crop land than to have it sit idle. It is also true that the system provides some flexibility for the crop manager and the contracting leaser in a water conserving agreement – the wheat crop can be planted and irrigated as the water year unfolds. If water is needed, the crop remains non-irrigated, but if water is available it can be set to the wheat crop. The water conservation in this simulation ranges from 440 AF of conserved CU in *Water Conserving System D* to 1,195 AF of CU in *Water Conserving System D*. In this type of an arrangement, the wheat can act as a drought "reservoir" for the leaser that is adjustable depending on circumstances.

Crop managers are concerned with both the upside and downside potential in alternative cropping systems. Upside potential is the inability to seize the profits in years during which prices are quite high and yields are above average. Downside potential refers to years when profits are quite low because of low prices and/or poor yields. This analysis suggests little difference exists in the cropping systems for downside potential, but substantial differences occur on the upside, and this might make crop managers less likely to sign leases. Payment contingencies might help to alleviate the crop managers' concerns. One alternative is a two-step payment program: the initial, baseline payment, would be paid to the producer when cropping decisions are made in the Fall, and a second payment is made when harvest prices are realized.

These prices can be a fixed interval above/below a publicly reported price such as the Chicago Board of Trade.

This research focuses on a narrow face of leasing CU from cropping systems. The legal verification of conserved CU is a thorny issue, and transactions costs associated with monitoring, diverting and transferring CU cannot exceed the surplus from leasing arrangements for this institution to exist. Further research and thought are needed in these areas.

Works Cited

Calatrava, J, and A. Garrido.2005. "Modelling water markets under uncertain water supply." European Review of Agricultural Economics 32, no. 2 (2005): 119-142.

Carey, J. M., and D. Zilberman. 2002. “A Model of Investment under Uncertainty: Modern Irrigation Technology and Emerging Markets in Water.” American Journal of Agricultural Economics 84(1):171-183.

Elder, K.L. 2004. Optimal Crop Mix for Northeastern Colorado Under Consideration of the 2002 Farm Security and Rural Investment Act. Unplublished Masters Thesis. May 2004.

Fathelrahman, E. M., J. C. Ascough, D. L. Hoag, R. W. Malone, P. Heilman, L. Wiles, and R. Kanwar. 2011. " Economic and Stochastic Efficiency Comparison of Experimental Tillage Systems in Corn and Soyabean Under Risk.” Experimental Agriculture 47, no. 01 (2011): 111-136.

Goodman, D. and C. Howe. 1997. Determinants of Ditch Company Share Prices in the South Platte Basin. American Journal of Agricultural Economics. Vol. 79. no. 3: 946-951.

Karagiannis, G. Tzouvelekas, V. Xepapadeas, A. 2003. “Measuring Irrigation Water Efficiency With a Stochastic Production Frontier.” Environmental and Resource Economics. , 26(1), 57-72.

Pritchett, J., K. Collins, G. Patrick and A. Rios. 2004. "Risk Management Strategy Evaluation for Corn and Soybean Producers." Agriculture Finance Review. Vol. 61. No 1. pp. 45-60.

Pritchett, J., J. Thorvaldson and M. Frasier. 2008. "Water as a Crop: Limited Irrigation and Water Leasing in Colorado." Review of Agricultural Economics. Vol 30. No. 3. pp. 435-444.

Serbina, L. 2012. Describing and Quantifying Revenue Risk Producers Face When Adopting Water Conserving Cropping System. Unpublished Master of Science Thesis. Colorado State University. Fort Collins, Colorado.

Schuck, E. and E. Green. 2002. Supply-Based Water Pricing in a Conjunctive Use System: Implications for Resource and Energy Use. Resource and Energy Economics, vol. 24, no. 3:175-92

Taylor, R., R. Young, and J. McKean. 1993. Some Economic Impacts of a Rural-to-Urban Water Transfer: A case Study of Crowley County, Colorado. CWRRI Completion Report No. 171. Colorado State University. Fort Collins, CO.

Tomek, W. and H. Peterson. 2001. Risk Management in Agricultural Markets: A Review. Journal of Futures Markets. V. 21. No. 10. pp. 953-985.

Williams, J. 1988. A Stochastic Dominance Analysis of Tillage and Crop Insurance Practices in a Semiarid Region. American Journal of Agricultural Economics. vol. 70, no. 3, pp. 741-742

Williams, J., R. Llewelyn, and A. Barnaby. 1990. “Risk Analysis of Tillage Alternatives with Government Programs” American Journal of Agricultural Economics. vol. 72, no. 1:172-81.