ECONOMIC IMPACT ANALYSIS OF REDUCED IRRIGATED ACREAGE IN FOUR RIVER BASINS IN COLORADO

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ABSTRACT

Colorado's water is an important natural resource that contributes to the state's economic, cultural and social well-being (Pritchett, et al., 2005). However, this resource is of limited supply and has many competing uses. Although agriculture is still the dominant water use, rapid changes are occurring, and the impacts to Colorado's agricultural communities are a key concern. In the next twenty-five years, Colorado's population is expected to exceed 7 million people and an additional 632,000 acre-feet of water will be needed in cities to support their growth.

An increasing consensus in the western water community is that new demands must be met primarily through the reallocation of existing supplies (Committee on Western Water Management, 1992). Because agriculture is the marginal-valued user of water supplies, the majority of this new water demand will be supplied through rural-to-urban water transfers, with an estimated 400,000 irrigated agricultural acres "drying up" as these transfers occur (Pritchett, et al., 2005). Rural-to-urban water transfers create contentious, emotionally charged discussions that often center on the health of rural economies whose irrigated agricultural base is reduced with each transfer.

The difference between the net value of water used for agriculture and municipalities' willingness-to-pay for water is substantial, so much so that both the buyers and sellers of water stand to gain from out-of-basin water transfers. However, water is a resource with productive capacity, and transferring productive capacity affects more than just the buyer and seller—third parties such as local governments and businesses are affected as well (Pritchett, Frasier, and Schuck, 2003). For example, temporary or permanent income losses may occur to factors of production in sectors with backward or forward linkages to irrigated agriculture. If depressed economic conditions persist, factors of production of agriculture, agricultural supplying activities, and agricultural processing activities can be idled for long periods of time, leading to real efficiency losses.

State and regional planning bodies, researchers, and the public are very concerned about the adequacy of available water supplies to sustain Colorado's population and economic growth. Clearly, it is important to quantify and describe the economic impact of a reduction in irrigated agriculture, to disaggregate the impact among different industries in the region and among households, and to determine how government revenues might shrink. This information will be valuable to many water stakeholders

including farmers, businesses, water supply administrators, and regional leaders charged with economic development.

In this project, a rigorous economic accounting establishes the agricultural and economic demographics for four river basins in Colorado: the East Arkansas, East South Platte, Republican, and Rio Grande Basins. The IMPLAN software is utilized to develop an input-output model for each basin. Impact analysis is then performed on each model in order to approximate the economic effects of a reduction in irrigated acreage on each regional economy.

The basins are analyzed separately because each basin has a unique economic base and idiosyncratic water demand/supply conditions. Indeed, the study finds that each basin is affected differently according to the basic demographics of the region, the diversity of the regional economy, the relative importance of irrigated agriculture in the regional economy, and the strength of the backward and forward linkages between irrigated agriculture and supplying and processing sectors. The impacts of the loss of irrigated crop sales are negative in nature and ripple throughout the entire regional economy, affecting every sector.

In terms of total impact, the East South Platte Basin experiences the largest total impact, which is not surprising considering that this basin is projected to experience the largest decrease in irrigated acreage. The South Platte Basin also has the largest multiplier, which can be explained by the greater size and diversity of the East South Platte Basin's economy. However, the East South Platte Basin experiences the lowest per capita impacts due to this basin's relatively high population density. Also, because of the greater diversity of the East South Platte Basin's economy, it may be better equipped to weather such an economic impact than the other economies under consideration.

The Rio Grande basin is projected to experience the largest employment loss, both in terms of total jobs lost and proportion of total workforce lost. This can be partially explained by the high labor requirements for producing hay, the main crop grown in this region. This outcome provides further evidence that it is important to look at more than just the raw numbers of acres that will be lost to predict the impact—the true impact depends on which crops are lost and in which region.

Substantial differences between the regions exist, both in terms of impacts and multipliers, leading to the conclusion that any policy or program intending to mitigate the negative impacts of lost irrigated acreage should not be a one-size-fits-all solution, but rather would be most effective if tailored specifically to the affected region.

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ACKNOWLEDGMENTS

The author wishes to thank Dr. James Pritchett, Dr. Marshall Frasier, Dr. Neil Hansen, Colorado Water Resources Research Institute directors, members, and staff, and Bill and Sharon Thorvaldson, for their guidance and support. The author also wishes to thank the Colorado Water Resources Research Institute's Advisory Committee on Water Research Policy for generously providing funding for this research through the CWRRI Water Fellowship Program.

INTRODUCTION AND BACKGROUND

Colorado is home to eight[1] major river basins[2], as illustrated in Figure 1. The four river basins under consideration in this study are the East Arkansas, East South Platte, Republican, and Rio Grande basins, where the majority of Colorado's irrigated agriculture takes place, and thus where the majority of the reductions in irrigated agriculture will take place.

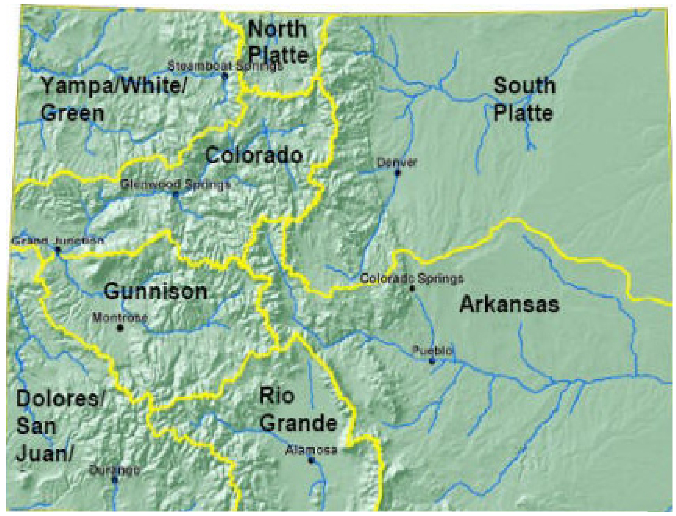

Figure 1: Colorado's River Basins

Increasing Population

Colorado's population is projected to increase by 2,820,900 residents between the years 2000 and 2030--an increase of about 65 percent. The Arkansas and South Platte Basins, which are already the most highly-populated basins, are projected to receive the most new residents. By the year 2030, the Arkansas and South Platte basins will be home to a combined total of almost 2.4 million additional residents, bringing the total population in these two basins to over 6 million people, making up more than 86 percent of Colorado's total projected population. Table 1 summarizes the population projections in the basins under study (CWCB, 2004).

Table 1: Projected Population Growth in Basins

Basin	2000 Population	2030 Projected Population	% Change	% Annual Growth
Arkansas	835,100	1,293,000	55%	1.5%
Rio Grande	46,400	62,700	35%	1.0%
South Platte/RR*	2,985,600	4,911,600	65%	1.7%

*The SWSI Report did not consider Republican River Basin separately from the South Platte Basin.

[1] The Republican River Basin is located within the same water division as the South Platte Basin. However, because the Republican River Basin has distinct cropping mixes and a greater level of ground water use, this study considers it separately from the South Platte Basin.

[2] A river basin is defined by the American Heritage Dictionary (2000) as the entire land area drained by a river and its tributaries.

Increasing Water Demand

As the state's population continues to grow, additional demands will be placed upon Colorado's water supplies. The Colorado Water Conservation Board (CWCB) recently completed the Statewide Water Supply Initiative (SWSI), a comprehensive assessment of current water demand and supply relationships in Colorado, and projections through the year 2030. SWSI predicts that, including increased conservation due to recent federal legislation[3], annual M&I water use will increase statewide from 1,194,900 acre-feet (AF)[4] in 2000 to 1,824,900 AF by 2030, an increase of 630,000 AF. The bulk of the increase in water use will be in the South Platte and Arkansas Basins, which together represent about 80 percent of the total projected increase in Colorado's gross M&I and SSI[5] demands. Table 2 indicates the M&I water use in the year 2000 and SWSI projections for the year 2030 (CWCB, 2004).

Table 2: Projected Growth in Municipal and Industrial Water

Basin	2000 Gross Water Demand (AFY)	2030 Projected Gross Water Demand (AFY)	Projected Increase (AFY)	Percent Increase in Water Demand
Arkansas	256,900	354,900	98,000	38%
Rio Grande	17,400	23,100	43,000	25%
South Platte/RR*	772,400	1,182,100	409,700	53%

*The SWSI Report did not consider the Republican River Basin separately from South Platte Basin.

In addition to the increases in water demand associated with population growth and urbanization, there is additional pressure from expanding recreational and environmental interests, interstate compacts, and changing well augmentation rules (which is especially true in the South Platte and Republican basins). Another source of pressure is declining ground water levels. According to Nolan Doesken of the CSU Climate Center, the 1980s and 1990s were moist, but since that time Colorado has been experiencing a wide-spread drought coupled with high temperatures, resulting in a decline in ground water (Brunswig, 2006). Reduced ground water in municipal settings leads to increasing pressure to acquire additional surface water rights.

The water economy of Colorado has passed from the "expansion" phase to the "mature phase". In the expansion phase, the incremental cost of water remained relatively constant over time, and water development project sites were available to meet growing demands. The mature phase, brought on by population growth and changes in the economy

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[3] This Level 1 conservation refers to mandated plumbing codes, ordinances, and standards that improve the efficiency of water use, and is the lowest level of conservation required by law. Detailed information regarding these conservation measures can be found on the Environmental Protection Agency website: http://www.epa.gov.

[4] An acre-foot of water is approximately 326,000 gallons.

[5] Self-Supplied Industrial (SSI) demand is made up of large industrial water users that have their own water supplies or lease raw water from others.

as a whole, is characterized by rapidly rising incremental costs and greatly increased interdependencies among water uses and users. In a maturing water economy, such as Colorado's, the high cost of new water brings about a search for supplies from existing uses, usually in agriculture, whose economic productivity is less than the cost of acquiring new supplies (Young, 1983). One of SWSI's major findings is that taking water from irrigated agricultural land and converting it to municipal use will be a primary source of water for cities[6]. Indeed, SWSI estimates that as many as 400,000 acres of Colorado's irrigated agriculture could be dried up by the year 2030 (Darst, 2005).

SWSI does not, however, quantify the economic impacts of such losses of irrigated land nor suggest solutions. The total economic impact will include (but is not limited to):

1. Direct impacts: Decreased production of irrigated crops resulting in decreased revenue flow from the sale of those crops.
2. Indirect impacts: As irrigated agriculture decreases its demand for inputs provided by other industries, these support industries will also experience a decrease in revenue flows. For instance, if a farmer reduces his production of irrigated crops, he/she will demand less fertilizer, seed, etc. from the industries that supply those inputs.
3. Induced impacts: A decrease in the production of irrigated crops leads to a decrease in the amount of labor that is required for production. The income loss associated with decreased employment leads to a reduction in spending attributed to wages.

Information relating Colorado's economy and agricultural water use is required by policy-makers as input for the decision-making process (Young, 1983), and understanding the impact of these changes on rural Colorado economies is a key challenge for all Coloradans. It is likely that a significant reduction in a region's economic activity will result as water is transferred to another region for M&I use.

Agriculture is one of the state's most significant economic sectors, encompassing a large share of the land in the state. Agriculture is the foundation of many rural communities, and a viable and healthy agriculture industry is essential to maintaining the economic, social, and cultural integrity of rural Colorado. Seventy-five percent of the total value of Colorado crops is derived from the irrigated sector, highlighting the importance of, and dependence on, a secure water supply. Clearly, it is important to quantify and describe the economic shock of such a reduction in irrigated agriculture, to disaggregate the shock among different industries in the region and among households according to their income, and to determine how government revenues might shrink. This information will be valuable to many water stakeholders, including farmers, businesses, water supply administrators, and regional leaders charged with economic development.

[6] Agricultural transfers, however, are also not without risk and uncertainty due to the water court process, volume of storage required, and local and federal permits needed for construction of necessary facilities.

The availability and distribution of water are the primary determinants of the character of all natural ecosystems and all modern economies (Smith, Klein, Bartholomay, Broner, Cardon, Frasier, Kuharich, Lile, Gross, Parker, Simpson, and Wilkinson, 1996). Colorado's water is an important natural resource that contributes to the state's economic, cultural and social well-being. However, this resource is of a limited supply with many competing uses. Traditional uses of water in Colorado are changing as a result of population growth, urbanization, and increased environmental and recreational uses for water (SWSI, 2004). Without question, these forces will lead to increased demand for M&I water use and intensified competition for water. Conservation will play an important role in meeting the increased water demand, but conservation alone cannot satisfy all these requirements. New storage projects will likely be needed and pursued, but these can take years or even decades to permit and construct, and their success is uncertain. In this setting, cities will increasingly look to agricultural water to meet their needs, creating impacts on rural Colorado that need to be recognized and addressed. The problem addressed by this research is to determine the economic impact to rural counties of removing just over 300,000 acres from irrigated agriculture in four Colorado water basins where the majority of water transfers are expected to occur.

Water is a necessary resource and, as such, everyone has the potential to benefit from having a better understanding of the issues, challenges, and potential solutions surrounding its management. This information will be especially valuable to many water stakeholders including farmers, businesses, water supply administrators, and regional leaders charged with economic development. Additional agriculture-to-urban water transfers, and subsequent reductions in irrigated agriculture, will inevitably occur in the future. This study will help predict the size and scope of the impact that such acreage reductions will have on the communities in which they occur. It is the authors' hope that, by better understanding these impacts, this study will also help to mitigate the negative effects of these changes and ease the adjustment to them.

Colorado Water Law

As in most arid western states, the allocation of water in Colorado is governed by the doctrine of "prior appropriation". Under this doctrine, rights to water are granted upon the appropriation of a certain quantity of water for beneficial use[7]. The date of appropriation determines the priority of the water right, with the earliest appropriation establishing the most senior, or superior, right. Water rights are quantified based on the rate of diversion from the stream system or the volume stored (Smith, et al., 1996). The appropriations system, in contrast to the older "riparian" system of water law of the eastern states, treats the use of water as personal property separate from the land and subject to transfer or sale (Howe and Goemans, 2003).

[7] Water in Colorado must be diverted for a purpose and used beneficially to get a water right. Beneficial use is the use of a reasonable amount of water necessary to accomplish the purpose of the appropriation, without waste. Some common types of beneficial use are: irrigation, municipal, wildlife, recreation, mining, household use.

The prior appropriation system in Colorado allows water rights to be transferred or changed, subject to the protection of other water right holders. Water right transfers or changes can be temporary or permanent and can involve changes in use, timing, amount, and location of diversion and/or use. Proposed changes in water use that deviate from the original water right decree require water court approval prior to implementation, to ensure that no other water user is adversely affected by the change.

When agricultural water rights are sold non-locally, the land that was formerly irrigated by that water is typically required to be dried up permanently. This is because only the consumptive use (CU) portion of a water right can be sold under Colorado law. Thus, if a farmer wanted to adopt a more technically efficient irrigation system with the goal of maintaining the same acreage and crop-mix while using less water, that farmer would not be able to sell the water savings. The increased efficiency allows the farmer to divert less water from the river while maintaining the same CU. The water that is no longer diverted from the river is considered "saved" water and cannot be sold or transferred because it is not CU--it was not acquired through a decrease in the farmer's CU—and if transferred, it could potentially decrease return flows to the stream. Although the farmer cannot sell "saved" water, he or she can use it to increase his or her CU within the limits of the original decree.

Conversely, non-return flow water that is recovered for use from a source unconnected with the receiving system is considered "salvaged" water and can be transferred to a new use subject to water court approval (to ensure non-injury to other water users) or used and reused to extinction so long as the user maintains control over the water. For example, agricultural water rights that are changed to municipal use may generate fully-consumable water that can be used to extinction. This may result in a reduction of return flows, on which many farmers depend.

Adjudicating a change of water rights can be time-consuming and costly (often requiring the services of lawyers, engineers, and other professionals), and formal notification is required by law. This means that cities will want to limit the number of transfer transactions in order to take advantage of economies of scale and to limit transactions costs. They will prefer to deal with entire ditches rather than individual farms, resulting in regional "hot spots" where large areas of land are dried up and where the impacts are concentrated, as has already occurred in the Arkansas Basin.

Making a new appropriation is another option for water planning, but this requires that there remain un-appropriated water in that river, which is not generally the case for the rivers in this study. Firstly, the South Platte Basin (including the Republican sub-basin) is already over-appropriated[8] (South Platte Research Team, 1987), rendering this a non-option for this

[8] A river is considered to be over-appropriated if water diversions and withdrawals from that river exceed the total amount of water available.

basin. Secondly, recent hydrologic analysis showed very little legally available flow in the Arkansas River (SWSI, 2003). Finally, as a result of compact limitations, there is very infrequent available flow in the Rio Grande for use in Colorado, and these flows (as in the Arkansas) do not provide a reliable source for new supply development (SWSI, 2003). No appropriation can be made when the proposed appropriation is based on the speculative sale or transfer of the appropriation rights. This anti-speculation doctrine prevents individuals or entities from acquiring water rights solely to sell to others.

An augmentation plan allows a water user to divert water out of priority from its decreed point of diversion, so long as replacement water is provided to the stream from another source to make up for any deficit to other water users. This is most common for ground water appropriators whose water source is "tributary" to appropriated surface water, and is thus administered according to the Doctrine of Prior Appropriation in the same general way as surface water.

Water Transfers

Surface water supplies in Colorado are largely over-appropriated, with little "new" water to be discovered. Thus, municipalities will need to purchase water rights from other users to meet increasing demand. In 1996, agriculture held 91 percent of the developed water sources in Colorado (Smith, et al., 1996). Today, agriculture controls about 85 percent of the developed water sources in Colorado (Smith, 2006), and this number is expected to decrease further as water is transferred from irrigated agriculture in order to support Colorado's growing M&I demand.

Cities and industries continue to grow, and they are willing to pay high prices for water. They seek to build major storage facilities and acquire rights from farmers whose uses command lower economic value. If the growing M&I demand is indeed fulfilled through agricultural transfers and SWSI projections of reduced irrigated acreage in Table 3 are correct, then, based on data from 2005 Colorado Agricultural Statistics data, the estimated acreage reductions account for up to 49 percent of all irrigated cropland in the East South Platte Basin[9], 31 percent of all irrigated cropland in the East Arkansas Basin[10], 4 percent of all irrigated cropland in the Republican Basin, and 32 percent of irrigated cropland in the Rio Grande Basin. Further reductions may occur in the South Platte Basin if adequate augmentation sources are not developed for the farms that use alluvial ground water as their primary source of water supply.

[9] The East South Platte Basin consists of Adams, Arapahoe, Elbert, Morgan, and Weld counties.

[10] The East Arkansas Basin consists of Baca, Bent, Cheyenne, Crowley, Kiowa, Otero, and Prowers counties.

Table 3: Projected Reduction in Irrigated Acres by 2030

Basin	Projected Reduction In Irrigated Acres	Reduction as % of Current (2005) Irrigated Cropland
Arkansas	23,000-72,000 acres	9-29%
Republican[11]	20,000 acres	1%
Rio Grande	60,000-100,000 acres	16-27%
South Platte	133,000-226,000 acres	27-45%

It is clear that water transfers will occur in order to support Colorado's population growth, and these transfers will likely include the dry-up of irrigated cropland. However, impacts from the dry-up extend beyond irrigated farmland. Colorado's crop production has thrived with its water resources and, in turn, crop production has supported commercial livestock, meat-packing, and dairy industries. Each of these primary agricultural industries has encouraged economic development directly, through the purchase of inputs, and indirectly, through the wages and salaries of employees. Without other viable local base industries to generate revenues and provide employment, a reduction in the revenue generated in the agricultural sector will have adverse economic impacts throughout the regional economy (Pritchett, et al., 2005).

Impacts will be felt by businesses and by local governments whose property and sales tax base is eroded. Governments experience decreased tax revenues because the appraised value of irrigated land decreases as it is converted to dryland (Pritchett, Frasier, and Schuck, 2003). Local governments may experience increased costs if they assist displaced workers. Smaller, rural domestic water suppliers and agricultural users will be especially challenged, as many lack the financial or planning resources of larger water suppliers. Offsetting some of these losses might be a reduction in services that follows a shift from irrigated to dryland crops, because dryland farming generally requires fewer inputs and because it takes significantly more acres of dryland to support a household than does irrigated land (Pritchett, Frasier, and Schuck, 2003).

If the economic region is economically diversified and buoyant, alternative employment opportunities are close at hand and the selling farmer may be able to find local investment opportunities for his or her money. Furthermore, the negative indirect and induced effects in such a setting are likely to be short-lived. In contrast, in areas where the economy has historically been depressed, such as in the Arkansas Basin (and the Republican and Rio Grande Basins to a somewhat lesser degree), limited opportunity exists for the

[11] SWSI did not focus on the Republican River Basin due to recent settlement of a lawsuit between Kansas, Nebraska and Colorado, which resulted in the need to reduce some of the consumptive use in the basin in Colorado. Therefore, estimates of reduced irrigated acreage for the Republican Basin were obtained from the Republican River Conservation District and were based on reductions required under the Conservation Reserve Enhancement Program (CREP).

proceeds from the water sale to be invested in the local economy and most of the water sale proceeds are instead used to reduce farm debt. While the reduction in debt is a financial gain to the farmer, it creates no new jobs in the absence of local investment opportunities. In such cases, the regional impacts of a permanent transfer of water rights can be quite severe (Howe and Goemans, 2003).

Howe and Goemans (2003) used IMPLAN to estimate the economic losses from reductions in irrigated acreage resulting from water transfers in the Arkansas and South Platte Basins. One of their major findings is that more severe economic and social impacts are likely in specialized, marginal agricultural regions like the Arkansas, Republican, and Rio Grande Basins. The losses per acre-foot are likely to be significantly higher than those in a more prosperous and diversified basin, such as the South Platte. The losses on a per capita basis are also much greater and are likely to persist over a longer time span. The authors conclude that the set of criteria to be considered by the transfer agencies in approving or modifying water transfers should be expanded to include consideration of the secondary economic and social costs imposed on the basin of origin, as is already the practice in Idaho, Utah, and Wyoming.

Naturally, the importance of the negative effects associated with a reduction in irrigated acreage depends on the accounting stance employed by the analyst. At the national level, where the agricultural losses can likely be made up by expanding production in other states, the losses in the area of origin may appear to be minor. At the state level, both direct and indirect losses of income and employment in the area of origin may be offset by gains in the importing areas. In the area of origin, however, these losses can be substantial and persistent (Howe, Lazo, and Wever, 1982). The severity of economic impacts on the area of origin will differ according to the economic vitality of the area of origin, whether or not the water sales proceeds are reinvested in the area of origin, and the strength of the backward and forward linkages between irrigated agriculture and supplying and processing sectors.

The severity of economic impacts on the area of origin will also depend on the number and magnitude of previous impacts the economy under consideration has already faced. The economy may be at a place where any additional impact will move it beyond some "tipping point" from which it may not be able to recover. Furthermore, the severity of economic impacts on the area of origin will also depend on the distribution of the losses. If the acreage losses all occur in one specific location in the basin, rather than spread diffusely throughout the basin, the economic consequences will be highly concentrated in these "hot spots".

The findings of the Howe and Goemans study suggest that both the per-capita losses and the losses per acre-foot are likely to be higher in the Arkansas, Republican, and Rio Grande basins than the more highly-diversified South Platte Basin. The findings of the Howe, Lazo, and Weber study suggest that when water is transferred from an agricultural economic area to another region, as is the case in this study, uncompensated costs will be imposed on the agricultural community. Their findings also suggest that the true impacts will vary greatly between study areas, based on the economic vitality of the area of origin, whether or not the water sales proceeds are reinvested in the area of origin, the strength of the linkages between irrigated agriculture and other sectors in the economy, the number and magnitude of previous impacts the economy under consideration has already faced, and the distribution of the losses.

Study Objectives

The current study makes use of the SWSI estimates of reduced irrigated acreage in order to quantify the economic impacts associated with such a reduction in irrigated acreage. The study considers four distinct agricultural areas separately in order to increase the accuracy and applicability of the estimates. The study then compares the impacts in each region in order to assist these communities (and possibly others in similar situations) to prepare for, and minimize, the impacts.

Each basin is analyzed separately due to each basin's unique economic base and idiosyncratic water demand and supply conditions. Analysis of the Arkansas and South Platte Basins is restricted to the eastern half of each basin because of the demographic dichotomy of these two basins, with the vast majority of the agricultural activity taking place in the eastern halves. According to the Forest Service Economics Team (2006), in order to isolate the effects of an impact, it is desirable to make the study area as small as possible while still including areas necessary to capture all-important effects.

SCOPE OF STUDY

A water buyer and seller are the two primary parties in a water transfer, each of whom must be satisfied with the results of the negotiations for a transfer to be consummated. This research is concerned with the welfare of third parties—those who stand to be affected by the transfer but who are not represented in the negotiations and lack control over or input into the processes by which transfer proposals are evaluated and implemented.

The impacts of transfers and the parties affected are many, diverse, and potentially substantial. The types of impacts felt by these parties are quite varied but can be broadly thought of as economic, social, and environmental (Committee on Western Water Management, 1992). This study focuses on the economic impacts of a reduction in irrigated crop sales.

This analysis considers the impact on the basins-of-origin only, and does not consider the impact on the communities that are expected to receive the water transfers. In order to get a full picture of the entire impact of such water transfers, this same type of analysis should be performed to assess the impact on the receiving communities. However, the impacts are likely to be distributed unevenly, with the negative impacts likely to be concentrated on the communities from which the transfers occur, thus deeming it appropriate to begin analysis in these areas.

The Arkansas Basin is spatially the largest river basin in Colorado, making up 27 percent of the surface area of the state. It is comprised of all or parts of 16 counties (Baca, Bent, Chaffee, Cheyenne, Crowley, Custer, El Paso, Fremont, Huerfano, Kiowa, Lake, Las Animas, Lincoln, Otero, Prowers, and Pueblo) located in the southeast corner of the state (Figure 2). The agricultural activity is concentrated on the eastern half of the basin. Because of this dichotomy, analysis is limited to the seven easternmost counties in this basin (Baca, Bent, Cheyenne, Crowley, Kiowa, Otero, and Prowers counties). Although Lincoln County is split evenly between the Republican and Arkansas River Basins, the majority of its agriculture occurs in the Republican River Basin; therefore, we have included all of Lincoln County in the Republican Basin.

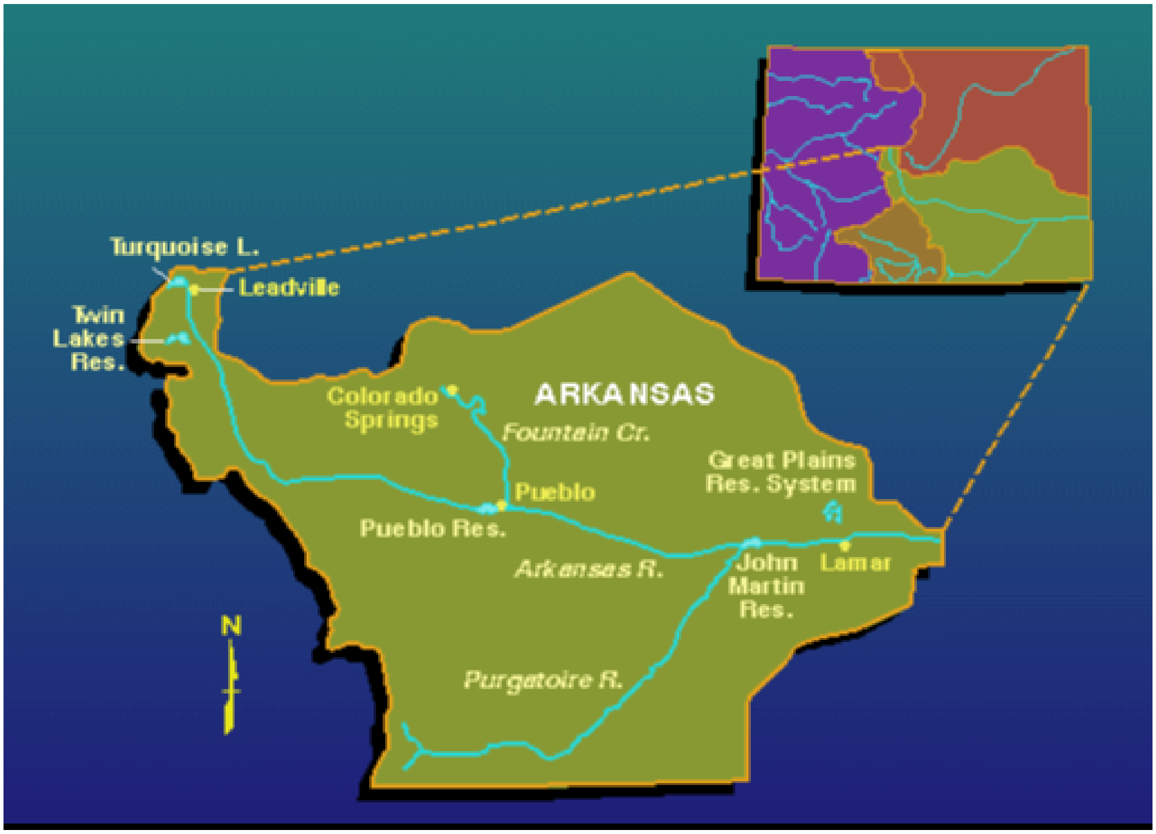

Figure 2: Arkansas River Basin

The South Platte River Basin comprises about 12 percent of the state's land area (when the Republican River Basin is considered separately rather than as a sub-basin of the South Platte) and is comprised of all or parts of 14 counties (Adams, Arapahoe, Boulder, Clear Creek, Denver, Douglas, Elbert, Gilpin, Jefferson, Larimer, Morgan, Park, Teller, and Weld) in the northeast corner of the state (Figure 3). As with the Arkansas Basin, the western half of the South Platte Basin is highly populated and industrialized, while the eastern half is less densely populated and more rural in nature. As such, analysis is limited to the five easternmost counties of the basin (Adams, Arapahoe, Elbert, Morgan, and Weld counties).

Figure 3: South Platte River Basin

The Republican River Basin comprises nine percent of the state's land area and consists of all or parts of 7 counties (Kit Carson, Lincoln, Logan, Phillips, Sedgwick, Washington, and Yuma) located in the northeast corner of the state (Figure 4).

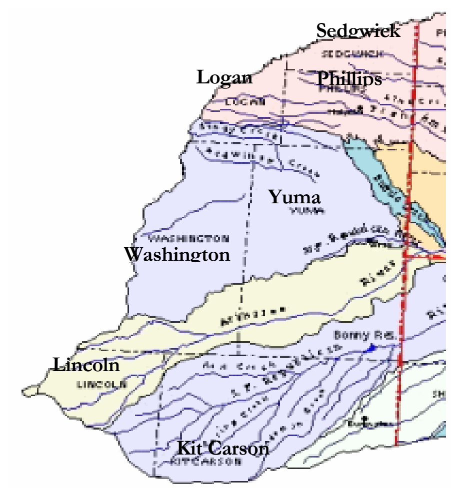

Figure 4: Republican River Basin

Finally, the Rio Grande Basin makes up five percent of the state's land area and is comprised of all or parts of 6 counties (Alamosa, Conejos, Costilla, Mineral, Rio Grande, and Saquache) located in the south-central part of the state (Figure 5).

Figure 5: Rio Grande River Basin

The following sections describe and compare each basin's economic, water use, and agricultural profiles.

Economic Demographics

Arkansas Basin

Annual value of sales and services in the Arkansas Basin equal $45,554 million, with agriculture industries comprising $1,134 million (2.5 percent) of this value (MIG, Inc., 2002). . Because agricultural activity is concentrated in the eastern portions of the basin, analysis is restricted to the easternmost seven counties in the basin (Baca, Bent, Cheyenne, Crowley, Kiowa, Otero, and Prowers counties). Focusing on the eastern half of the basin, agriculture industries comprise 33.22 percent ($637 million) of the total value from sales and services, which is the largest percentage relative to the other 3 basins studied. Irrigated crop sales make up $147 million (23.1%) of these agricultural sales. Table 4 lists the major industrial sectors of the eastern half of the basin.

Table 4: Economic Demographics for the 8 Eastern Arkansas River Basin Counties (2002)

Industry	*Value of Sales*	*Percent of Total*
Total	$2,001	100.0%
Cattle Ranching and Farming	$371	18.6%
Irrigated Crops	$147	7.3%
Owner-occupied dwellings	$109	5.4%
Monetary authorities and depository credit	$89	4.5%
State & Local Education	$86	4.3%
State & Local Non-Education	$77	3.9%
Wholesale trade	$58	2.9%
Offices of physicians, dentists, etc.	$48	2.4%
Other animal food manufacturing	$48	2.4%
Other State and local government enterprises	$42	2.1%

Seventeen percent of the state's employment is in the Arkansas Basin (SWSI, 2004). According to the U.S. Department of Labor's Bureau of Labor Statistics, the average unemployment rate in the East Arkansas Basin in 2005 was 5.5 percent, the second highest of all basins in the study. There are few economic alternatives to agriculture in the eastern half of the Arkansas River Basin such that the counties in this area are heavily dependant on agriculture for their economic base. Due to the high percentage of the total value of sales coming from agriculture, the anticipated reduction in irrigated cropland has many implications for the agricultural sector, as well as for the many other sectors of the economy. Areas relying more exclusively on irrigated agriculture for economic activity, such as the eastern Arkansas Basin, are likely to suffer greater impacts versus regions with a broader, more diverse economic base.

South Platte Basin

Annual value of sales and services in the South Platte Basin equal $251,377 million, the highest relative to the other 3 basins studied. Agriculture industries comprise $2,123 million (0.84 percent) of this value (MIG, Inc., 2002). Because agricultural activity is concentrated in the eastern portions of the basin, analysis is restricted to the easternmost five counties in the basin (Adams, Arapahoe, Elbert, Morgan, and Weld counties). Focusing on the eastern half of the basin, the percentage of the value of sales and services from agriculture industries rises to 2 percent ($1,952 million), which is the lowest percentage but the highest total value relative to the other 3 basins studied. Irrigated crops make up $211 million (11 percent) of these agricultural sales. Table 6 lists the major industrial sectors of the eastern half of the basin.

Table 6: Economic Demographics for the 5 Eastern South Platte River Basin Counties (2002)

Industry	*Value of Sales*	*Percent of Total*
Total	$95,827	100.0%
Telecommunications	$7,151	7.5%
Real estate	$6,260	6.5%
Cable networks and program distribution	$5,744	6.0%
Wholesale trade	$5,707	6.0%
Owner-occupied dwellings	$3,417	3.6%
New residential 1-unit structures, non-farm	$3,067	3.2%
Insurance carriers	$2,558	2.7%
Non-depository credit intermediation	$2,361	2.5%
Animal, except poultry, slaughtering	$1,848	1.9%
Commercial and institutional buildings	$1,791	1.9%

Approximately seventy percent of the state's employment is in the South Platte Basin (SWSI, 2004). According to the U.S. Department of Labor's Bureau of Labor Statistics, the average unemployment rate in the East South Platte Basin in 2005 was 4.9 percent, the second lowest of all basins in the study. Although there are many economic alternatives to agriculture in the basin, the high total value of sales coming from agriculture suggests that the reduction in irrigated cropland will indeed have implications for the agricultural sector, as well as for many other sectors of the economy. Based on the relatively large size of the economy in the East South Platte Basin, there are likely to be more inter-industry ties and thus a greater ripple effect in this basin, whereby the initial shock in irrigated agriculture ripples throughout the other industries in the economy.

Republican Basin

Annual value of sales and services of the Republican River Basin is $3,061 million, with agriculture industries comprising $1,339 million (44 percent) of this value, as shown in Table 8. The Republican River Basin accounts for approximately two percent of the state's employment. Employment and earnings are concentrated in the agricultural and related industries. According to the U.S. Department of Labor's Bureau of Labor Statistics, the average unemployment rate in the Republican Basin in 2005 was 3.7 percent, the lowest of all basins under study. There are few economic alternatives to agriculture in the Republican River Basin and the counties in this area are heavily dependant on agriculture for their economic base. Although the anticipated reduction in irrigated cropland in this basin is relatively small, it has many implications for the agricultural sector (and for the many other sectors of the economy) due to the high percentage of the total value of sales coming from agriculture. Areas relying more exclusively on irrigated agriculture for economic activity, such as the Republican Basin, are likely to suffer greater impacts versus regions with a broader, more diverse economic base.

Table 8: Economic Demographics for the 7 Republican River Basin Counties (2002)

Industry	*Value of Sales*	*Percent of Total*
Total	$3,117	100.0%
Cattle ranching and farming	$805	25.8%
Irrigated Crops	$650	20.9%
Animal production, except cattle and poultry	$126	4.1%
Owner-occupied dwellings	$123	4.0%
Wholesale trade	$110	3.5%
State & Local Education	$107	3.4%
State & Local Non-Education	$85	2.7%
Monetary authorities and depository credit in	$83	2.7%
Food services and drinking places	$59	1.9%
Grain farming	$56	1.8%

Rio Grande Basin

Annual value of sales and services of the Rio Grande River Basin is $1,845 million, with agriculture industries comprising $530 million (nearly 30 percent) of this value (MIG, Inc., 2002). The Rio Grande Basin accounts for nearly one percent of the state's employment. According to the U.S. Department of Labor's Bureau of Labor Statistics, the average unemployment rate in the basin in 2005 was 7 percent, the highest of all basins in the study. There are limited economic alternatives to agriculture in the Rio Grande Basin and the counties in this region are heavily dependant on agriculture for their economic base. Due to the high percentage of the total value of sales coming from agriculture, the anticipated reduction in irrigated cropland has many implications for the agricultural sector, as well as for the many other sectors of the economy. Areas relying more exclusively on irrigated agriculture for economic activity, such as the Rio Grande Basin, are likely to suffer greater impacts versus regions with a broader, more diverse economic base. Table 9 lists the major industrial sectors of the Rio Grande Basin.

Table 9: Rio Grande Basin Economic Demographics

Industry	*Value of Sales*	*Percent of Total*
Total	$2,449	100.0%
Irrigated Crops	$1,133	46.3%
Owner-occupied dwellings	$84	3.4%
State & Local Education	$83	3.4%
Wholesale trade	$65	2.7%
New residential 1-unit structures, non-farm	$60	2.5%
Power generation and supply	$54	2.2%
Wet corn milling	$51	2.1%
Monetary authorities and depository credit	$42	1.7%
Hospitals	$39	1.6%
Food services and drinking places	$38	1.6%

Agricultural Demographics

East Arkansas Basin

Agricultural land is located primarily in the eastern portion of the basin, below Pueblo Reservoir (Smith, et al., 1996). The total land area of the 7 eastern Arkansas River Basin counties is 27,315 square miles (17,481,536 acres), with nearly one third (29.96 percent) of this land area in farm and ranch. Nearly half (45.26 percent) of the area in farm and ranch is cropland. Nearly one-tenth (9.92 percent) of this cropland is irrigated (Figure 6). Table 10 lists the value of sales by crop.

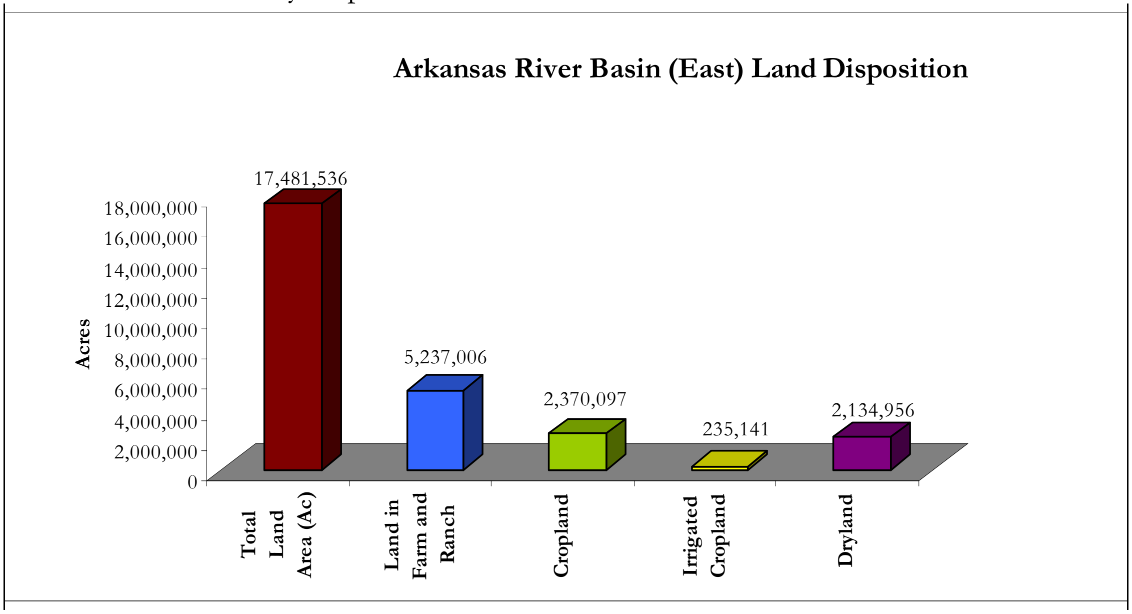

Figure 6: Eastern Arkansas Basin Land Disposition

Table 10: Value of Sales by Irrigated Crop for the 8 Eastern Arkansas River Basin Counties (2002)

Crops	*Total Production of Irrigated Crops*	*Value of Irrigated Crop Sales (million $)*	*Percent of Total Value*
Total		$101.43	100.00%
Notable Contributors			
Hay (TON)	645,825	$64.58	63.67%
Corn Grain (BU)	6,811,200	$14.64	14.44%
Sorghum Grain (BU)	8,510,175	$8.51	8.39%
All Wheat (BU)	1,927,800	$5.30	5.23%
Corn Silage (TON)	184,500	$4.06	4.00%
Soybeans (BU)	393,330	$2.89	2.85%

East South Platte Basin

The total land area of the 5 eastern South Platte River Basin counties is 9,124 square miles (5,839,616 acres), with over three quarters (80 percent) of this land area in farm and ranch. Nearly half (48 percent) of the area in farm and ranch is cropland. Of the cropland, 21 percent is irrigated and 79 percent is dryland (Figure 7). Table 11 lists the value of sales by crop. Forty percent of Colorado's agricultural production occurs in the South Platte Basin (South Platte Research Team, 1987). The lands are irrigated by direct flow rights from canals, storage from reservoirs, and pumping from alluvial aquifers.

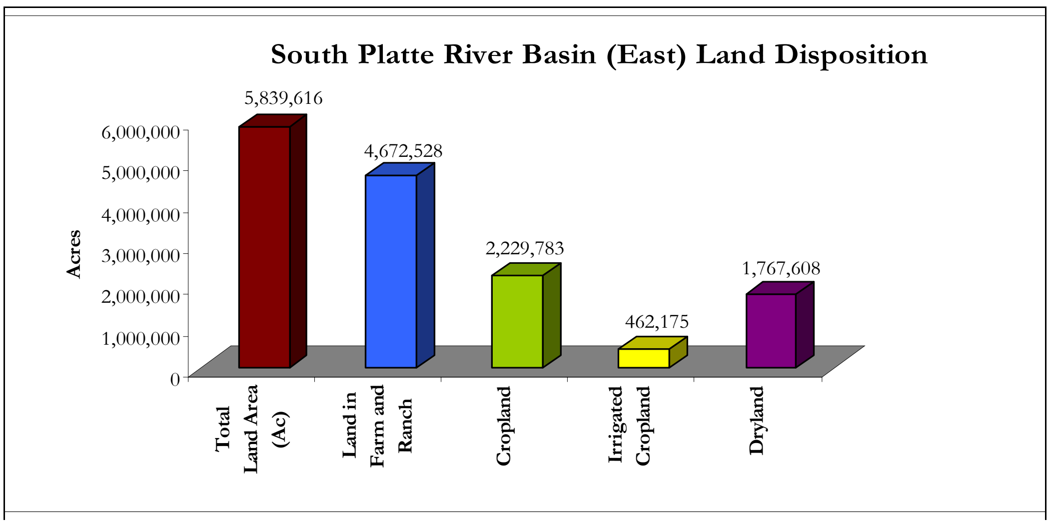

Figure 7: Eastern South Platte Basin Land Disposition

Table 11: Value of Sales by Crop for the 5 Eastern South Platte River Basin Counties (2002)

Crops	*Total Production of Irrigated Crops*	*Value of Irrigated Crop Sales (million $)*	*Percent of Total Value*
Total		210.55	100.00%
Notable Contributors			
Corn Grain (BU)	30,675,000	$70.86	33.65%
Hay (TON)	610,465	$54.94	26.09%
Corn Silage (TON)	1,521,600	$31.19	14.82%
Potatoes (CWT)	2,250,000	$20.93	9.94%
Sugarbeets Sugar (TON)	54,300,000	$18.46	8.77%
All Wheat (BU)	2,085,500	$6.42	3.05%
Barley Grain (BU)	1,820,850	$5.61	2.66%

*Here and throughout the entirety of this paper, "hay" refers to all hay types (e.g., alfalfa, clover, etc.)
**Here and throughout the entirety of this paper, "wheat" refers to all wheat types (e.g., summer, winter, etc.)
***Sunflower yields are for oil-type sunflowers only

Republican River Basin

Agriculture has been a major influence on both past trends and present conditions in almost every socioeconomic aspect in the Republican River Basin. The basin is located in one of the most agriculturally productive regions of the U.S. and, as such, the basin's agricultural output has both regional and national significance (BOR, 1985). The total land area of the Republican River Basin is 12,709 square miles (8,133,888 acres), with the highest proportion of this land area in farm and ranch (90 percent) relative to the other 3 basins studied. Of the area in farm and ranch, 61 percent is cropland. Of the cropland, 15 percent is irrigated cropland and 85 percent is dryland (Figure 8), with wheat being the primary dryland crop. The introduction of irrigation from both surface and ground water sources has diversified crops and increased livestock production. Corn, alfalfa hay, and dry edible beans are the main irrigated crops grown today. Grazing lands are utilized for beef cattle. Hay production also plays an important role in the economy. Table 12 lists the value of sales by crop.

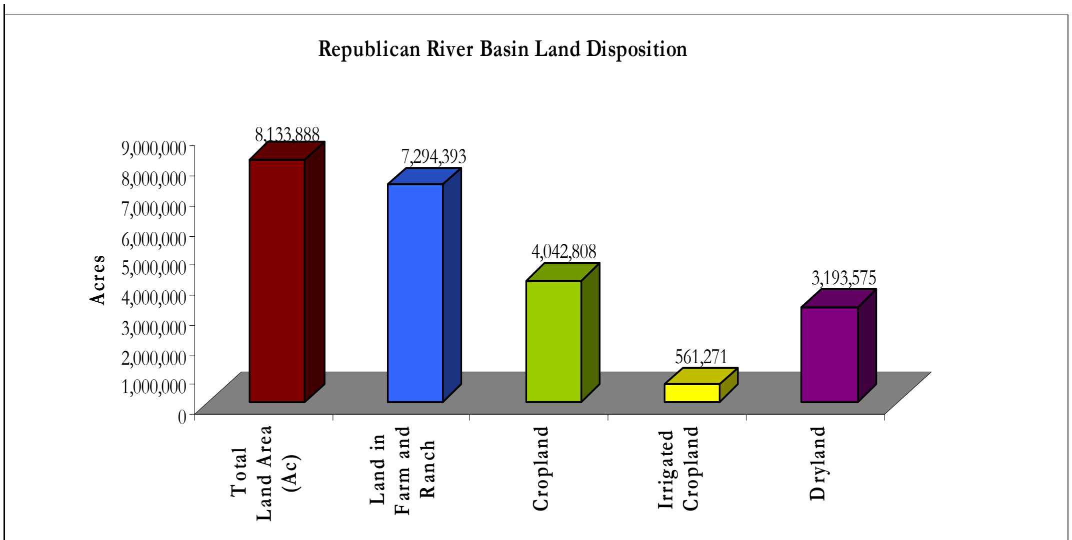

Figure 8: Republican Basin Land Disposition

Table 12: Value of Sales by Irrigated Crop for Republican River Basin Counties (2002)

Crops	*Total Production of Irrigated Crops*	*Value of Irrigated Crop Sales (million $)*	*Percent of Total Value*
Total		$367.06	100.00%
Notable Contributors			
Corn Grain (BU)	99,125,600	$206.18	56.17%
Hay (TON)	838,715	$75.48	20.56%
Sugarbeets (TON)	44,825,000	$15.24	4.15%
All Wheat (BU)	5,106,250	$13.79	3.76%
Sunflower (LBS)	120,104,600	$12.61	3.44%
Dry, Edible Beans	74,898,000	$11.98	3.26%
Corn Silage (TON)	552,500	$11.33	3.09%
Potatoes	731,000	$6.80	1.85%

Rio Grande Basin

The total land area is 8,194 square miles (5,244,288 acres), with over a quarter of this land area in farm and ranch (28 percent). Of the area in farm and ranch, 41 percent is cropland. Of the cropland, 51 percent is irrigated cropland and 49 percent is dryland (Figure 9). The short growing season limits the types of crops that can be grown. However, the San Luis Valley has a good supply of high quality water and raises some high value crops, including potatoes, lettuce and malting barley (Blewitt, 1991). Table 13 lists the value of sales by crop.

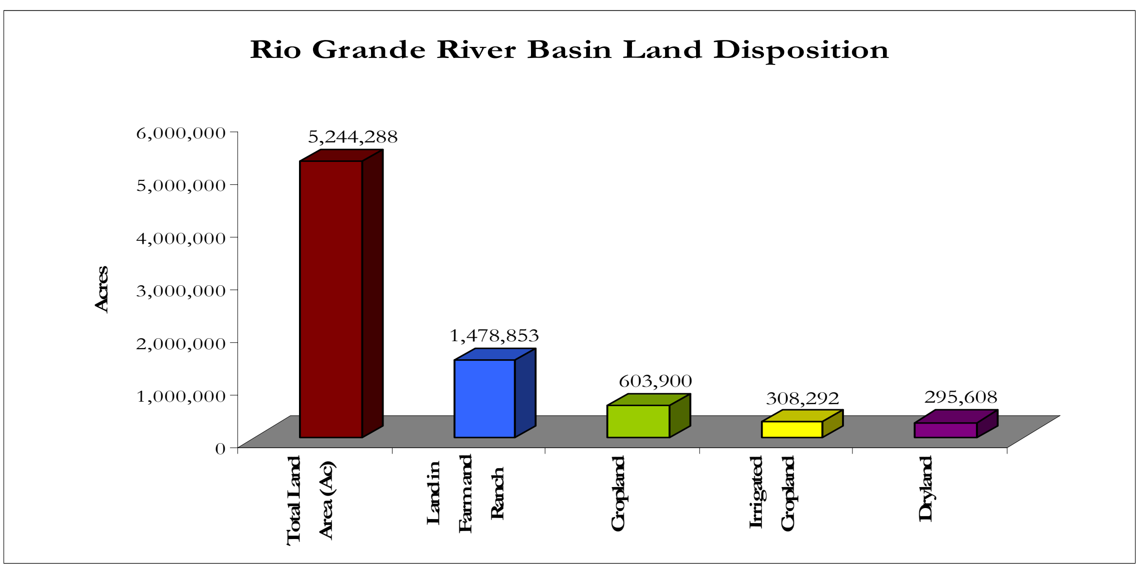

Figure 9: Rio Grande Basin Land Disposition

Table 13: Value of Sales by Irrigated Crop for Rio Grande River Basin Counties (2002)

Crops	*Total Production of Irrigated Crops*	*Value of Irrigated Crop Sales (million $)*	*Percent of Total Value*
Total		1,133.35	100.00%
Notable Contributors			
Potatoes (CWT)	112,255,000	$1,043.97	92.11%
Hay (TON)	606,950	$60.70	5.36%
Barley Grain (BU)	5,880,000	$16.46	1.45%
All Wheat (BU)	3,552,000	$9.59	0.85%
Oats Grain (BU)	1,385,500	$2.63	0.15%

Comparison of the Four River Basins

Variation in the importance of irrigated agriculture to the local economies in the different basins is directly related to population density, as shown in Table 14. Irrigated agriculture comprises a much lower percentage of total output in the East South Platte and Arkansas basins, where population densities are greatest. Variation in the economic activity generated per acre of irrigated cropland can be explained by variation in the major crop in each basin.

Table 14: Agriculture Summary and Comparison

Region	Population	Farm Gate Receipts[12] as % of Total Output in Region	Value of Irrigated Crop Sales (million $)	Irrigated Crop Sales as % of Total Output in Region	Representative Cropping Pattern	Projected Reductions in Irrigated Acres
East Arkansas	53,245	32 %	$147	7.3%	Hay, Wheat, Corn	47,500
East South Platte	1,136,568	2 %	$211	0.2%	Corn, Hay, Wheat	159,500
Republican	56,768	53 %	$650	20.9%	Corn, Hay, Sugarbeets	20,000
Rio Grande	46,726	48 %	$1,133	45.3%	Potatoes, Hay, Barley	80,000

[12] Farm gate receipts are the receipts from crops and livestock that have been sold in their primary, unprocessed form, without any value-added.

INPUT-OUTPUT MODELS AND IMPACT ANALYSIS

In previous sections, the imminent transfer of water from rural to urban uses was discussed. In particular, both the estimated number of AF to be transferred out of each basin and the estimated number of acres to be taken out of irrigation were given. Two overarching questions remain: what is irrigated agriculture's contribution to the economy and what will be lost to the economy if such a reduction in irrigated agriculture were to occur? This section outlines the data and procedures employed, as well as the assumptions made, in accomplishing the primary goal of this study—namely, approximating the economic impacts of a reduction in irrigated acres in eastern Colorado.

Irrigated agriculture affects the local economy through several different channels: the sale of irrigated crops impacts the economy *directly*, through the purchases of goods and services locally, and *indirectly*, as those purchases in turn generate purchases of intermediate goods and services from other, related sectors of the economy. In addition, these direct and indirect effects increases employment and income, enhancing overall economy purchasing power, thereby *inducing* further spending on goods and services. This cycle continues until the spending eventually leaks out of the local economy as a result of taxes, savings, or purchases of non-locally produced goods and services.

Multipliers describe these iterations, with the notion of a multiplier resting upon the difference between the initial effect of a change in final demand and the total effects of that change. Multipliers break the effects of stimuli on economic activity down into three components (Anderson, Wengert, and Heil, 1976):

1. *Direct effects* represent the change in final demand for the industry impacted.
2. *Indirect effects* are the changes to inter-industry purchases as they respond to the new demands of the directly-affected industries.
3. *Induced effects* reflect changes in household spending as household income increases or decreases due to the change in production.

The *total effect* is the sum of the direct, indirect and induced effects; it represents the entire response per million dollars of final demand. Indirect and induced effects are an important part of an industry's contribution to the regional economy. Economic multipliers measure these secondary effects by quantifying the relationship between an initial change in an industry's final demand and the total effect that this has on the sales of goods and services of all sectors within the region, as well as its effect on regional household spending.

The greater the indirect and induced effects are, the greater the multiplier will be. Multipliers are useful for determining a sector's relative effectiveness to promote regional growth and for providing information to identify economic development opportunities for different geographic areas (Cox and Munn, 2001). The multiplier for the irrigated agriculture sector is among the highest of all economic sectors, such that each added dollar's worth of crop output generates more than a dollar's worth of economic activity. In Colorado, the agriculture sector multiplier has been estimated to be 1.67 (MIG, Inc. 2002). The size of the multiplier will depend on the basic demographics of the region, the diversity of the regional economy, the relative importance of irrigated agriculture in the regional economy, and the strength of the backward and forward linkages between irrigated agriculture and supplying and processing sectors.

The economic modeling framework that best captures these direct, indirect, and induced effects is called input-output (I-O) modeling. I-O models provide an empirical representation of the economy and its inter-sectoral relationships, keeping track of the purchases and sales of every sector. This enables the user to determine the economy-wide effect that results from a change in the production of one sector of that economy (irrigated agriculture in the present case).

Input-Output Models

Input-output analysis is a means of examining relationships within an economy, both between businesses themselves and between businesses and final consumers (MIG, Inc., 2002). It captures all monetary market transactions for consumption in a given time period. The mathematical formulae allow examination of the effects of a change in one or several economic activities (an impact) on an entire economy.

Input-output analysis is comprised of two phases: descriptive modeling and predictive modeling (MIG, Inc., 2002). The descriptive model includes information about local economic interactions known as regional economic accounts. The regional account tables describe a local economy in terms of the flow of dollars from purchasers to producers within the region. In the predictive phase, these regional economic accounts are used to construct local-level multipliers, which express the response of the economy to an impact (a change in demand or production). The basic process by which multipliers are developed is discussed later in this section.

In agriculture, crop enterprise budgets describe the proportion of each dollar spent by farmers on particular inputs to produce a particular crop. These enterprise budgets served two key purposes in this study. First, they were used to adjust the basic IMPLAN I-O model, which is derived from a national model, to make it specific to Colorado and its crops. The national model represents the "average" condition for a particular industry. Consequently, without adjustments for regional differences, the national production functions do not necessarily represent industries comprising the regional economy. Second, these enterprise budgets were used to create a new sector in IMPLAN for each irrigated crop in that region. Having a separate sector for each irrigated crop makes it possible to "shock" each of these sectors separately, according to how many acres of each crop are expected to be dried up, resulting in a more accurate calculation of the output multiplier, and thus a more accurate portrayal of the size and distribution of the impact of reduced irrigated acreage.

For this study, crop prices and enterprise budgets were provided by Colorado State University's Cooperative Extension, Agriculture and Business Management Section. Crop enterprise budgets for NE Colorado were used in lieu of those that were not available for SE Colorado. These include the enterprise budgets for irrigated dry, edible beans, soybeans, sugar beets, and wheat. Enterprise budgets for irrigated sorghum and irrigated oats were borrowed from Texas and northwestern Oklahoma, respectively, as those same enterprise budgets for Colorado were not available. When using enterprise budgets to create production functions for the newly-created agriculture sectors in IMPLAN, the enterprise budget for pinto beans was taken to be representative of that for all dry, edible beans. Crop yield data from the year 2001 were used if data from the year 2003 were not available.

Using I-O Models to Perform Economic Impact Analysis

The economic activity that is generated by an industry does not end simply at its direct economic contribution. In order to more fully describe the economic contributions of specific industries in a regional economy, the indirect and induced effects must also be explored. For example, if an analyst were to study the economy of a rural farming region and add only the direct impacts of each sector in the economy, they would get a vastly-skewed picture of that region. Farming in this region is not only responsible for generating direct revenues, it also is responsible for demanding fertilizer and seed from the local farm supply store, and tractors from the local dealer, all of which are indirect effects. The farmers also spend their income at the local diner and provide tax revenues to the local school district, which are induced effects. Therefore, a one-dollar decline in agriculture revenue would have a greater than one-dollar effect on the regional economy because of these linkages. This is the fundamental rationale behind looking at indirect and induced effects in addition to direct effects when conducting regional economic impact analysis (Watson and Winter, 2005). The total effect is the sum of the direct, indirect, and induced effects, and the multiplier is calculated by dividing the total effect by the direct effect.

I-O modeling is based on several assumptions (MIG, Inc., 2002):

1. Constant returns to scale: This implies that the production functions are considered linear--if additional output is required, all inputs increase proportionately. This assumption generally holds and is rarely disputed.
2. No supply constraints: This implies that an industry has unlimited access to raw materials and its output is limited only by the demand for its products. This assumption is generally reasonable for agriculture, with the exception of water, which can certainly be a limiting factor in production. Because this study looks at industry

contraction, rather than expansion, limiting inputs is of no concern and this assumption has no effect on the results.

3. Fixed commodity input structure: This implies that price changes do not cause a firm to buy substitute goods--changes in the economy will affect the industry's output but not the mix of commodities and services it requires to make its product. This is the most troubling uncertain assumption and is the reason that the model is static and should not be used to forecast much beyond one year.
4. Homogenous sector output: This implies that the proportions of all the commodities produced by that industry remain the same, regardless of total output--an industry won't increase the output of one product without proportionately increasing the output of all its other products. This is a reasonable assumption for the agricultural sector. Furthermore, in this study, the crop sectors have been disaggregated among individual crops, as well as among irrigated vs. dryland agriculture, such that this study is more detailed and this assumption is virtually inconsequential.
5. Homogenous industry technology: This implies that an industry uses the same technology to produce all of its products. This is a reasonable assumption for the agricultural sector.

I-O models take into account all components to the national income account, given by the following equation (Watson and Winter, 2005):

Total Industry Output (TIO) = Intermediate Expenditures (IE) + Factor Payments (FP) + Payments to Institutions (PI)

What this equation means is that the total revenue generated by the industry (TIO) is accounted for by either expenditures on inputs from other sectors used to make its output (IE), payments to primary factors of production such as wages to employees and rents to land-owners (FP), or payments to institutions like taxes, investments, and inventory adjustments (PI). Together, FP and PI constitute what is called the *value-added* (VA). The VA is the amount of revenue that an industry generates above the cost of the basic input components of the product. Gross domestic product (GDP) of a region is the total value-added. There are four sub-components of value-added (MIG, Inc., 2002):

1. Employee compensation[13]
2. Proprietary income[14]
3. Other property-type income[15]
4. Indirect business taxes[16]

[13] Employee compensation includes wage and salary payments as well as benefits including health and life insurance, retirement payments, and any other non-cash compensation.

[14] Proprietary income is made up of payments received by self-employed individuals as income.

[15] Other property-type income includes payments from interest, rents, royalties, dividends, and profits.

[16] Indirect business taxes include excise and sales taxes paid by individuals to businesses, not including taxes on profit or income.

The TIO from the above equation includes local and non-local purchases, regionally purchased inputs, and imported inputs for that sector. A multiplier based on the structure of the regional economy is then applied to the total industry output, minus intermediate inputs purchased from the given industry by the given industry itself. This gives the total economic contribution of the industry to the regional economy. Employment is measured in total jobs (wage, salary, and self-employed) in the region. It includes both full-time and part-time workers, and is measured in annual average jobs (MIG, Inc., 2002).

IMPLAN is the I-O modeling system used in this study. IMPLAN (IMpact Analysis for PLANning) was originally developed by the USDA Forest Service in cooperation with the Federal Emergency Management Agency and the Bureau of Land Management to assist the Forest Service in land and resource management planning (MIG, Inc., 2002). It is now widely used by many state and federal agencies, universities and private consulting firms, and is the modeling system employed for this study. The following section describes how the IMPLAN software is used to create individualized I-O models and how impact analysis is then performed on those models.

MODELING WITH IMPLAN

Creating IMPLAN Regional Accounts

To create a regional I-O model, the regional data is combined with the national structural matrices to form the regional multipliers. In the first step, the software creates the regional study area file by combining the counties selected by the user. From the initial study area data, the software regionalizes the national structural matrices by eliminating industries that do not exist in the region and adjusts for VA/TIO ratios. Imports are then estimated via the *regional purchase coefficients* (RPC's**)**. An RPC represents the proportion of total supply of a good or service required to meet a particular industry's demands that are produced locally. For example, an RPC value of 0.8 for the commodity "potatoes" means that 80 percent of the demand for potatoes is provided by local farmers. Table 15 lists each basin's RPCs according to crop type, which were provided by IMPLAN and have not been altered.

Table 15: RPC's by Basin and Crop Category

Basin	Grains	Fruits and Vegetables	All Other Crops*
East South Platte	0.09	0.43	0.54
East Arkansas	0.15	0.74	0.81
Republican	0.35	0.68	0.35
Rio Grande	0.05	0.85	0.98

*Includes potatoes

Once RPC's are derived, imports are calculated using the minimum of the RPC or supply/demand pool ratio. Local demands are multiplied by the RPC's to create set of net local demands (total demand minus imports). This creates a set of matrices and final demands that are free of imports. Domestic exports are the residual of regional production not locally consumed. The result is a balanced set of regional economic accounts.

The I-O accounts are developed next. The regional use matrix and final demands are converted from commodity to industry basis. The subsequent inversion of the I-O accounts provides an import-free matrix of multipliers, which are used to calculate the indirect and induced impacts that result from the direct impact.

IMPLAN Multipliers

The net value forgone (or gained) is often the most suitable measure of direct economic impact. Value-added and employment are most often the chosen measures of indirect impacts (Young, 1983). These indirect effects are often measured with the use of multipliers derived from a regional I-O model. Applying the multipliers to estimates of decreased (or increased) sales by the industry of interest yields an estimate of reduced (or increased) economic activity in the region under study. The multiplier for the irrigated agriculture sector is among the highest of all economic sectors, such that each added dollar's worth of crop output generates more than a dollar's worth of economic activity (MIG, Inc. 2002). In Colorado, the agriculture sector multiplier has been estimated to be 1.67 (MIG, Inc. 2002).

However, the size of the multiplier will depend on the basic demographics of the region, the diversity of the regional economy, the relative importance of irrigated agriculture in the regional economy, and the strength of the backward and forward linkages between irrigated agriculture and supplying and processing sectors. There are three different types of multipliers developed for predictive modeling (MIG, Inc., 2002):

1. The Type I multiplier measures the direct and indirect effects of a change in economic activity. It captures the inter-industry effects only (i.e. industries buying from local industries).
2. Like the Type I multiplier, the Type II multiplier captures the direct and indirect effects, but it also takes into account the income and expenditures of households. The household income and the household expenditures are treated as industries. This internalizes the household sector, including the induced effects resulting from the household expenditures from new labor income.
3. Like the Type II multiplier, the Type SAM multiplier includes the direct, indirect and induced effects, but it also includes other non-industrial transactions, such as institution savings, payment of social security taxes, and commuting.

As recommended by MIG, Inc., Type II multipliers were used the present study. Using Type SAM multipliers can result in more information and detail but this additional information is often more complicated and harder to interpret and explain. In certain circumstances, Type II and Type SAM multipliers are equivalent, and as we are interested primarily in industries, not all institutions, Type II multipliers are quite sufficient for this study. We have followed the advice of MIG, Inc. and have not edited any multipliers.

The sectoring scheme used by the IMPLAN program has 509 sectors and very closely follows the 1997 Bureau of Economic Analysis (BEA) Benchmark Study for the United States sectoring. The IMPLAN sectoring scheme is based on national averages and thus needs to be calibrated to correspond better to Colorado data. According to Loveridge (2004), it is important for the analyst to double-check the validity of data in these models and make necessary adjustments, as they are often scaled down from national data sets under an assumption of fixed proportions, possibly resulting in the 'creation' of local sectors that in fact do not exist. The State Demographer's List of Businesses was used for this purpose. This list is a record of all businesses that currently exist in each study area, with each business organized by type according to the NAICS[17] code. The list was used to verify whether or not each IMPLAN sector truly exists in each study area under consideration. These sectors' NAICS codes were then aggregated and converted into to the appropriate IMPLAN sector codes.

Overview of Methodology

To begin, the IMPLAN system was used to construct an Input-Output (I-O) model for each basin and the model was calibrated to the most recently available data. Acreage data from Colorado Agricultural Statistical Services were used to disaggregate IMPLAN's default crop sectors into irrigated vs. dryland cropping. Crop enterprise budgets, provided by Colorado State University's Cooperative Extension Agriculture and Business Management section, were used to create a production function for each individual irrigated crop, resulting in the creation of a separate sector for each individual irrigated crop. These production functions are what tie the new irrigated crop sectors to other sectors in the economy and allow us to see the affect that a change in their output has on the rest of the economy. The model was then used to gauge irrigated agriculture's relative importance to each basin's economy and the spill-over effects that irrigated agriculture's sales create in the economy. At this point, the I-O models were ready to be "shocked".

The process of determining the size of the "shock" begins with the reduction in irrigated acreage. This was accomplished using the mid-points of the estimated number of acres to be taken out of irrigation provided by SWSI. The total number of lost acreage was distributed among all crops in the same proportions in which they are currently planted. Prices from the year 2002 were used to determine the value of lost sales of each crop due to the reduction in irrigated acres. It was assumed that all acres taken out of irrigation would be fallowed and the original crop-mix was maintained on all remaining acres.

These values of lost sales are the direct effects of the impact and were used to "shock" each basin's I-O model. The I-O model then determines the indirect and induced effects that ripple throughout the economy from this initial shock. As explained in more detail previously, the output multiplier is a good indicator of the size and extent of these ripple effects. Multipliers are useful for determining a sector's relative effectiveness to promote regional growth and for providing information to identify economic development opportunities for different geographic areas (Cox and Munn, 2001).

For the majority of this study, the most recent available IMPLAN data were used, which are from the year 2002. However, because 2002 was a drought year in Colorado, the year 2000 IMPLAN data for the industry output, employment, and income of the 18

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[17] The North American Industry Classification System (NAICS) was developed jointly by the U.S., Canada, and Mexico to provide new comparability in statistics about business activity across North America. NAICS replaces the 1987 Standard Industrial Classification (SIC).

agricultural sectors were used in order to avoid underestimation of these figures (and thus overestimation of the impact) for all of the basins with the exception of the Rio Grande Basin. Data from the year 2002 were used for the Rio Grande Basin under the assumption that the 2000 drought would have a negligible effect on this basin due to the fact that there is relatively little dryland cropping and greater use of ground water pumping in this basin. The entire agriculture industry is made up of all sectors as outlined in Appendix A. The 2000 IMPLAN agricultural sectors were converted to the 2002 agricultural sectors as outlined in Appendix B.

Assumptions and Notes

Economic activity is a generic term that applies to economic transactions such as businesses producing things, households buying things, etc. Economic output (value of sales) as defined in the model is a measure of economic activity on the local level that is similar to the measure of the gross domestic product on the national level. This study estimates the negative impacts that stem from the lost revenue due to a decrease in production; the study does not take into account the beneficial cost savings that would also be associated with a decrease in production, which may temper the revenue losses to some degree.

Historically, most water transfers have been conducted on a wholesale basis, with the formerly irrigated lands being fallowed (i.e., converted to grassland) or converted entirely to dryland (rain-fed) agriculture (Smith, 2005). However, the unfavorable economic outlook for dryland cropping and rangeland restoration has often led to land abandonment after water transfers, supporting the belief that all acres taken out of irrigation will be fallowed. In addition to being the most-likely scenario, the fallowing approach would also be the worst-case scenario, as no revenue would be generated by the land being fallowed. Because one of the primary goals of this study is to improve decision-making related to these reductions in irrigated acreage, it makes sense to analyze the worst-case scenario so that preparation is adequate for all possible scenarios. Thus, when calculating the initial impact (the direct effect), the present study assumes that all of the land that is taken out of irrigation is subsequently fallowed.

Finally, if, in the regional economy, a business exists that provides an input that is needed by agricultural producers in that region, then it is assumed that those producers purchase that factor from the local provider rather than from an outside source.

Limitations of Model

This model is instantaneous rather than dynamic, meaning that substitution effects (i.e., adaptations) are not taken into account. Thus, multipliers are a snapshot of the basin's economic activity—neither new lines of business that could potentially be generated in response to reduced irrigated agriculture, nor migration of businesses and residences out of the dwindling economy, are taken into account. Consequently, these multipliers typically overstate the economic losses for large-scale events (Pritchett, Frasier, and Schuck, 2003). For example, if all the acres that are estimated to be taken out of irrigation are converted to grassland, the entire industry output would not be lost to the economy because many of the affected producers would substitute other money-earning activities. However, if those activities have lower RPCs and provide lower-paying jobs, then there would indeed be a net loss to the regional economy from a reduction in the irrigated crops industry. Additionally, if producers of other commodities are dependent on farmers' goods as inputs to their production (e.g., corn silage for a dairy farm), these producers may be forced to purchase their inputs from farmers outside the region. This would represent a real loss of money to the local economy and would be considered an economic impact. The static nature of the model is also the reason that no discount rate was used in the analysis. Thus, the lost output values are in 2002 dollars.

The model is linear and thus is valid for marginal (i.e., small) changes only. Thus, all impacts are marginal rather than cumulative. The true outcome of the impact also depends on what previous impacts the regional economy has experienced recently. We don't know the tipping point (i.e., the critical threshold) of business activity in the regional economy and thus cannot say with certainty how it will fare when faced with this new impact.

I-O models do not take into account forward linkages (effects to downstream industries who use the outputs of irrigated agriculture as inputs to their own production), such as a reduction in the supply of corn to feedlots, dairies, or ethanol plants; rather, they only address backward linkages (e.g., reductions in the demand for inputs to irrigated agriculture, such as seed, fertilizer, etc.). There has been much concern expressed over the fate of dairy and livestock farmers in the affected regions, particularly in the East South Platte and Republican River Basins. This concern is certainly understandable and warrants consideration and comment, albeit brief. Colorado is a grain-deficit state, meaning that we already import grain (mainly for dairies and feedlots), so the reduction in irrigated acres will not require a substantial shift in grain flows to support these businesses. Colorado's corn production is small relative to national levels, such that large price changes are not expected. There likely will be some increased costs but these will not be of great magnitude, especially at the margin, which is what most production decisions are concerned with. Howe, Lazo, and Weber (1990) studied the economic impacts of agriculture-to-urban water transfers in the Arkansas River Basin and found no evidence that the phase-outs of feed grains, hay, and irrigated pasture held back the expansion of feedlots over the historical period from 1955 to 1985. Thus, forward linkages were judged to be absent during this historical period. The Texas Panhandle provides another example: a reduction in irrigated acreage has occurred in the area (also a net grain importer) in the recent past (due to depletion of the Ogallala aquifer), yet there is more cattle production there than ever before. These examples suggest that the fears of dairy and livestock farmers in eastern Colorado, though quite valid, are perhaps somewhat overstated. That being said, these are merely examples of what has occurred in the past; results will certainly be somewhat different due to the different area under study and the different time frame. Thus, further study on these specific industries would be beneficial and is encouraged.

The model does not distinguish between local versus global effects. The effects could be very different if, for instance, the lost acres are clustered around an individual city or town. Furthermore, the severity of economic impacts on the area of origin will also depend on the distribution of the losses. If the acreage losses all occur in one or a few specific location in the basin rather than being spread diffusely throughout the basin (as is likely given the high transactions costs of water transfers), the economic consequences will be highly concentrated in these "hot spots".

The model does not analyze distributional effects. Individuals with different characteristics are likely to be affected differently. For example, the owner of a farming enterprise may have additional skills that allow him or her to find other employment, or may have alternative sources of income, whereas a hired laborer on that same farm may not have either of these; thus, the impact will likely affect each one differently.

This study does not take into account the anticipated gains from urban use of water transferred from agriculture. Most of these gains would be difficult to document because most gains in the economy will occur in the future. While the use of the irrigation water for urban purposes would have a growth, or multiplier, effect, it is doubtful if this would be equal to the losses described because irrigated agriculture has one of the highest business multipliers observed in Colorado (Anderson, Wengert, and Heil, 1976). Furthermore, as the great majority of gains from the water transfers are likely to accrue to areas other than those experiencing the losses, we feel it is appropriate to exclude such gains from consideration.

Finally, it should be noted that if the initial impact results in decreased demand for a particular good, the entire purchase price of that good is not lost to the regional economy if that good is not produced entirely in that region. If a good (a pesticide, for instance) is produced outside the region but sold by a local retailer (by a coop, for instance), only the margin--the retailer's mark-up—rather than the entire purchase price, will be lost to the local economy. Only if the good is produced entirely in the local economy will the entire purchase price be lost to that local economy.

RESULTS

The model is "shocked" by the acreage reductions as predicted by SWSI and provided in Tables 3 and 17. The total effects are presented and then broken down into the direct, indirect, induced effects. Output multipliers for each region are calculated and discussed. Substantial differences between the regions exist, both in terms of impacts and multipliers, and further analysis suggests that differences in multipliers has much to do with differences in the diversity of each region's economic base, as is expected.

The economic and social impacts of water transfers on the area of origin are hypothesized to depend on the size and seniority of the transfer, the vitality of the regional economy, and whether the transfer takes place within the same economic region or to a different region (Howe and Goemans, 2003). When agricultural water rights (typically senior) are sold in Colorado, the land that had been irrigated by that water is usually required by the water court to be dried up permanently.

The losses represent what is likely to occur in the short run, when there is limited ability to react to the reduction in agricultural output. Over time, human resources and substitutable capital will migrate to other employment, although there will be less migration out of agriculture than would be the case with other sectors because of the culture of an agricultural way of life, the older average ages of farmers, and their more isolated locations (Howe and Goemans, 2003). In a prosperous region like the South Platte, displaced labor, capital, and land are likely to be reemployed in other productive activities within a relatively short period. The losses in the other basins are likely to persist over a longer period.

Output Impacts

Using the model and methods outlined in the previous section, economic impacts from a reduction in irrigated acreage were simulated. Table 16 shows the total output impact in each basin and compares the total impact to each basin's total output and agricultural output. The rows display the impacts by basin. The first column displays the value of total output in each basin, while the second column shows the total impact as a proportion of this output. The third column shows the total impact as a proportion of *all* agricultural output, while the fourth column shows the total impact as a proportion of *irrigated* agricultural output. The last column shows the impact per acre lost, which can also be interpreted as the economic activity generated by one acre of irrigated crops in that basin.

The total impact is greatest in the East South Platte Basin, which is expected due to the fact that this basin is projected to experience the greatest loss of irrigated acreage.

Economic activity per acre tends to be higher when high value crops are sold outside the region and when local support industries use local labor and inputs. The greatest economic activity generated per acre is found in the Rio Grande Basin, where a high-value crop (potatoes) is largely exported out of the region.

Table 16: Output Impacts Relative to Total Output and Agricultural Output

Basin	Total Output (million $)	Total Economic Impact (million $)	Impact as % of Total Output	Impact as % of Agriculture	Impact as % of Irrigated Crop Sales	Economic Activity per Acre
Arkansas East	$2,001.26	-$20.33	1.02%	3.20%	13.87%	$428
East South Platte	$95,827.04	-$110.07	0.12%	5.64%	52.28%	$690
Republican	$3,116.60	-$13.55	0.43%	0.82%	2.08%	$678
Rio Grande	$2,499.35	-$98.78	3.95%	8.16%	8.72%	$1,235

In Table 17, the total impact is broken down into its component parts, with the rows displaying the impacts by basin and the first column restating the acreage reduction, as estimated by SWSI. The total effect is the sum of the direct, indirect and induced effects, and is shown in the second column of the table. The direct effects represent the lost irrigated crop sales, and are shown in the third column of the table. The indirect and induced effects are an important part of an industry's contribution to the regional economy, and are shown in the fourth and fifth columns of the table, respectively. The indirect effects are the decreases in inter-industry purchases (fertilizer, seeds, etc.) in response to the decreased demands of irrigated agriculture. The induced effects reflect changes in household spending as household income decreases due to the decrease in production.

Economic multipliers measure these secondary effects by quantifying the relationship between an initial change in an industry's final demand and the total effect that this has on the sales of goods and services of all sectors within the region, as well as its effect on regional household spending. The greater the indirect and induced effects are, the greater the multiplier will be. Each basin's output multiplier for irrigated agriculture is displayed in the final column of the table.

Table 17: Impact Components and Multipliers

Basin	Estimated Acres Lost	Total Economic Impact	Direct Effect (Value of Lost Acres)	Indirect Effects	Induced Effects	Output Multiplier
East South Platte	159,500	-$110,065,962	-$61,984,519	-$36,958,492	-$11,122,950	1.78
Arkansas East	47,500	-$20,333,467	-$13,799,923	-$5,464,589	-$1,068,955	1.43
Republican	20,000	-$13,550,801	-$10,748,980	-$2,114,282	-$687,539	1.25
Rio Grande	80,000	-$98,783,450	-$80,975,354	-$9,098,167	-$8,709,928	1.22

The output multiplier is a measure of economic inter-connectedness and it measures the degree to which a decrease in activity of a given local industry (irrigated agriculture in this case) causes a decrease in purchases from other local industries and local resource providers. A large multiplier indicates that that industry has many ties to the local economy (it does not necessarily indicate high output). For instance, the East South Platte multiplier of 1.78 means that for every $1 we take out of the production of irrigated agriculture, the total impact on the entire East South Platte Basin will be a loss of $1.78 of economic activity. The output multiplier is thus a good indicator of the size and extent of the ripple effects and is intimately related to the proportion of inputs to irrigated agriculture that are purchased locally (i.e., within the study region). There are likely many factors that influence the variations in output multipliers across basins seen here. Three important ones are mentioned here:

1. Size of the regional economy: Typically, the larger the size of the economy, the more economic activity is internalized. Conversely, the smaller the economy, the more dependent the area is on economic activity from other functional economies, and hence the more income tends to leak outside the area as goods and services necessary for day-to-day commerce are imported (purchased from outside the area). Given the limited number of linkages that exist in these smaller economies, multipliers tend to be smaller, resulting in a smaller total effect for a given impact, since more of the ripple effects occur outside of the region. However, because there are fewer businesses among which the losses can be spread, the losses could actually be more concentrated and severe in these areas. According to the U.S. Forest Service Economics Team (2006), in order to isolate the effects of an impact it is desirable to make the study area as small as possible while still including areas necessary to capture all-important effects. To capture the most reliable estimates of economic impacts, the study area should represent a "functional economic area", which is defined as a semi-self-sufficient economic unit (U.S. Forest Service Economics Team, 2006). These views provide support to the choice of study area sizes in this research paper.
2. The diversity of the local economy: In general, more complex economies will have larger multipliers because more inputs will be provided locally. One indicator of the diversity of an economy is the number of industries that make up that economy. The economy in the East South Platte Basin consists of roughly twice as many unique industries as the other three basins. This may suggest that farmers in the East South Platte Basin are able to purchase a larger proportion of their factors of production from within the basin, as compared to the other three basins. If indeed crop farmers can buy more of their inputs locally, then a reduction in the crop farmers' output will have a larger effect on the local economy as the providers of those inputs to crop farming face reduced demand. Thus, the ripple effect within the region will be larger, resulting in a higher multiplier.

   Another indicator of the diversity of an economy is the Shannon-Weaver diversity index, which is provided by IMPLAN. The Shannon-Weaver diversity index is determined by the number of industries there are in the region and how well-distributed employment is throughout all of those industries. Its values range from zero to one, with one being perfect diversity. Conversely, as employment and output become concentrated in fewer industries, the Shannon-Weaver index approaches zero. The Shannon-Weaver diversity indices for each basin are displayed in Table 18. As might be expected, the Shannon-Weaver diversity index corresponds positively to the size of the multipliers in all four basins. For comparison purposes, the Shannon-Weaver diversity index for Colorado's economy as a whole is 0.77.

Table 18: Relationship between Shannon-Weaver Diversity Indices and Output Multipliers

Basin	S-W Index	Output Multiplier
East South Platte	0.7219	1.78
East Arkansas	0.6095	1.43
Republican	0.6228	1.25
Rio Grande	0.5776	1.22

3. Local factors of production: When a sector relies heavily on local industries for inputs, it will have a relatively large multiplier. Large multipliers indicate that there are many ties to the local economy and that there is less leakage of new money so that money is used more times before it escapes from the economy again. Different crops and different growing regions require the use of different sets and amounts of inputs. The Agriculture and Forestry Support Activities[18] sector is a major provider of inputs to irrigated agriculture and is provided by local business in each basin. However, purchase amounts from this Agriculture and Forestry Support Activities sector vary across basins, based on the different crops grown in each basin and their different requirements, thus affecting the size of the multiplier. For instance, crop farmers in the Rio Grande Basin purchase the lowest percentage of their inputs from the Agriculture and Forestry Support Activities sector, according to the IMPLAN model, suggesting a lower multiplier in that basin, which we indeed observe. In general, more complex economies will have larger multipliers. It is not surprising then, that the largest output multiplier observed is for the East South Platte Basin.

Impacts per Capita

Howe and Goemans (2003) argue that the per capita losses are more relevant measures of the welfare impacts associated with a reduction in irrigated agriculture. This idea seems appropriate, especially given that the low population typical of rural areas means that the impacts per capita are likely to be higher than in urban areas. Even if the *total* impact to a basin is smaller compared to that in other basins, if the population density in the first basin is much lower than in the others, the impact will be spread out over fewer people and thus the

[18] Agriculture and Forestry Support Activities include crop consultants, custom application of chemicals, custom bailing and hauling, and irrigation labor.

impact *per person* will be higher. Support for this idea can be seen in Table 19. Due to the much lower population densities in the East Arkansas, Republican, and Rio Grande basins, the per capita losses are much greater in these basins. In contrast, the South Platte Basin, which has the highest population density of all basins under study, has the lowest per capita impact.

Table 19: Per Capita Impacts

	Total Impact	Population	Per Capita Impact
East South Platte	-$110,065,962	1,136,568	-$97
East Arkansas	-$20,333,467	53,245	-$382
Republican	-$13,550,801	56,768	-$239
Rio Grande	-$98,783,450	46,726	-$1,929

Impacts by Sector

The previous results examine the impact to the regional economy as a whole, but do not disaggregate the impact among different sectors. The distribution of the impact will be uneven among sectors, and this distribution is sure to be important to stakeholders. Thus, the following section breaks down the total impact by sector. Furthermore, each sector is expected to be affected to different degrees in each basin as a result of the basins' differing economic profiles; thus, the disaggregated impacts are also displayed by basin. Table 22 shows the five sectors in each basin which will experience the greatest total impact stemming from the reduction in irrigated acreage. In each basin, Irrigated Crops is the sector most affected by the acreage reductions. This is not surprising, and can be explained by the fact that this sector is where all of the direct impacts occur. The impacts to all other sectors are a result of the indirect and induced effects, as defined earlier.

The Wholesale Trade sector also appears in each basin's list of top 5 most-affected sectors. According to the NAICS definition, this sector comprises establishments engaged in wholesaling merchandise, generally without transformation, and rendering services incidental to the sale of merchandise. The merchandise described in this sector includes the outputs of **agriculture**, mining, manufacturing, and certain information industries, such as publishing. The wholesaling process is an intermediate step in the distribution of merchandise. Wholesalers are organized to sell or arrange the purchase or sale of:

a. goods for resale (i.e., goods sold to other wholesalers or retailers),
b. capital or durable non-consumer goods, and
c. raw and intermediate materials and supplies used in production.

This sector comprises two main types of wholesalers:

a. merchant wholesalers, who sell goods on their own account and
b. business-to-business electronic markets, agents, and brokers that arrange sales and purchases for others, generally for a commission or fee. Chemical dealers, fertilizer dealers, tractor dealers, etc., would likely fit into this category.

The Agriculture and Forestry Support sector appears in three of the four basin's top five list of impacted sectors, and is described by NAICS as providing support services that are an essential part of agricultural and forestry production. These support activities may be performed by the agriculture- or forestry-producing establishment itself or conducted independently as an alternative source of inputs required for the production process for a given crop, animal, or forestry industry. Crop consultants, soil-testing services, etc., would likely be included here. Other sectors providing support services to agricultural production that are also shown to bear a large portion of the total impact include truck and rail transportation sectors, machinery and equipment rental, and repair and maintenance sectors, the Scientific Research and Development sector (which services include research and development on seed and plant genetics).

The Cattle Ranching and Farming sector relies heavily upon crop farmers for cattle feed, and thus will be affected by a reduction in crop sales. This is especially evident in the East Arkansas Basin, as can be seen in Table 20. The Owner-Occupied Dwellings sector represents home-ownership. Home-ownership is treated like an industry--it has a production function and value-added (mostly property taxes), and households make payments to this sector as part of their consumption function (it is like home-owners paying a rent to themselves). This sector is one of the most-affected sectors in the East Arkansas and Rio Grande Basins, signifying that there is a lot of household spending being impacted in these basins (MIG, Inc., 2006). The impact felt by this sector is due entirely to induced effects (those of reduced household spending due to decreased household income). Finally, the Monetary Authorities and Depository Credit sector appears in the list of most-affected sectors in the Rio Grande Basin, for which there are likely several contributing factors. Firstly, as farmers decrease the number of acres under irrigation, they will have fewer inputs to purchase and thus will likely take out fewer operating loans from local banks and other lending institutions. There will also likely be a decrease in real estate activity in the region, resulting in fewer mortgages and their associated fees. Finally, because banks and other financial institutions in this basin are more likely to be locally-owned, a larger portion of their revenues stay within the region, resulting in a larger ripple effect occurring in this sector.

Table 20: Impact by Sector

Basin	Sector	Direct	Indirect	Induced	Total
East Arkansas	Irrigated Crops	-$13,799,923	-$3,332,842	-$1,843	-$17,134,608
	Agriculture and forestry support	$0	-$578,004	-$375	-$578,379
	Wholesale trade	$0	-$216,677	-$44,915	-$261,592
	Cattle ranching and farming	$0	-$221,480	-$11,309	-$232,789
	Owner-occupied dwellings	$0	$0	-$186,185	-$186,185
East South Platte	Irrigated Crops	-$61,984,519	-$1,569,878	-$5,601	-$63,559,998
	Wholesale trade	$0	-$8,809,051	-$759,688	-$9,568,739
	Machinery and equipment rental and leasing	$0	-$4,550,087	-$19,892	-$4,569,979
	Commercial machinery repair and maintenance	$0	-$2,123,600	-$13,693	-$2,137,293
	Scientific research and development	$0	-$2,070,535	-$10,080	-$2,080,615
Republican	Irrigated Crops	-$10,748,980	-$181,735	-$2,857	-$10,933,573
	Wholesale trade	$0	-$532,088	-$32,695	-$564,783
	Truck transportation	$0	-$152,644	-$9,798	-$162,443
	Agriculture and forestry support	$0	-$154,141	-$62	-$154,203
	Rail transportation	$0	-$136,760	-$1,178	-$137,938
Rio Grande	Irrigated Crops	-$80,975,354	-$164,775	-$25,646	-$81,165,775
	Wholesale trade	0	-2,254,154	-274,452	-2,528,606
	Agriculture and forestry support	0	-1,607,693	-2,274	-1,609,967
	Owner-occupied dwellings	0	0	-1,404,495	-1,404,495
	Monetary authorities and depository credit	0	-378,399	-404,114	-782,513

Economic Activity per Acre

Local economies are impacted by a loss of irrigated acres, and these impacts are not uniform across basins because the economic activity generated by an acre of irrigated land differs by basin. Economic activity per acre tends to be higher when high value crops are being sold to areas outside of the local region (thus bringing new money into the region) because there will be more money lost to the local economy. If the goods produced in a region are sold back to consumers in that same region, the total amount of money in that economy has not increased, because simply trading money within the local economy does not increase the total amount of money in that economy. In order to increase the total amount of money in an economy, locally-produced goods must be sold to consumers outside of the region. Table 21 shows the percentage of the major crop in each basin that is exported and how this compares to the average economic activity generated per acre in that basin. With the exception of the East South Platte Basin, the economic activity generated per acre increases as the proportion of crops exported increases. Crops in the East South Platte Basin generate a relatively high economic activity per acre, in comparison to the percentage of the crops that are exported from the basin, mainly due to the relatively higher level of economic diversity in this basin, as discussed previously.

Table 21: Relationship between Exports and Economic Activity per Acre

Basin	Top 2 Irrigated Crops*	% Exported**	Average Economic Activity per Irrigated Acre
East South Platte	Grain Corn and Hay	61%	$772
East Arkansas	Hay and Wheat	82%	$335
Republican	Grain Corn and Hay	96%	$678
Rio Grande	Hay and Potatoes	98%	$1,235

*In terms of dollars of output

**Refers to domestic exports (it is assumed that there are no foreign exports out of the area)

Economic activity per acre also tends to be higher when local support industries use high amounts of local labor and inputs. For instance, potatoes, a major crop in the Rio Grande Basin, are a high-input costs and high-revenues crop, contributing to a high amount of economic activity generated per acre in this basin. Although hay, another major crop in the Rio Grande Basin, is a low-input cost crop, it is treated as a high-value crop in this basin since the majority of it is shipped to dairy farmers and horse-owners outside of the region, thus bringing "new" money into the economy. In contrast, the hay grown in the Arkansas Basin is primarily sold for forage (a lower-value use) within the region, thus bringing less "new" money into the region and resulting in a lower economic activity per acre in the basin.

Another possible explanation for differences in the economic activity per acre is the differing levels of ground water use relative to surface water use for irrigation across basins. Increased ground water use generally coincides with greater economic activity lost. This can be explained by the increased irrigation costs and increased revenues per acre associated with greater ground water resources as opposed to more-variable surface water flows. The higher irrigation costs are primarily due to the higher energy costs associated with pumping the ground water, whereas the higher revenues per acre are primarily due to increased crop yields (due to greater consistency in irrigation amounts and timing) and the tendency to grow higher-value crops with ground water (Wilkins-Wells, et al., 2002). Irrigation in the Rio Grande Basin relies heavily upon conjunctive use of ground water and surface water, and the results of this study suggest that the Rio Grande Basin generates the greatest economic activity per acre. The primary source of water in the Republican River Basin is groundwater from the Ogallala Aquifer (SWSI, 2004) and this basin also has a relatively high economic activity per acre. There is also a relatively high economic activity per acre in the South Platte Basin, where ground water is a substantial resource, with approximately 880,000 acre-feet per year (AFY) of groundwater used for irrigation and 100,000 AFY used to meet municipal, domestic, livestock, industrial, and commercial purposes in the basin. The Arkansas Basin uses a higher proportion of surface water and has a lower impact per acre lost than the other three basins.

Impacts by Crop

Different crops are also affected to different degrees in each basin. Furthermore, each crop has a different production function and thus is associated with differing degrees of ripple effects (indirect and induced effects), resulting in magnitudes of impact per acre lost that vary across crops. Table 22 outlines the five crops in each basin that experience the greatest total impact, as well as the economic activity generated per acre of these crops. Because the total impact is made up of the direct, indirect, and induced effects, a crop may experience a large total impact due a variety of factors. For instance, hay appears in the list of most-affected crops in each basin primarily due to the large number of acres of that crop that are lost (direct effects). Potatoes and sugar beets, on the other hand, appear in the top five because these crops generates a high level of economic activity per acre, and thus generate a large drop in economic activity per acre lost.

Table 22: Impact by Crop

	Crop	Acres Lost	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Economic Activity per Acre*
East Arkansas	Hay	19,681	$7,774,123	$2,721,345	$207	$10,495,674	$533
	Sorghum	12,964	$3,179,518	$364,625	$719	$3,544,861	$273
	Grain Corn	4,767	$1,762,782	$225,131	$1	$1,987,914	$417
	Silage corn	1,083	$488,602	$5,737	$121	$494,460	$456
	Soy beans	843	$348,001	$11,766	$741	$360,508	$428
East South Platte	Grain Corn	63,866	$22,129,640	$26,854	$257	$22,156,752	$347
	Hay	45,940	$17,158,570	$1,336,892	$3,007	$18,498,468	$403
	Silage corn	19,800	$9,741,642	$59,086	$241	$9,800,969	$495
	Potatoes	1,124	$6,534,965	$137,352	$6	$6,672,323	$5,935
	Wheat	6,059	$2,006,036	$106	$119	$2,006,261	$331
Republican	Grain Corn	5,548	$4,676,250	$4,837	$900	$4,681,987	$844
	Hay	11,745	$4,386,585	$2,899	$553	$4,390,036	$374
	Dry, Edible Beans	415	$271,793	$79,339	$22	$351,154	$845
	Sugar beets	218	$291,777	$54,541	$1	$346,319	$1,590
	Silage corn	268	$256,883	$2,318	$136	$259,336	$966
Rio_Grande	Potatoes	15,933	$55,312,980	$24,276	$8,003	$55,345,260	$3,474
	Wheat	4,123	$8,259,744	$11,855	$935	$8,272,533	$2,007
	Hay	44,345	$6,866,886	$1,601	$1,211	$6,966,526	$157
	Oats	3,788	$6,866,886	$15,225	$1,626	$6,869,698	$1,813
	Barley	10,919	$3,668,858	$86,629	$13,011	$3,685,710	$338

*Can also be interpreted as the impact per acre lost in that region

The employment impacts obtained from IMPLAN I-O models include the total number of jobs lost and the number of agricultural jobs lost in each basin, as shown in Table 23. These figures can be used to calculate the number of jobs lost per acre lost in each basin, the inverse of which is the number of acres required to support one job in each basin, which are also shown in the table. The lowest number of acres required to support one job is seen in the Rio Grande Basin, while the highest number of acres required to support one job is seen in the East South Platte Basin. This could be due in part to the fact that the main crop, in terms of acres planted, in the Rio Grande Basin is hay, which requires more labor than grain corn, the main crop in the East South Platte Basin[19]. The job loss figures are also used to calculate the number of jobs lost as a percentage of the total workforce in each basin and as a percentage of all farm jobs in each basin, also shown in the table.

Also included in Table 23 are the average unemployment rates in each basin, which can be considered alongside the job loss numbers to provide an idea of the severity of the employment impacts and to better predict whether or not the local economy will be able to absorb these job losses. Such a comparison shows the shocking severity of consequences that may befall the Rio Grande Basin. The Rio Grande Basin has the highest unemployment rate and is predicted to experience the greatest job losses, both in terms of total jobs and in terms of percentages. These harsh consequences will adversely affect the Rio Grande Basin's economy, which leaves us with the important question of whether or not the Rio Grande Basin's economy will able to withstand the impact. Economic impact analysis cannot diagnose the exact tipping point of a particular economy--further research would be required, and is suggested, to better predict how each basin's economy will fare in the face of these impacts.

Table 23: Employment Impacts

Basin	Unemployment Rate*	Total Jobs Lost	Agriculture Jobs Lost	Jobs Lost as % of Total Workforce**	Jobs Lost as % of Farm Jobs	# Acres that Support One Job
East South Platte	4.9	907	580	0.13%	9.1%	176
East Arkansas	5.5	437	412	2.14%	10.5%	109
Republican	3.7	187	162	0.64%	2.8%	107
Rio Grande	7.0	1,086	884	5.03%	39.3%	74

*Unemployment rates are averages from the year 2005.
**Job numbers in some industries were not disclosed; therefore, the actual workforce is likely to be somewhat higher, resulting in job loss percentages that are somewhat lower that what is shown here.

The reduction in economic activity, whether it takes place in the value of sales or wages, will adversely affect sales and tax revenues in each region. The overall decrease in economic activity due to the acreage reductions will decrease tax revenues in each region. Table 24 shows the total tax impact and breaks it down into its component parts.

[19] Hay is typically produces three to four crops each year, requiring three to four harvests per year, whereas corn yields only one crop a year, requiring only one harvest per year.

Table 24: Tax Impacts

Basin	Employee Comp.	Proprietary Income	Household Expenditures	Enterprises	Indirect Business Taxes	Total*
East South Platte	-$1,726,206	-$297,080	-$6,809,661	-$1,147,664	-$3,518,726	-$13,499,338
East Arkansas	-$186,666	-$55,663	-$685,409	-$262,490	-$934,326	-$2,124,545
Republican	-$121,688	-$30,634	-$462,319	-$136,822	-$591,366	-$1,342,829
Rio Grande	-$1,272,309	-$324,797	-$5,321,615	-$914,283	-$4,001,330	-$11,834,333

*Does not include property taxes.

The SWSI estimates of reduced irrigated acreage were used to "shock" the IMPLAN I-O models that had been built for each basin. This section presented the total economic impacts in each basin, as generated by IMPLAN. The total impact was then disaggregated into the direct, indirect, and induced effects. Impacts were also segregated by sector and by crop, and output multipliers for each region were displayed and discussed. Substantial differences between the regions exist, both in terms of impacts and multipliers, and further analysis suggests that differences in multipliers has much to do with differences in the diversity of each region's economic base, as is expected.

In terms of total impact, the East South Platte Basin experiences the largest total impact, which is not surprising considering that this basin is projected to experience the largest decrease in irrigated acreage. The South Platte Basin also has the largest multiplier, meaning that the initial impact will generate more ripple effects within this basin. This can be explained by the greater size and diversity of the East South Platte Basin's economy. At first glance, these results may seem to suggest that the East South Platte Basin will be the area worst-hit by the acreage reductions. However, upon further analysis, it becomes apparent that the East South Platte Basin experiences the lowest per capita impacts due to this basin's relatively high population density. Also, because of the greater diversity of the East South Platte Basin's economy, it may be better equipped to weather such an economic impact than the other economies under consideration.

Finally, the employment and tax impacts were displayed and briefly discussed. Although the Rio Grande basin did not experience the greatest loss of acres, it did experience the largest employment loss, both in terms of total jobs lost and proportion of total workforce lost. This can be partially explained by the high labor requirements for producing hay, the main crop grown in this region. This outcome provides further evidence that it is important to look at more than just the raw numbers of acres that will be lost to predict the impact—the true impact depends on which crops are lost and in which region.

CONCLUSIONS

Farming at the urban fringe has many challenges and trade-offs. Maintaining the availability of inexpensive, reliable, and timely water supplies to irrigated farms, in the face of urbanization, is an overarching concern of agricultural producers (Wilkins-Wells, et al., 2002). Irrigators are clearly trying to adapt to the seemingly inevitable trend toward urbanization of prime irrigated lands throughout the West.

This study forecasts the size and scope of the impacts associated with predicted reductions in irrigated acreage, with the hope that the affected communities can take steps to minimize and prepare for the impacts, and better adapt to the changes. The study began by establishing demographics for each region under consideration, and then provided general estimates of what the agricultural sector, and irrigation in particular, contributes to the regional economic activity of each region. An input-output model was created for each region, and then these I-O models were "shocked", using SWSI estimates of future reductions in irrigated acreage, with the final goal of providing preliminary estimates of what might happen should such an acreage reduction occur, and should this previously-irrigated land be converted to grassland. This scenario involved the simplifying assumption that all of the value was instantly lost, rather than being lost gradually over the next twenty-five years. The estimated impacts are permanent losses.

The estimates from the input-output analysis indicate that the effect of farms lowering production or going out of business because of a lack of irrigation water would substantially hurt the rural economy from which the water transfers originate. Not only would the agricultural sector be damaged but several other sectors of the economy would be adversely affected as well. In addition to the agricultural jobs that would be lost, jobs would be eliminated in other sectors as well. Income to both agricultural families and non-agricultural families would be lost. Tax revenue losses would be substantial--amounting to millions of dollars.

On one hand, the estimates may be considered conservative in that the model does not take into consideration any possible interactions with livestock production or food processing (forward linkages), nor the impact of unemployed people moving out of the region. On the other hand, the estimates do not take into consideration any adaptive behavior aimed at lessening the losses, nor the potential re-employment of the unemployed people within some new business. This is, of course, the nature of all models—they are imperfect replicas of the real world.

Substantial differences between the regions exist, both in terms of impacts and multipliers, leading to the conclusion that any policy or program intending to mitigate the negative impacts of lost irrigated acreage should not be a one-size-fits-all solution, but rather would be most effective if tailored specifically to the affected region.

Many factors affect the magnitude of the initial impact and thus there are many reasons why the magnitude and extent of the actual impacts may differ somewhat from these initial estimates. Firstly, as mentioned earlier, the initial impacts were based on the means of SWSI's estimated ranges of reduced irrigated acres. Thus, it is important to note that the number of irrigated acres that will actually be lost could be higher or lower. Secondly, these estimates of lost irrigated acres could be considered minimums in that they are made under the assumption that 80 percent of all identified water projects and processes are successfully implemented, when in truth water projects involve a lengthy, and very political, process that may preclude their development. Thirdly, rather than maintaining the current crop-mix in the remaining acres, as assumed in this study, it is more likely that some crops will be taken out of production in greater proportions than others, based on relative profitability. And lastly, rather than all lost acres being fallowed, as assumed in this study, it is more likely that a variety of alternatives (such as conversion to dryland or rangeland) will be undertaken as well.

It should also be noted that the SWSI estimates are through the year 2030—it is quite possible that additional losses will occur beyond the year 2030. Because additional agriculture-to-urban water transfers are inevitable, these results will help predict what will happen to the communities affected by such transfers. It is the authors' hope that these results will also help to mitigate/minimize any negative effects and/or distribute them more equitably. Water is necessary for every one of us and it would be beneficial for us all to have a better understanding of the issues, challenges, and potential solutions surrounding its management.

REFERENCES

Anderson, R.L., N.I Wengert, and R.D. Heil. "The Physical and Economic Effects on the Local Agricultural Economy of Water Transfer from Irrigation Companies to Cities in the Northern Denver Metropolitan Area." *Colorado Water Resources Research Institute Completion Report No. 75*. October 1976.

Blewitt, Donald I. "Administration of the Rio Grande Compact in Colorado." 1991.

Brunswig, Lori. "Ogallala Symposium Venue for Discussion of Shared Interests." *Colorado Water*. April 2006.

Colorado Water Resources Research Institute. "East South Platte Forum: Valuing your Water." *Colorado Water*. April 2005.

Committee on Western Water Management. "Water Transfers in the West: Efficiency, Equity, and the Environment." *National Research Council*. 1992.

Darst, Kevin. "Taking the Initiative: Comprehensive Study Outlines Colorado's Future Water Needs." *Headwaters*, Winter 2005.

Howe, Charles W. and Christopher Goemans. "Water Transfers and Their Impacts: Lessons from Three Colorado Water Markets." *Journal of the American Water Resources Association*. October 2003.

Lindall, Scott A., and Douglas C. Olson. "The IMPLAN Input-Output System." *MIG, Inc*. www.implan.com.

Loveridge, Scott. "A Typology and Assessment of Multi-Sector Regional Economic Impact Models." *Regional Studies*. May 2004.

Minnesota IMPLAN Group, Inc.. "IMPLAN Professional Version 2.0: User's Guide, Analysis Guide, Data Guide." 2002.

Population Division. "Table 1: Annual Estimates of the Population for Counties of Colorado: April 1, 2000 to July 1, 2003 (CO-EST2003-01-08)." *U.S. Census Bureau*. April 2004.

Pritchett, James, Marshall Frasier, and Eric Schuck. "Third Party Compensation for Out-of-Basin Transfers: Comments on HB 03111." *Agricultural and Resource Policy Report*. July 2003.

Pritchett, James, Phil Watson, Jennifer Thorvaldson, and Lindsey Ellingson. "Economic Impacts of Reduced Irrigated Acres: Example from the Republican River Basin." *Colorado Water*. February 2005.

Service-Wide Economics Team. "Economic Impact Technical Guide." *U.S. Forest Service*. January 2006.

Smith, Klein, Bartholomay, Broner, Cardon, Frasier, Kuharich, Lile, Gross, Parker, Simpson, and Wilkinson. "Irrigation Water Conservation: Opportunities and Limitations in Colorado—A Report of the Agricultural Water Conservation Task Force." *Colorado Water Resources Research Institute Completion Report No. 190*. October 1996.

Smith, Dan. "Agronomic Perspectives on Irrigation Water Conservation to Meet Growing Urban Demands." *Colorado Water*. February 2005.

Smith, Danny H. "Dryland Cropping." *Colorado Water*. February 2006.

South Platte Research Team. "Voluntary Basin-Wide Water Management: South Platte Basin, Colorado." *Colorado Water,* May 1987.

Statewide Water Supply Initiative. "Update on Statewide Water Supply Initiative-Arkansas Basin." *Colorado Water Conservation Board*. October 2004.

Statewide Water Supply Initiative. "Update on Statewide Water Supply Initiative-South Platte Basin." *Colorado Water Conservation Board*. October 2004.

U.S. Geological Survey, "Water Resources Appraisal of the Upper Arkansas River Basin from Leadville to Pueblo, Colorado." *Water-Resources Investigations Report 82-4114*. 1984.

Watson, Phil and Susan Winter. "Determining Economic Contributions and Impacts: What is the difference and why do we care?" *U.S. Forest Service, U.S. Department of Agriculture*. 2005.

Watson, Phil and Susan Winter. "Using Regional Economic Analysis." *U.S. Forest Service, U.S. Department of Agriculture*. 2005.

Wilkins-Wells, Freeman, Epperson, Hoff, Anderson, and Griguhn, "Water Exchanges and Agricultural Production in Northeast Colorado: Opportunities and Constraints for the Future." *Colorado State University Agricultural Experiment Station Research Project*. 2002.