Irrigation Management in Colorado: Survey Data and Findings

by

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Executive Summary

Very little is known about how many producers adopt irrigation technologies developed by researchers at Colorado State University. The few surveys that have been done suggest that producers are not making full use of available technology. Tight profit margins and environmental impacts, such as groundwater pollution, make it important to understand why producers are not adopting irrigation technologies at a faster rate. This information, in turn, would help CSU focus its research and extension programs to better serve Colorado producers.

We conducted a survey of irrigation management practices in Colorado to better understand what irrigation technologies and management practices producers use and why. In a joint effort by the Department of Agriculture and Natural Resource Economics and the Department of Soil and Crop Sciences, researchers and extension professionals gave producers an opportunity to provide feedback about our programs. Specifically, we asked about the management practices that producers are currently using, how those management decisions are made, and the relative importance of various factors in those decisions. The survey was mailed in early 1997 to 3,281 irrigators identified through the Colorado Agricultural Statistics annual crop production survey. Over 40% of the surveys were returned as usable responses. Basic data and results are provided in this report. Analyses and interpretations will follow in later reports.

The survey contained six sections. Section 1 asked for information about the entire farming operation including farm size, commodities produced, the types of irrigation systems in operation, and best management practices (BMP’s) used. In Section 2, Describe a Representative Irrigated Field, we asked producers information about the irrigation system used on and the water applied to a field that is most representative of
their farm. The representative field was also referenced in Section 3, Management of the Representative Field. In this section, producers identified methods used to decide when and how much water to apply, changes in management, and resources applied to the representative field. In Section 4, Technology Comparison, respondents were asked to rank alternative irrigation systems on different attributes. Section 5, Water Management Decisions, rates decision factors, quality of information available to the farmer, and the work conducted by CSU on water management. The last section, Section 6, Personal Information, elicited demographic information about the respondent including experience, education, gross sales, and off-farm employment.

Colorado irrigators are highly experienced with an average of 31 years of irrigation experience. They tend to be well educated, with two-thirds having completed at least some college or vocational training. Over one-third of respondents had gross farm sales of less than $50,000 annually, while only 4% grossed over $1,000,000. Collectively, 43% of the respondents grossed between $50,000 and $250,000. Over one-third of respondents had off-farm employment, but 40% of their income was still derived from the farm. Although there was much regional variability, the average whole-farm size for the sample was 2,009 acres (median was 480) with an average cropped area of 529 acres, of which 387 acres, or 73%, was irrigated.

Surface water accounted for nearly three-quarters of the irrigation water used by all respondents, with the balance coming from groundwater. Many respondents rely on water from both surface and aquifer sources. Statewide, gravity (flood, siphon tubes, gated pipe, and other gravity) and sprinkler systems (center pivot and other sprinkler)
account for nearly equal proportions of irrigated acreage, but the distribution is much more variable regionally.

While results varied widely by region and farm demographic, overall we found many of the common Best Management Practices were widely adopted. For example, eighty-four percent of respondents reported at least one irrigation system upgrade somewhere on their farm. Additionally, two-thirds of Colorado producers used soil test analysis to help determine their fertilizer rate. However, crediting of other nutrient sources such as past manure applications, legume crops, or irrigation water was cited much less frequently. Among pest and pesticide management practices, field scouting was widely used (64%) with more producers reporting using field scouting than pesticides. However, use of resistant varieties or banding/spot application for pest control were not widely reported and only half of all pesticide users reported keeping records of pesticide applications.

Overall, Colorado irrigators consider their water sources to be highly reliable. For example, 65% of respondents described their water supply as highly reliable, providing adequate water ten years out of ten. This result varied greatly by region, especially in the Arkansas Valley where lower water reliability was reported. We also found that some producers have concerns about the quality of their irrigation water for crop production. Fifteen percent of respondents cited concerns about their irrigation water quality. Irrigators in the South Platte and the Arkansas Valley most frequently indicated concern. The most common water quality concern statewide is salinity; with sediment, sewage, and nitrate contamination also cited with some frequency.
Flood and siphon tube systems were installed an average of nearly 75 and 35 years ago, respectively. The average age of all other systems falls below 20 years. Nearly all center pivot users had upgraded their system in some manner, but less than 40% of the flood systems in any of the three western regions have been upgraded. Field leveling and lining ditches occurs frequently with flood systems in the eastern regions and for siphon tube systems across the state. An upgrade that very few producers in Colorado have adopted is flow meters, a tool for keeping track of water application.

The majority of respondents indicated that they knew their system's efficiency, but their estimates of application efficiency tended to be much higher than commonly measured values obtained from research and field demonstration projects, especially among surface irrigators. Only slightly over one quarter of respondents reported they knew the amount of water applied to their representative field, and less than one-sixth of respondents indicated keeping records of water application.

The majority of producers (51%) said they used “crop appearance” as the primary method to determine when to irrigate their crops and nearly one third cited a “fixed number of days” between irrigations. Irrigation scheduling methods such as using accumulated ET or available soil moisture was selected by only about one quarter of the respondents, but more frequently by center pivot users and groundwater users. Producers cited “same amount each time” and “crop determines” as their primary methods to determine how much water should be applied. There was also notable variation among some demographic groups and regions in the level of irrigation scheduling and water application decision-making.
Finally, when looking at how producers rated the quality of information provided by CSU Cooperative Extension and other sources for crop production and irrigation management decisions, we found Cooperative Extension received an average rating of 3.0 or “Good”. This rating compares to consultants, soil testing labs, and chemical dealers receiving ratings of 2.6 to 2.7 and neighbors, the NRCS, Water Management District, and Popular Press with ratings of 3.0 to 3.8 respectively. However, producers rated research and extension activities at CSU as “Good” to “Very Good”. The striking result is the number of respondents (50%) who believe they have not directly used CSU’s work in their operation.

This survey provides us with quantitative data on how Colorado producers are managing their irrigation water. The age of many irrigation systems, the lack of “scientific” management practices, and the limited knowledge of how much water is being applied represent significant barriers to improving water conservation and quality in Colorado. These data should cause us to reevaluate current extension and research programs and question whether high-tech solutions are appropriate for many Colorado producers. On a positive note, we documented widespread understanding and adoption of some Best Management Practices and irrigation system upgrades among producers. This information, combined with producers’ ratings of CSU work on water issues, indicates the success of past research and outreach efforts.
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Purpose of Report

Land Grant Universities helped reduce water scarcity in the West with research that enhances irrigation efficiency. Technologies such as surge valves and low energy precision application (LEPA) make water usage more efficient and uniform. Better management techniques such as irrigation scheduling can also boost efficiency and yields. Colorado State University (CSU), the Agricultural Experiment Station, and Cooperative Extension commit millions of dollars annually in faculty time and other resources to improve irrigation management and technology. However, little is known about how many producers adopt technologies that CSU researchers identify as beneficial. Information that is available varies widely.

A few studies have been conducted concerning irrigation practices used, including Agricultural Census (1996), Tri-State G&T Irrigation End-Use Survey (1995), and Klein & Smith Irrigation Practices Survey (1995). These surveys suggest that producers are not making full use of available technology that research has identified as beneficial, but do little to explain why. Tight profit margins and environmental impacts, such as groundwater pollution, make it important to understand why producers are not adopting irrigation technologies at a faster rate.

The purpose of this report is to summarize data from a survey of Colorado irrigators that is more extensive and comprehensive than past efforts. The survey was conducted to determine which management practices producers are currently using, how those management decisions are made, and the relative importance of various factors in those decisions. This knowledge creates an opportunity for extension efforts to be directed toward the needs of their clients and for them to communicate needs back to researchers, who can better fit their research programs to address clientele needs.
The following pages are divided into three major sections. First, we describe the survey procedures and response rates. Second, we provide a brief description of basic findings. Finally, we provide a comprehensive set of tables and figures that summarize our data. The primary purpose of this report is to summarize data. It is a description of what we found. A variety of analyses will follow in future reports.

**Survey Procedures and Response Rates**

An advisory committee of researchers and extension personnel representing the major irrigation-related disciplines at Colorado State University was appointed and consulted throughout the development of the survey. This committee helped define a general set of questions. As prescribed by Dillon (1978), cooperating producers assisted in pre-testing the survey that was ultimately mailed to a representative sample of Colorado irrigators.

The survey was divided into six main sections with a total of 48 questions. The entire survey instrument is included as Appendix A. Section 1, *General Farm Information*, asked for information about the entire farming operation including farm size, commodities produced, the types of irrigation systems in operation, and best management practices (BMP’s) used. In Section 2, *Describe a Representative Irrigated Field*, producers were instructed to think of a specific field that best represented their entire farm for answering questions. This section elicited information about a particular field, the irrigation system used, and the water applied to this field. The representative field was also used in Section 3, *Management of the Representative Field*. In this section, producers identified methods used to decide when and how much water to apply, changes
in management, and resources applied to the representative field. In Section 4, *Technology Comparison*, respondents were asked to rank alternative irrigation systems on different attributes. Section 5, *Water Management Decisions*, rates decision factors, quality of information available to the farmer, and Colorado State University’s work on water management. The last section, Section 6, *Personal Information*, elicited information about the respondent including experience, education, gross sales, and off-farm employment.

The USDA National Agricultural Statistics Service (NASS) provided names for the mailing. NASS was used to obtain a representative sample of all irrigators in the state. Irrigators were drawn from the sampling frame for the Colorado Agricultural Statistics annual crop production survey, and limited to those producers who irrigated any crops, and had at least 40 acres of cropland. These criteria yielded a list of 3,281 addresses distributed across the state as shown in Table 1. Appendix Table B1 details this distribution at the county level.
The surveys were mailed the first week of February 1997. As prescribed by Dillman (1978), reminder postcards were sent three and ten days following the initial mailing of the survey. In his Total Design Method, Dillman suggests sending the survey again to non-respondents two weeks after initial mailing. However, because of NASS’s confidentiality requirement, it was not possible to identify who had and had not responded, so no follow-up surveys were sent.

To control for the diversity of irrigation practices in Colorado, six geographic regions were identified: the South Platte, the Eastern Plains, the Arkansas Valley, the San Luis Valley, the Mountains, and the Western Slope (Figure 1). These regions were selected based on known differences in water distribution and management. The South Platte region includes counties obtaining most of their water from the South Platte River or its alluvial aquifer, whereas the Eastern Plains are characterized by the primary use of groundwater from the Ogallala aquifer. The Arkansas Valley is characterized by use of the Arkansas River as the primary source for irrigation. The San Luis Valley region obtains water primarily from the Rio Grande River and the valley’s shallow aquifer. The

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<td>South Platte</td>
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<td>Eastern Plains</td>
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a Includes all irrigated and dry cropland, pasture, and rangeland.
Western Slope gets water primarily from rivers, such as the Yampa and Colorado. Finally, counties in the Mountain region are characterized primarily by the use of individual surface diversion from streams and rivers.

Over the following weeks, 1,319 usable responses were returned. This accounted for over 40 percent of the surveys mailed. If adjusted for undeliverable surveys and non-usable (incomplete) returns, the overall response rate was 42 percent.

Response by Region and Farm Size

NASS was able to provide a summary of the number of surveys mailed to each county and farm-size category based on previous responses to their survey efforts (Appendix Table B2). Using that information, an estimate of response rate by region and farm size was generated (Table 2). Response rates across regions were relatively similar to the overall response of 40 percent, with the Eastern Plains being lowest at 35 percent and the Mountains and San Luis Valley highest at 43 percent.
There is, however, a systematic difference in response rate when considering farm size. Across the state, the smallest farms (less than 100 acres) responded at the greatest rate (56 percent) while the largest farms (over 5,000 acres) provided the lowest response (20 percent). In fact, at the state level, the response rate for each farm-size category is less than for all categories with less acreage. Similar trends hold within each region. County-level response rates are included in Appendix Table B3.

There are several possible reasons to explain the lower response rate for larger farms. First, larger farms tend to be more diversified, especially into grazing and dryland farming enterprises, so it is more likely that an irrigation enterprise may take on relatively less importance in their operation, reducing interest in the survey. Second, large farms with a higher proportion of irrigation often have a number of individuals involved in management. There may have been some difficulty in getting the survey to the appropriate individual to respond to it.
Summary and Discussion of Survey Data

Respondent Characteristics

Personal characteristics of producers can give some insight into explaining why they take different actions in managing their enterprises (Table 3). The survey shows that Colorado irrigators are highly experienced, with an average of 31 years of irrigation experience. All regions were similar except the Eastern Plains, which was lower at 25 years. Major development of irrigation in this region did not occur until the 1970s. This does not provide the opportunity for the number of producers to have 40 to 50 years of experience as observed in the other regions.

Statewide, producers’ educational experiences were divided by near even thirds among those with a high school background, those with some college or vocational degree, and those earning a college degree. Some differences were evident across regions. The Arkansas Valley had the lowest proportion of graduate degrees (3 percent) but also the lowest proportion with a high school education (27 percent). At 32 percent, the Eastern Plains had the highest proportion of those with a bachelor’s degree, while the Mountains and Western Slope had the most producers with post-graduate degrees at 15 and 13 percent, respectively.

Gross farm sales for Colorado irrigators show some interesting distributions. For the entire state, over one-third grossed less than $50,000 annually, while only four percent grossed over $1,000,000. Collectively, 43 percent of the respondents grossed between $50,000 and $250,000 while 17 percent grossed between $250,000 and $1,000,000. Differences in gross sales between regions are obvious. On the Eastern Plains three-quarters of the producers had annual sales exceeding $100,000, whereas this
was true for less than one-quarter of those responding from the Mountains and Western Slope. Differences in the typical scale of operations and value of product likely account for these differences.

Trends in off-farm employment follow a related pattern. Statewide averages show that over one third of respondents had off-farm employment. Regions with lower gross sales tended to have greater off-farm employment. The low-grossing Mountains and Western Slope had the highest off-farm employment at 45 and 38 percent, respectively, while the high-sales Eastern Plains had the lowest off-farm rate at 20 percent.

For Colorado irrigators with a job off the farm, 40 percent of their income was still derived from the farm. This ranged from 35 percent in the San Luis Valley and the Western Slope to 49 percent in the Eastern Plains. Among all respondents, 81 percent of their total income came from farm operations, ranging from 91 percent in the Eastern Plains down to 76 percent in the Mountains and Western Slope.

**Farm Resources**

**Land**

Farm resources differ greatly by region (Table 4). The average farm size for the state was 2,009 acres, ranging from 890 acres in the San Luis Valley to 3,015 acres on the Western Slope. The inclusion of a few very large operations in the sample pulls these averages up so the median farm size is also included to characterize the typical operation.

Significant variation exists in the average cropped area across regions. The area cropped in the Eastern Plains is more than twice the statewide average while the Western
Slope is less than half. Variation in average area irrigated is less, but similar patterns exist with the Eastern Plains averaging much more and the Western Slope much less. Note that for all regions, the majority of cropped acres that respondents farm are irrigated. The average cropped area for all respondents was 529 acres, of which 387 acres, or 73 percent, was irrigated. The proportion of cropped area irrigated ranges from 100 percent in the San Luis Valley down to 53 percent in the Eastern Plains.

Statewide, producers leased or rented an average of 29 percent of their irrigated acres. In the three mountainous western regions, a much smaller fraction of the irrigated acres were leased or rented. Higher percentages of rented acres were found in the regions comprising eastern Colorado.

**Water Sources**

Water sources had the greatest variation across regions. Surface water accounted for 72 percent of the irrigation water used by all respondents with the balance coming from groundwater. Surface water sources supplied practically all of the irrigation water in the Mountains and Western Slope regions. The Arkansas Valley used primarily surface water, with only 12 percent coming from a groundwater source. In the South Platte region, two-thirds of the water used for irrigation came from surface water sources, primarily out of the South Platte River. The San Luis Valley is similar with almost two-thirds of the water coming from a surface source. In contrast to the other regions, farmers on the Eastern Plains obtained 92 percent of their irrigation water from a groundwater source.

In the Arkansas Valley, surface water accounts for 88 percent of use, but only 68 percent of respondents in the region were totally dependent on these sources. Both the
San Luis Valley and the South Platte rely upon surface water to provide about two-thirds of their needs. However, 43 percent of South Platte respondents are entirely dependent upon surface water compared to 37 percent of those in the San Luis Valley. In fact, for 45 percent of those in the San Luis Valley, surface water provides less than two-thirds of their irrigation needs while this is true for only 37 percent of producers in the South Platte.

**Irrigation Systems**

Statewide, gravity (flood, siphon tubes, gated pipe, and other gravity) and sprinkler systems (center pivot and other sprinkler) account for nearly the same proportion of irrigated acreage at 52 and 48 percent, respectively (Table 5). In the Eastern Plains sprinkler systems (primarily center pivots) serve 90 percent of the acres. In the Arkansas Valley and the Mountains, gravity systems serve over 90 percent. On the Western Slope gravity systems account for 80 percent of acres, though other sprinklers (predominantly side roll systems) are important. Finally, a mixture of sprinkler and gravity systems serves the South Platte and San Luis Valley with 47 and 58 percent of each respective region served by sprinklers.

Among all respondents, center pivots dominated sprinkler usage except on the Western Slope where side roll systems are prevalent. Flood systems account for over half of the gravity-served acres in the state. Flood irrigation was nearly the exclusive gravity method in the Mountains and San Luis Valley and dominant in the Arkansas Valley and Western Slope. Siphon tubes were the dominant gravity system in the South Platte.
While center pivots account for nearly one half the total acreage served, less than one-third of respondents use these systems. Conversely, flood irrigation accounted for about a quarter of the acres, but more than one half of respondents use this system. Similarly, for gated pipe, siphon tubes, and other sprinkler systems, the proportion of farmers using these technologies is higher than the proportion of acres that they serve. This holds across the entire sample and, in many cases, regionally. For example, note that only 13 percent of the South Platte acreage is served by gated pipe, but that 45 percent of producers use this technology. Each statistic will clearly have different implications in the development of policy, research, and extension programs.

A final aspect of farm-wide use of irrigation systems is the percent of farm irrigated acres served by a particular type of system (Table 5). For example, the respondents that use gated pipe on their farms use this technology on an average of 42 percent of their irrigated acreage. When producers chose to install a certain application system, that technology is commonly used on a significant portion of their farm. Statewide, the chosen system type accounts for 41 to 78 percent of the irrigated acreage on the farm.

Farm Products

Crops

Producers in Colorado grow a diverse set of crops and livestock. Survey responses were grouped into broad crop categories to facilitate summarization (Table 6). Alfalfa or other hay is the most common crop with 77 percent of producers in the survey growing it. Within each region farmers chose to grow hay more frequently than any other
crop, except for the Eastern Plains. The selection of non-hay crops varies across region. Corn and wheat are dominant crops among the three eastern regions with beans also being important in the South Platte and Eastern Plains. Potatoes, barley, and wheat are the major crops grown in the San Luis Valley. Producers in the eastern regions and the Western Slope frequently grow crops not falling into these categories. Dryland crops are important in the Eastern Plains whereas vegetables and other specialty crops are frequently grown in the Arkansas Valley and the South Platte. Fruit and vegetable production are also prevalent on the Western Slope.

On a statewide basis, wheat is the largest cropping enterprise with an average of 442 acres per farm. Potatoes and corn are next with 376 and 359 acres, respectively. Examination of the table, however, reveals that the average per-farm-acreage of each crop grown varies widely from region to region and from crop to crop.

Among crops that are widely grown by the respondents, the majority of acreage is irrigated. On average, better than 80 percent of the acreage of each of the field crops grown are irrigated with the exception of wheat in the South Platte and wheat and “other crops” in the Eastern Plains. This provides an indication that the sample primarily represents individuals who are active in irrigation enterprises, not merely irrigating a few acres.

Livestock

The majority of producers in each region have some livestock on the farm (68 percent statewide) (Table 7). Of these, the vast majority are beef cows with stocker and
fat cattle exhibiting some prevalence. Sheep are found on nearly 10 percent of operations in the San Luis Valley and the Western Slope.

On average, producers with beef cows own about 150 head. Specialization in the other livestock types tends to result in greater herd numbers than beef cows. Average swine herds are known to be larger than reported but none of the large-scale operations appear in the sampling. Across the state, nearly half of the respondents had greater than 50 head of animals. Only in the South Platte and the San Luis Valley were herds of this size less common with frequencies of 36 and 42 percent respectively.

Management Practices on Whole Farm

Respondents were asked to identify practices regularly used anywhere on their farm for with respect to irrigation, fertilizer, and pest management. Many of the possible responses are recommended Best Management Practices (BMPs) to maintain productivity and protect environmental quality (Waskom et al., 1994). The results are summarized in Table 8. The most conspicuous finding is that the number of producers reporting use of BMP’s varies widely by region. Some of this variation can be attributed to the different major crop rotations grown in each region and the applicability of BMPs for different areas. For example, corn grown under center pivot irrigation systems dominates the Eastern Plains while the major crop grown in the Mountains is meadow hay under flood irrigation.
Irrigation Upgrades

The first set of farm-level management questions asked for upgrades installed on irrigation equipment. Because more in-depth questioning of a selected field was presented subsequently, these questions were framed to characterize farm-wide adoption. Table 8 shows that 84 percent of respondents employed at least one of the identified upgrades. The three western regions, however, each had greater than 15 percent of the respondents making none of these upgrades. Measurement devices such as flumes, weirs, or flow meters were among the more common upgrades.

Fertilization Practices

Fertilizer practices are also an integral part of irrigated agriculture. Other than their own experience, the survey data show that Colorado producers rely upon soil test analysis more than any other method to determine their fertilizer rate. In some regions (South Platte and Eastern Plains) a large majority of irrigated producers are using this practice. Soil testing is the basis for sound fertilizer management and producers have recognized the economic and agronomic benefits of this practice. The percent of crop acres sampled also reflects the varied crop rotations around the state. For instance, producers in the San Luis Valley said they sampled about 50% of their acreage on average in 1996. A two-year potato to small-grains rotation is common in the San Luis Valley, and producers most likely sample fields to be planted into potatoes. The percentage of producers using soil testing also increases as the number of crops grown increases (Table 9).
Fewer producers take into consideration other nutrient sources such as past manure applications, legume crops, or irrigation water than do soil testing. The majority of producers who used manure on the representative field (69%) reported using manure credit on any fields. Although we cannot quantify how many pounds of nutrients that producers credit toward manure applications, these results suggest a general awareness of manure as a nutrient source. Producers in some areas of the state (namely the South Platte) use manure from livestock they do not own.

The nutrient sources that respondents were least likely to credit toward their fertilizer rate were irrigation water and previous legume crops. Only one quarter of the producers growing alfalfa or beans statewide reported using a legume credit when determining their fertilizer rate. Only a few producers credit their water as a nutrient source. Crediting nitrate-nitrogen from irrigation water is primarily practiced by producers using groundwater in the San Luis Valley and the South Platte. Both regions have large areas with groundwater high in nitrate-nitrogen (Austin et al., 1995ab) that can be used by a crop when applied with the irrigation water. The San Luis Valley also has a USDA Water Quality demonstration project that has promoted this practice since 1991.

**Pest and Pesticide Management**

The results for pest and pesticide management practices show that field scouting was the most widely used pest management technique among respondents (Table 8). Producers were asked to include all weed, insect, and disease control practices used. On average, more producers reported using field scouting than pesticides. The percentage
using field scouting increases when the data is sorted by pesticide users and nonusers as in Table 10. Determining pesticide applications by field scouting is widely considered a basic practice for integrated pest management (IPM). When using IPM, producers reduce their reliance on pesticides by applying only when potential crop damage exceeds the cost of application.

More pesticide users are using pest management BMP’s than those producers not reporting pesticide use. However, some “non-pesticide” users reported using such pesticide management practices as “economic thresholds” and “banding or spot application.” Often the term “pesticides” is confused with only meaning insecticides and not herbicides and fungicides. The responses suggest that misinterpretation about the term “pesticides” may have occurred in this instance. Nevertheless, the results show that among producers reporting pesticide use, field scouting, crop rotation, economic thresholds, and tillage are also popular tools used for pest management.

The results show that using resistant varieties and banding or spot application are not widely used practices. Varietal resistance is both a disease and insect pest prevention tool, but most producers apparently select varieties based upon yield potential with resistance being a secondary goal. Banding and spot application for weed and insect control reduces how much pesticide is required. Still, these practices require more management and are often not available when using commercial applicators. Only a minority of producers use intensive management techniques such as pest forecasting and biological controls. These practices require additional time and locally adapted information that is not available for many crops.
One practice that varied significantly by region, but was lower than expected statewide, was pest and pesticide record keeping. Half of all pesticide users (Table 10) reported keeping these records. These records are important for monitoring pests, keeping track of plant back restrictions, and are required by law for restricted use pesticides (RUPs). Economic thresholds were used by more than 50% of pesticide users. However, these thresholds are not available for all crops and areas of the state. More producers reported using consultants for pest and pesticide than for fertilizer and irrigation management advice. This fact is readily explained by the higher cost of pesticides and the labor needed for good pest control.

**Representative Field**

The diversity of most Colorado farms makes it very difficult to obtain information on specific irrigation management decisions across the entire farm. To facilitate detailed questioning of how those decisions are made, each respondent was asked to identify a specific field on their farm that was representative of their farm. All of the questions in this section of the survey were specific to that identified field.

**Land**

Across the state, the average field size was 67 acres (Table 12). Average field size ranged from 127 acres on the Eastern Plains to 37 acres in the Arkansas Valley. The large field sizes in the Eastern Plains correspond to the typical size of the quarter-section center pivots that are common there. Median values for field acreage are also reported to off-set the distorting effect of several larger fields in each region.
Twenty-three percent of the representative fields were identified as rented or leased. The proportion of rented fields was higher for the three eastern regions than for those to the west. Soil texture varied dramatically within each region. Comparisons between regions are difficult at best.

For those using gravity systems, length of row and field slope are factors in system efficiency, irrigation timing, and labor requirements. All of the regions except the Western Slope had average row lengths of about one quarter mile and substantially similar distributions. Row lengths on the Western Slope were generally much shorter. Field slopes were found to be the greatest for the Western Slope and the Mountains with the San Luis Valley having the least slope under gravity systems.

**Water Sources**

The survey identified the proportion of respondents indicating a primary reliance on groundwater, a ditch company, or a private diversion right direct from a stream, respectively (Table 13). Paired with this value is an indication of the proportion of these individuals that have access to supplemental sources of water. For instance, 69 percent of the representative fields in the South Platte rely on a ditch company for their primary source of water and 45 percent of the farms also have a supplemental source.

Groundwater serves as the primary source for the vast majority of the Eastern Plains fields (90%) and a significant number of South Platte and San Luis Valley fields (33 and 38%, respectively). However, very few fields in the Eastern Plains (2%) have access to supplemental water, whereas many in the South Platte and San Luis Valley do (20 and 39%, respectively).
Ditch companies provide the primary source of irrigation water to the majority of representative fields (57%). Thirty-four percent of those fields also have a supplemental source. Direct diversions are the primary source of water for the majority of respondents only in the Mountains (81%). Supplemental sources are available for 25 percent of those using direct diversions as their primary source, statewide.

The reliability of water supply is an important factor in many irrigation decisions. Whether or not a given water source is reliable is contingent upon the source of water, the application system, and the crop grown. To quantify reliability, we asked producers to estimate the number of years out of ten that the primary and supplemental water sources together provided a full water supply for the crops grown on the representative field. Once again, the results from this question varied by region.

Overall, 65 percent of respondents described their water supply as highly reliable, providing adequate water ten years out of ten. Regions with higher reliance on groundwater sources were found to have higher water reliability, while regions more reliant upon a ditch company have lower water reliability. In the Eastern Plains where reliability was the greatest, groundwater supplies 90 percent of the irrigation water with most producers applying the water with a center pivot. Conversely, in the Arkansas Valley where reliability was rated the lowest, 86 percent of irrigators used a ditch company as a primary water source and most water is applied using a gravity system.

The pump depth and well capacity are important parameters to the groundwater pumper. Pump lifts exceeded 100 feet for the majority of representative fields in the Eastern Plains (68%) and the Western Slope (80%) whereas they were less than 100 feet for the majority of those in other regions. Pumping yields were greatest for those in the
San Luis Valley, South Platte, and Eastern Plains (52%, 34%, and 24% over 1,000 gpm, respectively) while a large majority of wells in each of the other three regions produced less than 500 gpm.

Finally, producers using sprinkler systems on their representative field were asked about nozzle pressures. Nozzle pressure impacts water and energy conservation. Higher pressure requires more energy and generally leads to greater evaporation during application. On average, respondents cited nozzle pressures of 35 psi with the lowest pressures observed in the Eastern Plains and the Arkansas Valley. Much higher pressures were observed in the Mountains and the Western Slope. Use of lower pressure in the two eastern regions is expected because of sensitivity to high pumping costs and the increased need to conserve scarce water resources.

We included a question to assess concerns that irrigated producers have about the quality of the water used for crop production on the representative field (Table 14). Fifteen percent of producers affirmed concerns about their irrigation water quality with those in the South Platte (19%) and the Arkansas Valley (35%) indicating concern most frequently. The categories of impairment concerns are as diverse as the different regions of Colorado. The most common concern statewide and particularly in the Arkansas Valley and Western Slope region is salinity. These are legitimate concerns with high soluble salt content reported by several studies (Austin et al. 1997; Butler and von Guerard, 1996) in surface and ground water within these basins. Sediment, sewage, and nitrate contamination also have producers’ interest in several basins. Other water quality issues ranged from heavy metals from mining to pesticides from other farms.
About 34 percent of all operators reported that there was no runoff from their representative field. About 80 percent of sprinkler operators claimed no runoff while only 12 percent of producers who surface irrigate reported none. Of all producers that reported runoff, 14 percent of irrigators reported runoff to on-farm collection systems, with the remainder going to surface drainage ways (43%) or other unspecified destinations (8%). Runoff to surface waterways was the destination for 59% of the surface irrigation water on a statewide basis.

**Irrigation System on Representative Field**

**Type**

Flood (32%) and center pivot (26%) systems comprise over half of the systems used by producers on their representative field. There are major differences between regions, however. While center pivots are most frequent in the Eastern Plains (79%) and San Luis Valley (50%), flood systems are most prevalent in the Mountains (82%), Western Slope (43%), and Arkansas Valley (41%) and second most important in the San Luis Valley (28%). Remaining producers on the Western Slope use primarily gated pipe or side roll sprinklers. Most non-flood Arkansas Valley producers use gated pipe or siphon tubes. The South Platte region revealed a variety of irrigation systems in use. Gravity systems were most prominent, with 36 percent of the respondents using siphon tubes, 20 percent using gated pipe, and 15 percent using flood. Center pivots were used by 25 percent of the respondents.
Age

Considerable variation was observed in the average age of the systems used. On average, the flood systems on the representative field were installed nearly 75 years ago. At less than half the age, the siphon tube system have been around for about 35 years. The average age of all other systems falls below 20 years at the regional level except for the small number of gated pipe systems found in the Eastern Plains (29 years).

Upgrades

Detailed questions were asked to determine which upgrades are implemented on representative field systems. The results are presented by irrigation system in the latter part of Table 15 because significant differences existed between system types. Nearly all center pivot users have upgraded their system in some manner with low pressure systems and drop nozzles catching on rapidly, but high technology systems like LEPA, corner catchers, and computer controllers are less common. A notable finding among side roll systems was the lack of upgrades. Forty-five percent of side roll systems have not been improved.

Among gravity systems, flood irrigation components are least frequently improved. Less than 40% of the flood systems in any of the three western regions have received an upgrade. Field leveling and lining ditches occurs frequently among flood systems in the eastern regions and for siphon tube systems across the state. Among gated pipe users, field leveling and surge valves were the most frequent upgrades. Surge valves prove especially popular in the more water-scarce Eastern Plains (50%) and Arkansas
Valley (32%). The percentage of producers using surge valves was surprising given that this technology has been promoted for less than 10 years in Colorado.

The feasibility and ease of upgrading certain systems and the technology available probably explains the contrasts seen between systems. Options available for upgrading systems such as center pivots are numerous, but practically the only way to upgrade a flood system is to change to a different system. The results in Table 15 show one tool that is not being often used is flow meters. The highest use is among producers with sprinkler systems, especially those in the San Luis Valley (32%). This finding is consistent with the low number of people reporting knowledge of how much water they applied to the representative field (Table 18). Flow meter cost may be a deterrent to adoption with little obvious return in yield increase or labor savings.

Many of the attributes describing the representative field vary more by the system installed than by region (Table 16). For example, typical field size is approximately 40 acres or less, except for center pivots that typically service a quarter section. Fields with siphon tube systems are leased more frequently than other systems (36%) while fields with side roll systems are seldom rented (6%). Center pivots are used on more coarse textured soils than other systems, while side roll systems are more often used on fine textured soils. Center pivot systems are used most frequently with groundwater as primary water source (79%) whereas side roll, gated pipe, and siphon tubes are primarily used with ditch company water (70, 80, and 86%, respectively). Flood systems are nearly evenly split on ditch versus direct diversion sources. Center pivots are associated with the most reliable water sources while side roll and flood systems are associated with the least reliable.
Center pivots are generally used with deeper wells than other systems and wells with moderate yield. Siphon tube and flood systems relying on groundwater generally use shallower wells with high yield. The greatest water quality concern for all systems except center pivots is salinity. Nitrate was cited as the major concern for center pivots.

Application Efficiency

When asked to estimate the field level irrigation application efficiency (Application Efficiency = Crop Water Use ÷ Water Applied) on their representative field, the majority of respondents (64%) indicated they knew system efficiency. Users of sprinkler systems generally claimed greater knowledge of efficiency than for gravity systems. As discussed later, this is difficult to reconcile with a much lower rate (28%) knowing how much water was applied to their representative field.

On one hand, producers indicated a high knowledge of system efficiency, but their estimates of surface efficiency indicate that their knowledge may be imperfect (Table 17). Producer application efficiency estimates tended to be much higher than values commonly reported from research, especially among surface irrigators. Sixty-six percent of producers using gated pipe to furrow irrigate their fields indicated they knew their system efficiency, estimating average efficiency at 72%. Northern Colorado Water Conservancy District (NCWCD) data suggests that efficiencies of less than 50% are most common for this kind of system. Producer estimates of sprinkler system application efficiency are theoretically attainable, but are also above what is typically measured in the field. Possible explanations are that producers did not understand the question, were not careful in answering the questions, or they tended to overestimate efficiency. This
suggests that further study is needed to discover why producers are reporting such high values.

Management of the Representative Field

This section characterizes the management of the representative field and details several irrigation management decisions.

Amount of Water Applied

Only 28 percent of respondents indicated knowledge of the amount applied with the Eastern Plains being highest and the Mountains and Western Slope the least (Table 18). In general, only sprinkler systems and groundwater users claimed knowledge of irrigation water applied. Potato and barley growers in the San Luis Valley had the highest proportion of respondents knowing how much water was applied among commodity groups.

Knowledge of actual irrigation water applied and seasonal crop water use is essential to scientific water management and improving application efficiency. When asked how much water was applied on their representative field, producers indicated that they applied 19 inches on average with surprisingly little difference between crops (Table 19). Based on research about water requirements, it appears that producers are underestimating water application, perhaps explaining the high estimations of application efficiency reported previously in Table 17.

In an effort to reconcile reported irrigation application rates with accepted agronomic rates, the amount of water applied was summarized by average crop yield for
some selected crops (Table 20). When comparing these values to data synthesized from the annual Irrigation Management Service reports by NCWCD, we find that the survey results are well below those of the published reports. It may be that producers need further education on how to estimate crop water needs and actual irrigation application, but again, further research is needed to determine why this difference exists.

The number of irrigation applications per season is presented in Table 21. These varied by region, application system, and crop. Overall, an average of eight irrigations per crop year was reported, with the Eastern Plains (13) and the San Luis Valley (11) well above the average and the Arkansas Valley (4) below average. Center pivot systems enable frequent irrigation application with minimal labor impact. Hay and pasture fields tend to be irrigated least frequently. Potato and barley producers in the San Luis Valley reported irrigating most frequently.

Recordkeeping

We found that only 16% of producers statewide indicated they kept records of water applied to their representative field (Table 22). Farmers in the San Luis Valley using sprinkler systems and growing potatoes and barley had a much higher likelihood of keeping records (62% and 47%, respectively) and tended to give more realistic answers on how much water they applied as well (Tables 17-21). Better record keeping systems may need to be developed to help producers track crops water needs and irrigation applications.

An important factor in any management decision is the cost of the inputs required. Irrigation decisions are no different. Table 23 reports the proportion of respondents that
indicated that they purchased water for irrigating the representative field. Statewide, 21 percent of respondents paid for their water, with producers in the Arkansas Valley (35%) and Western Slope (38%) paying most frequently. Survey participants were asked for the amount paid for their water, but responses were generally unusable. This seemed to be tied to an inability to quantify the amount of water to which they were entitled.

The Irrigation Decision

Having characterized the representative field and its management in the last crop year, we turn our attention to understanding the irrigation application decision. The basic questions that we seek to answer are “how do you decide when to irrigate” and “how do you decide how much to apply?”

When to Apply

When asked the primary method used to determine when to irrigate their crops, 51 percent of producers indicated that “crop appearance” was the primary method used (Table 24). A “fixed number of days” between irrigations was the second most common method used to determine when to irrigate (29%). Irrigators receiving water from ditch companies reported using a “fixed number of days” method most often. The rule-based irrigation scheduling methods such as accumulated ET or available soil moisture were used most frequently by center pivot users and groundwater appropriators. Additionally, center pivot and groundwater users were the only groups to frequently use crop consultants to help schedule irrigation. It should be noted that many producers indicated they used more than one method to decide when to irrigate.
When sorted by crop only potato, barley, and wheat producers used rule-based scheduling methods with any frequency. They reported that consultants were working on more than 30% of the representative fields where potatoes or barley were grown. Irrigators frequently marked that they used “other” methods to determine when to irrigate, often specifying experience and tradition as the method.

Producers citing a fixed-day rule used an average interval of 12 days (Table 25). The longest intervals were associated with flood systems, surface water sources, and hay and pasture crops. These are all common in the Arkansas Valley which had the longest average interval of the regions. Shortest intervals were associated with center pivots and groundwater use. Of the crops with sufficient numbers of users citing a given number of days, corn was irrigated most frequently—on average at six days under this rule.

Over a quarter of all producers and as much as one half of some commodity producers cited using a soil moisture threshold as their decision rule for timing irrigation applications. Among all users of the soil moisture decision rule, the shovel or feel method was mentioned most frequently (38%) with the soil probe cited second most frequently (30%) (Table 26). A number of producers claimed to determine soil moisture through some visual means, but it was not clear how this was accomplished. One interpretation is that this is primarily determined by crop appearance with a “dash of experience” added.

Gypsum blocks or consultants are very seldom used. Gypsum blocks find some favor in the Eastern Plains and Arkansas Valley. The soil probe is the preferred method in these two regions as it is across all center pivots and gated pipe systems, groundwater sources, and bean and corn crops. The shovel method is preferred in the three western
regions, across all flood, siphon tube, and non-pivot sprinkler systems, all surface water sources, and most crops.

An important aspect of using soil moisture thresholds is to identify how far the soil moisture profile is depleted. Users of soil moisture methods were asked to specify the level of available soil moisture that would trigger an irrigation event. Only one quarter of all producers using this method provided a quantified level. Not surprisingly, almost all producers using gypsum blocks knew their thresholds. Nearly half of all those using soil probes and nearly three-quarters of the probe users in the San Luis Valley cited a threshold. Those using the less sophisticated shovel and feel methods provided thresholds less than half as often. Few using the visual method provided a threshold.

While a producer may be able to manage a given crop on a given field very well without knowing the threshold in terms of percent of field capacity, there are some important implications for not being able to quantify the threshold. Much of our research literature and extension programming conveys crop management in such terms. Given the low reporting rates of thresholds, particularly among the less sophisticated methods that are used so frequently, perhaps some specific efforts should be directed at increasing the level of understanding of quantifying available soil moisture or translating such figures into terms that are more understandable.

A similar question arises among those citing the use of evapotranspiration (ET) thresholds. For those using the “checkbook method” of scheduling, they often trigger irrigations based on reaching some level of accumulated ET since the last irrigation or precipitation event. Unlike the soil moisture methods, an inability to quantify the ET threshold renders this method ineffective. While over a quarter of all respondents
claimed to use accumulated ET thresholds, only 8 percent of those individuals provided a quantified threshold (Table 28). Only potato growers in the San Luis Valley who used ET scheduling provided a quantified threshold more than a quarter of the time (46%). Again, this suggests that some rethinking is likely needed regarding educational efforts targeted toward producers.

Amount to Apply

The second half of the irrigation decision is to determine how much water should be applied once the timing threshold has been met. Unfortunately, the survey contained a typographic error, listing one choice as “crop determines amount” rather than “crop consultant determines amount” as intended. Interestingly, for all regions, water sources, crops, and irrigation categories except sideroll, respondents indicated that the “crop determines amount” of irrigation water to apply as the most commonly used method (Table 29). We can infer from this that producers consider crop growth stage and accumulated ET when making an application decision. It is also possible that they were equating “crop determines amount” with the idea that crop appearance indicates how much water is needed. Only in the case of side roll sprinkler systems did producers more commonly indicate they “always apply the same amount.” Producers infrequently indicated that they use ET and soil water depletion in determining how much water to apply, although replenishment of soil moisture was indicated by nearly a third of those in the Eastern Plains, all center pivots, all groundwater users, and all potato growers. Other methods such as experience and tradition were cited frequently, particularly in alfalfa,
hay, small grains, and under flood irrigation systems. Most commonly, producers only used one method to determine how much water to apply.

We infer the effectiveness of the quantified decision rules (soil moisture and accumulated ET) by the indication of specific thresholds (Table 30). The majority of producers specifying either of these methods also provided the threshold for the quantity of water to be applied. Fifty-eight percent of those indicating that they made quantity decisions to replenish soil moisture specified a threshold. Higher portions of those in the Eastern Plains and San Luis Valley, center pivot and gated pipe users, and potato and wheat growers reported thresholds. On average, users of this method attempt to return the soil profile to 87 percent of available soil water capacity. Of those replenishing accumulated ET, 63 percent specified a threshold. On average they attempt to replenish 93 percent of accumulated ET. In the Eastern Plains where 72 percent provided a threshold, they attempt to replace 109 percent of ET.

Why Methods Were Selected

Respondents were asked to provide the rationale for selecting both the timing and quantity thresholds. Responses to this open-ended question were classified into the twelve categories heading Table 31. Experience or tradition (25%) and water availability (21%) were the two reasons cited most frequently by all respondents for selecting the chosen timing rule. Water availability was the primary factor in the Arkansas Valley and the Mountains, for all flood and non-pivot sprinklers, all direct diversions, and all hay crops. On the other hand, water availability was not a major factor for those on the
Easter Plains, groundwater appropriators, center pivot systems, or barley and potato producers.

The reasons for selecting the method for determining the amount to apply, shown in Table 32, were similar to those for timing. Experience or tradition was the primary reason for every category except the Arkansas Valley, where producers cited water availability as most important.

Changes in Management

The last question on the representative field asked whether management had changed in the last five years and, if so, what had changed. About 27 percent of all producers reported changing management in the last five years, with 40 percent changing in the Eastern Plains, but only 18 percent indicating a change in the Mountains. Among the irrigation systems, center pivot, side roll, and gated pipe users reported the most changes. Flood changed least frequently. Ground water sources showed the most change. No strong patterns emerged from the crop summaries with the exception of beans, corn, and wheat on the Eastern Plains that indicated fairly high rates of change.

When characterizing the nature of the changes, it was found that nearly half of the changes involved the water application system (Table 34). Water management, fertilizer management, crop management, and tillage were the categories best classifying the other changes indicated. Improving water use efficiency was the most frequent reason given for the management change (Table 35).
**Irrigation Decision Factors and Information Sources**

A primary goal for the survey effort was to discover the relative importance of various factors influencing irrigation decisions for producers in Colorado. Section 4 of the survey was designed to evaluate the trade-offs that producers perceive would result from using different application systems. A more meaningful evaluation of this data requires the use of advanced statistical techniques that will be reported in subsequent publications. However, ratings of factors in the decision process and the quality of information available are summarized here.

**Importance of Factors on Irrigation Decisions**

Producers were asked to rate the relative importance of selected factors in their irrigation management decisions including system reliability, water availability, and yield impact were the most important factors identified (Table 36). Cropping flexibility and water laws were the least important factors. However, only cropping flexibility rated on average as less than “important”. Apparently all of the issues selected weigh heavily in most irrigators’ decisions. When ranking the averages, major differences did not appear across region or other summary attributes (detailed summaries presented in Appendix Tables B5 and B6, respectively), although the rating for cropping flexibility is understandably less in the Mountains and West Slope and for hay and pasture.

**Quality of Information**

We also asked respondents to rate the quality of information received from selected sources for irrigation and crop production decisions (Table 37). Consultants, soil
testing laboratories, and chemical dealers garnered the highest ratings for quality of information provided, with an average rating between “Good” and “Very Good”. Cooperative Extension and neighbors were next with an average “Good” rating. NRCS and water management districts followed closely with slightly less than a “Good” rating. Popular press received the lowest average rating of just better than “Fair”. The majority of respondents had an opinion on each of the sources. Only consultants, water management districts, and popular press earned ratings from less than three-quarters of the respondents. As with the decision factors, major differences in rating of information quality did not appear across region or other summary attributes (see Appendix Tables B7 and B8, respectively).

Opinion of CSU Water Management Activities

Finally, respondents were asked to rate CSU research and extension activities in water management (Table 38). The average ratings for both technical research and extension/education activities are “Good” to “Very Good”. No significant rating differences were observed among the different regions. The striking result, however, is the number of respondents who have not directly used the services that are available.

Only half and slightly over half of producers have used CSU’s technical research and extension, respectively. Irrigators in the Eastern Plains and Arkansas Valley appear to make the greatest use of both of these resources while those in the Mountains use them the least. One caveat that should be raised is that producers may receive information from another source that is based on CSU activities. As such, while the responses here
provide an indication of direct use by producers, they do not capture information that is transferred by less direct means.

When examining the ratings of CSU’s work in water management provided by cross sections of respondents, some subtle differences appear (Table 39). The average rating for each subgroup falls in the range of “Good” to “Very Good”. When evaluated by application system, those with “other sprinkler” systems provide the highest ratings for both research and extension, while those with sideroll systems provide the lowest. Those diverting water directly from a stream or river gave the lowest rating among all water sources. Finally, among growers of different commodities, barley, bean, and wheat producers rated CSU work highest while those with pasture gave the lowest ratings.
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<th>Eastern Plains</th>
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<th>San Luis Valley</th>
<th>San Luis Mountains</th>
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<td>Over $1,000,000</td>
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<td><strong>Off-Farm Job (%)</strong></td>
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<td>36</td>
<td>31</td>
<td>45</td>
<td>38</td>
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<tr>
<td><strong>Percent of Income from Farm (respondents with off-farm employment)</strong></td>
<td>42</td>
<td>49</td>
<td>40</td>
<td>35</td>
<td>44</td>
<td>35</td>
<td>40</td>
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<td><strong>Percent of Income from Farm (all respondents)</strong></td>
<td>82</td>
<td>91</td>
<td>80</td>
<td>81</td>
<td>76</td>
<td>76</td>
<td>81</td>
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Table 4. General Characteristics of Entire Farm

<table>
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<th>San Luis Valley</th>
<th>San Luis Mountains</th>
<th>Western Slope</th>
<th>Colorado</th>
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<tbody>
<tr>
<td>Farm Size(^a) (acres)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Average</td>
<td>890</td>
<td>2555</td>
<td>2326</td>
<td>800</td>
<td>2883</td>
<td>3015</td>
<td>2009</td>
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<tr>
<td>Median</td>
<td>400</td>
<td>1600</td>
<td>398</td>
<td>585</td>
<td>850</td>
<td>263</td>
<td>480</td>
</tr>
<tr>
<td>Avg. Cropped Area (acres)</td>
<td>548</td>
<td>1345</td>
<td>415</td>
<td>495</td>
<td>382</td>
<td>174</td>
<td>529</td>
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<td>Avg. Irrigated Area (acres)</td>
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<td>719</td>
<td>332</td>
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<td>387</td>
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<td>Irrigated Area Rented (%)</td>
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<td>30</td>
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<td>23</td>
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<tr>
<td>Water Source (average %)</td>
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<tr>
<td>Surface Water</td>
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<td>88</td>
<td>63</td>
<td>99</td>
<td>99</td>
<td>72</td>
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<tr>
<td>Water Source (% of respondents)</td>
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<tr>
<td>All Surface Water</td>
<td>43</td>
<td>5</td>
<td>68</td>
<td>37</td>
<td>97</td>
<td>98</td>
<td>59</td>
</tr>
<tr>
<td>&lt;33% GW, &gt;67% SW</td>
<td>19</td>
<td>2</td>
<td>22</td>
<td>18</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>&quot;Half'n'half&quot;(^b)</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>17</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>6</td>
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<tr>
<td>&gt;67% GW, &lt;33% SW</td>
<td>7</td>
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<td>1</td>
<td>15</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<tr>
<td>All Ground Water</td>
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<td>7</td>
<td>13</td>
<td>1</td>
<td>&lt;1</td>
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</tbody>
</table>

\(^a\) Includes all irrigated and dry cropland, pasture, and rangeland.

\(^b\) Between 33% and 67% surface water with the balance from groundwater.
## Table 5. Irrigation Systems Used on Entire Farm

<table>
<thead>
<tr>
<th>System</th>
<th>South Platte</th>
<th>Eastern Plains</th>
<th>Arkansas Valley</th>
<th>San Luis Valley</th>
<th>San Luis Mountains</th>
<th>Western Slope</th>
<th>Colorado</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gated Pipe</td>
<td>13</td>
<td>9</td>
<td>21</td>
<td>1</td>
<td>3</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Siphon Tubes</td>
<td>27</td>
<td>1</td>
<td>23</td>
<td>7</td>
<td>&lt;1</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Flood</td>
<td>10</td>
<td>1</td>
<td>48</td>
<td>33</td>
<td>91</td>
<td>45</td>
<td>27</td>
</tr>
<tr>
<td>Other Gravity System</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Center Pivot</td>
<td>46</td>
<td>89</td>
<td>7</td>
<td>58</td>
<td>1</td>
<td>4</td>
<td>46</td>
</tr>
<tr>
<td>Other Sprinkler</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>&lt;1</td>
<td>2</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Other Irrigation System</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>1</td>
<td>2</td>
<td>&lt;1</td>
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</tbody>
</table>

### Percent of Irrigated Area Served

<table>
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<th>System</th>
<th>Percent of Irrigated Area Served</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gated Pipe</td>
<td>45</td>
</tr>
<tr>
<td>Siphon Tubes</td>
<td>58</td>
</tr>
<tr>
<td>Flood</td>
<td>45</td>
</tr>
<tr>
<td>Other Gravity System</td>
<td>8</td>
</tr>
<tr>
<td>Center Pivot</td>
<td>35</td>
</tr>
<tr>
<td>Other Sprinkler</td>
<td>6</td>
</tr>
<tr>
<td>Other Irrigation System</td>
<td>2</td>
</tr>
</tbody>
</table>

### Percent of Respondents Using System

<table>
<thead>
<tr>
<th>System</th>
<th>Percent of Respondents Using System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gated Pipe</td>
<td>45</td>
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<tr>
<td>Siphon Tubes</td>
<td>58</td>
</tr>
<tr>
<td>Flood</td>
<td>45</td>
</tr>
<tr>
<td>Other Gravity System</td>
<td>8</td>
</tr>
<tr>
<td>Center Pivot</td>
<td>35</td>
</tr>
<tr>
<td>Other Sprinkler</td>
<td>6</td>
</tr>
<tr>
<td>Other Irrigation System</td>
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</table>

### Average Percent of Irrigated Area Served if Using System

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<th>Average Percent of Irrigated Area Served</th>
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<tr>
<td>Gated Pipe</td>
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<td>Siphon Tubes</td>
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</tr>
<tr>
<td>Flood</td>
<td>46</td>
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<tr>
<td>Other Gravity System</td>
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<tr>
<td>Center Pivot</td>
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<tr>
<td>Other Sprinkler</td>
<td>39</td>
</tr>
<tr>
<td>Other Irrigation System</td>
<td>45</td>
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</tbody>
</table>

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*Percentages do not add to 100 because many respondents use more than one type of system on their farm.*
### Table 6. Crops Grown on Entire Farm

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<thead>
<tr>
<th>Region</th>
<th>Alfalfa or Other Hay</th>
<th>Corn for Grain or Silage</th>
<th>Wheat</th>
<th>Beans</th>
<th>Barley</th>
<th>Potatoes</th>
<th>Other Crops</th>
<th>Pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Platte</td>
<td>72</td>
<td>38</td>
<td>88</td>
<td>80</td>
<td>97</td>
<td>89</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Eastern Plains</td>
<td>72</td>
<td>77</td>
<td>53</td>
<td>--</td>
<td>1</td>
<td>18</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Arkansas Valley</td>
<td>35</td>
<td>68</td>
<td>33</td>
<td>22</td>
<td>2</td>
<td>14</td>
<td>29</td>
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<tr>
<td>San Luis Valley</td>
<td>28</td>
<td>25</td>
<td>8</td>
<td>--</td>
<td>--</td>
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<td>Western Mountains</td>
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<td>1</td>
<td>2</td>
<td>24</td>
<td>1</td>
<td>3</td>
<td>6</td>
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<tr>
<td>Western Slope</td>
<td>2</td>
<td>1</td>
<td>--</td>
<td>23</td>
<td>1</td>
<td>0</td>
<td>3</td>
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</tr>
<tr>
<td>Colorado</td>
<td>37</td>
<td>30</td>
<td>44</td>
<td>15</td>
<td>1</td>
<td>21</td>
<td>26</td>
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</tr>
<tr>
<td>Total</td>
<td>128</td>
<td>135</td>
<td>196</td>
<td>243</td>
<td>375</td>
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**Proportion of Respondents Growing Each Crop (%)**

<table>
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<th>Corn for Grain or Silage</th>
<th>Wheat</th>
<th>Beans</th>
<th>Barley</th>
<th>Potatoes</th>
<th>Other Crops</th>
<th>Pasture</th>
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<td>71</td>
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<td>76</td>
<td>123</td>
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<td>110</td>
<td>145</td>
<td>411</td>
<td>25</td>
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<td>220</td>
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<td>85</td>
<td>97</td>
<td>67</td>
<td>84</td>
<td>442</td>
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<tr>
<td>San Luis Valley</td>
<td>94</td>
<td>96</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>100</td>
<td>96</td>
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<tr>
<td>Western Mountains</td>
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<td>75</td>
<td>99</td>
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<td>89</td>
<td>91</td>
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<tr>
<td>Western Slope</td>
<td>157</td>
<td>336</td>
<td>160</td>
<td>250</td>
<td>33</td>
<td>61</td>
<td>171</td>
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<tr>
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<td>411</td>
<td>1345</td>
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**Average Acreage of Respondents Growing Each Crop**

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<th>Barley</th>
<th>Potatoes</th>
<th>Other Crops</th>
<th>Pasture</th>
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<td>--</td>
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<td>75</td>
<td>99</td>
<td>0</td>
<td>89</td>
<td>91</td>
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</tr>
<tr>
<td>Western Slope</td>
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<td>--</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>90</td>
<td>97</td>
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<td>67</td>
<td>47</td>
<td>63</td>
<td>56</td>
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</table>

**Average Proportion Irrigated for Respondents Growing Each Crop (%)**

<table>
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<th>Corn for Grain or Silage</th>
<th>Wheat</th>
<th>Beans</th>
<th>Barley</th>
<th>Potatoes</th>
<th>Other Crops</th>
<th>Pasture</th>
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</thead>
<tbody>
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<td>93</td>
<td>89</td>
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<td>93</td>
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<td>98</td>
<td>--</td>
<td>100</td>
<td>97</td>
<td>95</td>
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<tr>
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<td>85</td>
<td>97</td>
<td>67</td>
<td>84</td>
<td>56</td>
<td></td>
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<td>--</td>
<td>--</td>
<td>--</td>
<td>100</td>
<td>96</td>
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<td>75</td>
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<td>91</td>
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<td>100</td>
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<td>67</td>
<td>47</td>
<td>63</td>
<td>56</td>
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</tbody>
</table>

*"--" indicates that no respondents reported growing crop in region.*
Table 7. Livestock Grown on Entire Farm

<table>
<thead>
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<th>Region</th>
<th>South</th>
<th>Eastern</th>
<th>Arkansas</th>
<th>San Luis</th>
<th>Mountains</th>
<th>Western</th>
<th>Colorado</th>
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<td>59</td>
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<td>Beef Cows</td>
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<td>46</td>
<td>62</td>
<td>53</td>
<td>83</td>
<td>70</td>
<td>57</td>
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<td>4</td>
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<td>3</td>
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<td>--</td>
<td>413</td>
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<td>679</td>
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<td>421</td>
<td>674</td>
<td>406</td>
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* Five respondents or fewer in category
Table 10. Adoption of Pest Control and Pesticide Best Management Practices (BMPs)

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### Table 13. Characteristics of Water Source for Representative Field

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<td>75</td>
<td>75</td>
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<td>47</td>
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<td>25</td>
<td>51</td>
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<td>1000 - 1500 gpm</td>
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a Number of years out of 10 that the water source provides a full water supply for the crop grown on the representative field.
Table 14. Water Quality Characteristics for Representative Field

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<th>Surface Drainage Ways</th>
<th>Other Destination</th>
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<td>Region</td>
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<td>Arkansas Valley</td>
<td>San Luis Valley</td>
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Table 15. Irrigation Application System Used on Representative Field

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** Five respondents or fewer in category
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<th>Tubes</th>
<th>Flood</th>
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<td>1000 - 1500 gpm</td>
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<th>Tubes</th>
<th>Flood</th>
<th>All Systems</th>
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<th>Siphon</th>
<th>Tubes</th>
<th>Flood</th>
<th>All Systems</th>
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<td>17</td>
<td>7</td>
<td>8</td>
<td>17</td>
<td>12</td>
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<table>
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<th>Side</th>
<th>Other</th>
<th>Gated</th>
<th>Pipe</th>
<th>Siphon</th>
<th>Tubes</th>
<th>Flood</th>
<th>All Systems</th>
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<td>--</td>
<td>--</td>
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<td>--</td>
<td>--</td>
<td>--</td>
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<td>33</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>22</td>
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<tr>
<td>Drop Nozzles</td>
<td>74</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>20</td>
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<td>LEPA</td>
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<td>--</td>
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<td>Flow Meter</td>
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<td>15</td>
<td>6</td>
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<td>50</td>
<td>9</td>
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<td>15</td>
<td>13</td>
<td>4</td>
<td>10</td>
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<td>33</td>
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<td>25</td>
<td>57</td>
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</table>

-- Indicates upgrade not appropriate for system type.
Table 17. Irrigation Application Efficiency on Representative Field

<table>
<thead>
<tr>
<th>Respondents Knowing Application Efficiency(^a) (%)</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South Platte</td>
</tr>
<tr>
<td>Center Pivot Sprinkler</td>
<td>78</td>
</tr>
<tr>
<td>Side Roll Sprinkler</td>
<td>63</td>
</tr>
<tr>
<td>Other Sprinkler</td>
<td>**</td>
</tr>
<tr>
<td>Gated Pipe or Tube</td>
<td>65</td>
</tr>
<tr>
<td>Siphon Tubes</td>
<td>59</td>
</tr>
<tr>
<td>Flood</td>
<td>49</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Estimate of Application Efficiency (%)</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
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<td>South Platte</td>
</tr>
<tr>
<td>Center Pivot Sprinkler</td>
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<tr>
<td>Side Roll Sprinkler</td>
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</tr>
<tr>
<td>Other Sprinkler</td>
<td>**</td>
</tr>
<tr>
<td>Gated Pipe or Tube</td>
<td>70</td>
</tr>
<tr>
<td>Siphon Tubes</td>
<td>74</td>
</tr>
<tr>
<td>Flood</td>
<td>76</td>
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</tbody>
</table>

\(^a\) Respondents were asked to specify the irrigation application efficiency for the representative field. The definition was provided as follows:

Application Efficiency = (Crop Water Use / Water Applied) x 100%.

** Five respondents or fewer in category
Table 18. Respondents Knowing Amount of Water Applied to Representative Field

<table>
<thead>
<tr>
<th>Region</th>
<th>South Platte</th>
<th>Eastern Plains</th>
<th>Arkansas Valley</th>
<th>San Luis Valley</th>
<th>San Luis Mountains</th>
<th>Western Slope</th>
<th>Colorado</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Categories</td>
<td>36</td>
<td>38</td>
<td>25</td>
<td>30</td>
<td>17</td>
<td>17</td>
<td>28</td>
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</tbody>
</table>

By Application System

<table>
<thead>
<tr>
<th></th>
<th>Center Pivot</th>
<th>Sideroll</th>
<th>Other Sprinkler</th>
<th>Gated Pipe</th>
<th>Siphon Tubes</th>
<th>Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater</td>
<td>39</td>
<td>36</td>
<td>17</td>
<td>54</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Ditch Company</td>
<td>35</td>
<td>50</td>
<td>23</td>
<td>17</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Direct Diversion</td>
<td>14</td>
<td>45</td>
<td>11</td>
<td>11</td>
<td>17</td>
<td>9</td>
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</tbody>
</table>

By Water Source

<table>
<thead>
<tr>
<th></th>
<th>Groundwater</th>
<th>Ditch Company</th>
<th>Direct Diversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa &amp; Hay</td>
<td>30</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>Barley</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Beans</td>
<td>30</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>Corn (grain &amp; silage)</td>
<td>36</td>
<td>42</td>
<td>0</td>
</tr>
<tr>
<td>Pasture</td>
<td>**</td>
<td>**</td>
<td>0</td>
</tr>
<tr>
<td>Potatoes</td>
<td>**</td>
<td>**</td>
<td>0</td>
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<tr>
<td>Wheat</td>
<td>44</td>
<td>27</td>
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<tr>
<td>Other Crops</td>
<td>48</td>
<td>25</td>
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</table>

** Five respondents or fewer in category

---

53
Table 19. Average Reported Water Applied for Representative Field

<table>
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<tr>
<th>Region</th>
<th>South Platte</th>
<th>Eastern Plains</th>
<th>Arkansas Valley</th>
<th>San Luis Valley</th>
<th>Mountains</th>
<th>Western Slope</th>
<th>Colorado</th>
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<tr>
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<td><strong>By Application System</strong></td>
<td><strong>By Application System</strong></td>
<td><strong>By Application System</strong></td>
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<td><strong>By Application System</strong></td>
<td><strong>By Application System</strong></td>
<td><strong>By Application System</strong></td>
<td><strong>By Application System</strong></td>
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<td>Center Pivot</td>
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<td>**</td>
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<td>Sideroll</td>
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<td>22</td>
<td>20</td>
<td>**</td>
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<td>Other Sprinkler</td>
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<td>**</td>
<td>**</td>
<td>**</td>
</tr>
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<td>Gated Pipe</td>
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<td>27</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>21</td>
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<td>Siphon Tubes</td>
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<td>Flood</td>
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<td>14</td>
<td>**</td>
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<td>21</td>
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<td><strong>By Water Source</strong></td>
<td><strong>By Water Source</strong></td>
<td><strong>By Water Source</strong></td>
<td><strong>By Water Source</strong></td>
<td><strong>By Water Source</strong></td>
<td><strong>By Water Source</strong></td>
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<td><strong>By 1996 Crop</strong></td>
<td><strong>By 1996 Crop</strong></td>
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<td><strong>By 1996 Crop</strong></td>
<td><strong>By 1996 Crop</strong></td>
</tr>
<tr>
<td>Alfalfa &amp; Hay</td>
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<td>17</td>
<td>22</td>
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<td>19</td>
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<tr>
<td>Barley</td>
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<td>18</td>
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<td>**</td>
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<td>Beans</td>
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<td>Pasture</td>
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<td>**</td>
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** Five respondents or fewer in category
Table 20. Average Reported Water Applied for Selected Crops on Representative Field

<table>
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<tr>
<th>Region</th>
<th>South Platte</th>
<th>Eastern Plains</th>
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<th>San Luis Valley</th>
<th>Mountains</th>
<th>Slope</th>
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<tr>
<td>Inches Applied</td>
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</tr>
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</tr>
<tr>
<td>2 - 4 ton</td>
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<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Greater than 4 ton</td>
<td>19</td>
<td>**</td>
<td>16</td>
<td>25</td>
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<td>23</td>
<td>20</td>
</tr>
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<td>150 - 180 bu</td>
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<td>**</td>
<td>**</td>
<td>19</td>
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<tr>
<td>Greater than 180 bu</td>
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<td>20</td>
<td>21</td>
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<td>**</td>
<td>**</td>
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</tr>
<tr>
<td>Barley</td>
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** Three respondents or fewer in category
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** Five respondents or fewer in category
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** Five respondents or fewer in category
Table 23. Respondents Purchasing Water Applied to Representative Field

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** Five respondents or fewer in category
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</table>

** Percentages do not necessarily sum to 100 percent because many producers cited more than one rule.

<sup>a</sup> Most respondents indicating the use of accumulated ET thresholds also indicated the use of a soil moisture threshold. The simple correlation coefficient between these two rules was 0.937.
Table 25. Average Number of Days Between Applications for Fixed Day Users

<table>
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<tr>
<th>Region</th>
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<th>Arkansas</th>
<th>San Luis</th>
<th>Mountains</th>
<th>Western</th>
<th>Colorado</th>
</tr>
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<tbody>
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<td>Plains</td>
<td>Valley</td>
<td>Valley</td>
<td>Mountains</td>
<td>Slope</td>
<td>Colorado</td>
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** Five respondents or fewer in category
Table 26. Method Used to Determine Soil Moisture for Timing of Irrigation Applications

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<th>Method</th>
<th>Soil Probe</th>
<th>Gypsum Blocks</th>
<th>Shovel/Feel</th>
<th>Visual</th>
<th>Consultant</th>
<th>Not Specified</th>
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### Table 27. Soil Moisture Method Users Reporting Percent Moisture Threshold

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<th>Gypsum Blocks</th>
<th>Shovel/Feel</th>
<th>Visual</th>
<th>Consultant</th>
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<tr>
<td>South Platte</td>
<td>48</td>
<td>**</td>
<td>19</td>
<td>6</td>
<td>**</td>
<td>24</td>
</tr>
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<td>33</td>
<td>9</td>
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<td>**</td>
<td>25</td>
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<td>**</td>
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<td>**</td>
<td>28</td>
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<td>29</td>
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<tr>
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<td>**</td>
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<td>15</td>
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</table>

** Five respondents or fewer in category
Table 28. Use of Evapotranspiration (ET) Thresholds in Determining When to Irrigate

<table>
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<tr>
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<td>9</td>
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<tr>
<td>Arkansas Valley</td>
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</tr>
<tr>
<td>Western Slope</td>
<td>24</td>
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<td>By Application System</td>
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<td>By Water Source</td>
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<tr>
<td>Groundwater</td>
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<td>Direct Diversion</td>
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<tr>
<td>By 1996 Crop</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Beans</td>
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<tr>
<td>Corn (grain &amp; silage)</td>
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<tr>
<td>Potatoes</td>
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Table 29. Decision Rule Used to Determine How Much Water to Apply When Irrigating

<table>
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<th>Decision Rule</th>
<th>Replenish Accumulated ET</th>
<th>Replenish Soil Moisture</th>
<th>Crop Determines</th>
<th>Other</th>
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By Region

<table>
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<th>Replenish Soil Moisture</th>
<th>Crop Determines</th>
<th>Other</th>
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</thead>
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<td>53</td>
</tr>
<tr>
<td>Eastern Plains</td>
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<td>6</td>
<td>32</td>
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<td>Arkansas Valley</td>
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<td>Mountains</td>
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By Application System

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<td>Gated Pipe</td>
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<td>3</td>
<td>10</td>
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By Water Source

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<th>Crop Determines</th>
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</table>

By 1996 Crop

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<th>Crop Determines</th>
<th>Other</th>
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<tr>
<td>Beans</td>
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<td>3</td>
<td>18</td>
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<td>Corn (grain &amp; silage)</td>
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<td>Potatoes</td>
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<td>Wheat</td>
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** Percentages do not necessarily sum to 100 percent because many producers cited more than one reason.
Table 30. Use of Quantified Rules in Determining How Much Water to Apply

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** Five respondents or fewer in category
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Table 33. Respondents Reporting Change in Management in Last Five Years

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** Five respondents or fewer in category
Table 34. Management Changes Implemented on Farms

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Table 35. Reason Cited for Management Changes Implemented on Farms

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** Percentages do not necessarily sum to 100 percent because many producers cited more than one reason.
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<td>4</td>
<td>19</td>
<td>25</td>
<td>17</td>
<td>33</td>
<td>3.8</td>
</tr>
</tbody>
</table>

¹ Average of respondents with a stated opinion of given information source.
Table 38. Respondent Rating of CSU’s Work in Water Management

<table>
<thead>
<tr>
<th>Rating</th>
<th>Percent of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent (1)</td>
<td>Very Good (2)</td>
</tr>
<tr>
<td>Technical Research</td>
<td></td>
</tr>
<tr>
<td>All Categories</td>
<td>6</td>
</tr>
<tr>
<td>South Platte</td>
<td>8</td>
</tr>
<tr>
<td>Eastern Plains</td>
<td>6</td>
</tr>
<tr>
<td>Arkansas Valley</td>
<td>6</td>
</tr>
<tr>
<td>San Luis Valley</td>
<td>4</td>
</tr>
<tr>
<td>Mountains</td>
<td>4</td>
</tr>
<tr>
<td>Western Slope</td>
<td>6</td>
</tr>
<tr>
<td>Extension/Education</td>
<td></td>
</tr>
<tr>
<td>All Categories</td>
<td>6</td>
</tr>
<tr>
<td>South Platte</td>
<td>5</td>
</tr>
<tr>
<td>Eastern Plains</td>
<td>6</td>
</tr>
<tr>
<td>Arkansas Valley</td>
<td>6</td>
</tr>
<tr>
<td>San Luis Valley</td>
<td>5</td>
</tr>
<tr>
<td>Mountains</td>
<td>8</td>
</tr>
<tr>
<td>Western Slope</td>
<td>6</td>
</tr>
</tbody>
</table>

^a Average of those rating CSU water management activities.
Table 39. Average Rating of CSU's Work in Water Management\textsuperscript{a}

<table>
<thead>
<tr>
<th>CSU Source</th>
<th>Technical Research</th>
<th>Extension/ Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Categories</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>By Application System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center Pivot</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Sideroll</td>
<td>2.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Other Sprinkler</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Gated Pipe</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Siphon Tubes</td>
<td>2.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Flood</td>
<td>2.6</td>
<td>2.8</td>
</tr>
<tr>
<td>By Water Source</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Ditch Company</td>
<td>2.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Direct Diversion</td>
<td>2.6</td>
<td>2.8</td>
</tr>
<tr>
<td>By 1996 Crop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa &amp; Hay</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Barley</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Beans</td>
<td>2.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Corn (grain &amp; silage)</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Pasture</td>
<td>3.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Potatoes</td>
<td>2.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Wheat</td>
<td>2.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Other Crops</td>
<td>2.6</td>
<td>2.8</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Average rating of those rating CSU water management activities.

(1 = Excellent, 2 = Very Good, 3 = Good, 4 = Fair, 5 = Poor.)
REFERENCES


APPENDIX A

The Survey Instrument
Survey of Irrigation Management in Colorado

Sponsored by:
The Water Center at Colorado State University
Colorado State University Cooperative Extension
Colorado State University Agricultural Experiment Station
Colorado Department of Agriculture
Dear Survey Respondent:

Thank you for taking time out of your busy schedule to complete this survey. It should take about 20 minutes to complete.

Please attempt to answer every question in the survey. However, if you cannot or do not wish to answer a particular question, please skip it and proceed through the remainder of the questionnaire.

When you have completed the survey, please return it in the envelope provided. No stamp is required as postage has been prepaid.

Your response is anonymous. This questionnaire is not marked in any way that would allow us to identify who you are.

If you have any questions or comments regarding this survey, please don’t hesitate to call us collect.

Thank you!

Marshall Frasier
(970) 491-6071
Reagan Waskom
(970) 491-6201
SECTION 1: General Farm Information

1. In what county is your farm located? ____________________________________________

2. What is the total size of your farm? ___________________________ acres

3. List your major farm enterprises:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Number of Acres</th>
<th>Percent Irrigated</th>
<th>Livestock type</th>
<th>Number of Head</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. What portion of your irrigated acres are rented or leased from someone else? ______% OR ______ acres

5. Approximately what percentage of irrigation water used on your farm comes from the following sources? (allocations should total 100 percent)

- Groundwater well: ______%  
- Surface water: ______%

6. Approximately what percentage of the irrigated acres on your farm are serviced by each of the following types of irrigation systems? (should total 100 percent)

- Gravity: gated pipe: ______%  
- siphon tubes: ______%  
- flood: ______%  
- other gravity: ______%

- Sprinkler: center pivot: ______%  
- other sprinkler: ______%  
- Other System: ______%

7. Check ☑ all irrigation components used on your farm.

- Surge valves  
- Flow meters  
- Flume or weir for measurement  
- Drop nozzles  
- LEPA  
- Low pressure sprinklers  
- Lined ditches  
- None of these used
8. Check ☑ all techniques that you use in determining fertilizer application rates.
   - Soil test analysis
   - Manure credit
   - Crop yield goal
   - Legume credit
   - Past experience
   - Consultant
   - None of these used

9. IF YOU SOIL TEST:
   What percent of your irrigated acreage was sampled in 1996?  

10. Check ☑ all pest management practices that you routinely use.
   (Include all weed, insect, and disease controls)
   - Field scouting
   - Pesticides
   - Crop rotation
   - Tillage
   - Pest forecasting
   - None of these used

11. With respect to your pest management program do you... (check all that apply)
   - Keep pest and pesticide records
   - Use crop consultants for pest scouting and management advice
   - Use economic thresholds to determine pesticide application timing
   - Use banding or spot application as opposed to broadcast application
   - None of these used

SECTION 2: Describe a Representative Irrigated Field

The following questions target a specific field that you farm. Select the ONE irrigated field that is most representative of your farm. Please answer all questions in Sections 2, 3, and 4 thinking only about this representative field.

1. What is the size of this representative field? acres

2. Is this representative field rented or leased?
   - Yes
   - No

3. Check ☑ the circle that best characterizes the predominant soil texture of the representative field.
   - Sand
   - Loam
   - Clay
4. What crops have been grown over the last three years on the representative field? 

<table>
<thead>
<tr>
<th>Crop</th>
<th>1996</th>
<th>1995</th>
<th>1994</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Yield / acre

5. Check ☑ the source(s) of the irrigation water used on the representative field.

- Groundwater well
- Ditch company
- Individual surface diversion

Primary
Supplemental

6. IF YOU CHECKED GROUNDWATER WELL ABOVE:

What is the depth to water? feet

Pumping capacity? gpm

7. Check ☑ the number of years out of 10 that the primary and supplemental water sources together are able to provide a full water supply for the crops grown on the representative field.

0 1 2 3 4 5 6 7 8 9 10

8. Are there any concerns about the quality of your water for crop production?

- ☑ No Skip to number 9 on the next page.
- ☑ Yes

Please briefly describe these water quality concerns:
9. Check ☑ the irrigation application system used on the representative field.
   - Center pivot
   - Gated pipe
   - Siphon tubes
   - Flood
   - Other (specify)________________________________________

10. How long ago was this system installed? _______ years

11. Check ☑ all irrigation upgrades used on the system identified for this field.
   - Surge valves
   - Flow meters
   - Low pressure sprinklers
   - LEPA
   - Drop nozzles
   - Computer controller
   - Field leveling
   - Lined ditches
   - Corner catcher
   - None apply
   - Other (specify)________________________

12. IF THIS IS A GRAVITY SYSTEM:
    What is the average row length of this field? _____ mile OR _____ feet
    What is the approximate slope of this field? _____ %

13. IF THIS IS A SPRINKLER SYSTEM:
    What is the pressure at the nozzle? _____ psi

14. Check ☑ the destination of runoff from this field.
    - On-farm collection for reuse
    - Surface drainage ways
    - There is no runoff
    - Other _______________________

15. Check ☑ your best estimate of the system’s average field application efficiency for 1996.  
    (Application Efficiency = Crop Water Use / Water Applied)
    20% 40% 60% 80% 100% Don't Know
SECTION 3: 1996 Management of the Representative Field
Please answer all questions in this section thinking only about your 1996 management of the crop and irrigation system on the representative field identified in Section 2.

1. Do you know how much water was applied to the representative field in 1996?
   - No
   - Yes, How much irrigation water was applied? inches

2. How many irrigation applications were made to the representative field throughout 1996?

3. How many pounds of nitrogen were applied to this field in 1996?
   - Preplant Fertilizer
   - Sidedress Fertilizer
   - Fertigation
   - Manure

4. Did you keep written or computerized records of water applied throughout the season?
   - YES
   - NO

5. Did you purchase or lease water applied to the representative field in 1996?
   - No
   - Yes, How much did you pay for the water?
     - $/ac ft
     - $/ac in
     - $/ac

6. Check ☑ the ONE primary method that you used in 1996 to decide WHEN to irrigate.
   - Fixed number of days between irrigations, How many days?
   - Accumulated evapotranspiration (ET), How much ET?
   - Available soil moisture, How determined?
     - What percent available moisture?
   - Crop appearance
   - Crop consultant determines schedule
   - Other (specify)
7. Explain **WHY** you used the method identified previously to determine **WHEN** to irrigate.

8. Check ☑ the ONE primary method used in 1996 to decide **HOW MUCH** water to apply for each irrigation application.
   - ☑ Always apply the same amount each time
   - ☑ Replenish accumulated ET since last irrigation ☐ What portion? ______%  
   - ☑ Replenish soil profile to a given level ☐ What level? ______ % avail water cap
   - ☑ Crop determines the quantity applied
   - ☑ Other (specify)__________________________________________________________

9. Please explain **WHY** you used this method to determine **HOW MUCH** to apply.

10. Have you changed any management practices on this field in the last five years?
    - ☑ Yes  ☐ No ☐ Skip to Section 4 on the next page.
      List the specific practices that you changed and why.
SECTION 4: **Technology Comparison**

Please rate each of three different gravity or sprinkler irrigation systems as if they could be used on your representative field.

<table>
<thead>
<tr>
<th>Gravity Systems</th>
<th>Sprinkler Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate each of the three systems for…</td>
<td></td>
</tr>
<tr>
<td>1. Your familiarity with each</td>
<td></td>
</tr>
<tr>
<td>2. Competition with other farm and non-farm activities for your time</td>
<td></td>
</tr>
<tr>
<td>3. Difficulty to operate and manage</td>
<td></td>
</tr>
<tr>
<td>4. Reliability in consistently delivering water to crop</td>
<td></td>
</tr>
<tr>
<td>5. Overall desirability (&lt;span style=&quot;text-decoration: underline&quot;&gt;consider all factors important to you&lt;/span&gt;)</td>
<td></td>
</tr>
</tbody>
</table>

Please estimate the 10-year average per-acre yield that you think would be produced under each system.

(Indicate for crop grown on the representative field in 1996)

Specify units (e.g. bushels, ton)____________________
SECTION 5: Water Management Decisions

1. Rate each of the following for how they affect your irrigation management decisions.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Very Important</th>
<th>Important</th>
<th>Slightly Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiarity with system</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Timing of labor required</td>
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<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Difficulty to operate/manage</td>
<td>○</td>
<td>○</td>
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<tr>
<td>System reliability</td>
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<tr>
<td>Yield impact</td>
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<td>○</td>
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<tr>
<td>Soil type</td>
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<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Water availability</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Cropping flexibility</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Water laws</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

2. Check the circle that best indicates the quality of information provided by each of the following for your crop production and irrigation management decisions.

Very Excellent              No Good Good Fair Poor Opinion
<table>
<thead>
<tr>
<th>Source</th>
<th>○</th>
<th>○</th>
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<tr>
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<tr>
<td>Cooperative Extension</td>
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<td>○</td>
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<tr>
<td>Neighbors</td>
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<td>Popular Press</td>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Other________________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. We are interested in whether CSU’s work on water management meets your needs. Please rate CSU’s job on the following:

Very Excellent              Very Good Good Have Not Fair Poor Used It
| Technical research:          | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Extension/Education:         | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
SECTION 6: Personal Information

1. How many years of irrigation experience do you have? ____________________ years

2. Check ☑ your highest level of education.
   ☑ High School
   ☐ Some college
   ☐ Bachelors degree
   ☐ Graduate or Professional degree
   ☐ Technical/Vocational Degree

3. Check ☑ your annual gross farm sales.
   ☑ less than $50,000
   ☑ $50,000 - $99,000
   ☑ $100,000 - $249,000
   ☑ $250,000 - $499,000
   ☑ $500,000 - $1,000,000
   ☑ over $1,000,000

4. Do you have another job off the farm?
   ☑ No
   ☑ Yes ☐ What percentage of your net income comes from farming? ________ %

THANK YOU very much for taking the time to answer this questionnaire. Please return the completed survey in the enclosed postage-paid envelope. Feel free to use the space below to give us any comments you may have.
APPENDIX B

Tables of Supporting Details
Table B1. Number of Surveys Mailed by County and Farm Size

<table>
<thead>
<tr>
<th>Region/County</th>
<th>Under 100</th>
<th>100 to 249</th>
<th>250 to 499</th>
<th>500 to 999</th>
<th>1000 to 2499</th>
<th>2500 to 4999</th>
<th>Over 5000</th>
<th>All Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>236</td>
<td>638</td>
<td>565</td>
<td>590</td>
<td>619</td>
<td>343</td>
<td>290</td>
<td>3,281</td>
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<tr>
<td>South Platte</td>
<td>93</td>
<td>237</td>
<td>205</td>
<td>190</td>
<td>139</td>
<td>65</td>
<td>65</td>
<td>968</td>
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<td>Adams</td>
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<td>44</td>
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<tr>
<td>Boulder</td>
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<td>6</td>
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<td>21</td>
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<td>11</td>
<td>7</td>
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<td>103</td>
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<td>12</td>
<td>17</td>
<td>20</td>
<td>14</td>
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<td>42</td>
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<td>47</td>
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<td>12</td>
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<td>205</td>
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<tr>
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<td>4</td>
<td>5</td>
<td>7</td>
<td>6</td>
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<td>Weld</td>
<td>47</td>
<td>133</td>
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<td>89</td>
<td>51</td>
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<td>446</td>
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<td>Eastern Plains</td>
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<td>35</td>
<td>69</td>
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<td>Arapahoe</td>
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<td>2</td>
<td>0</td>
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<tr>
<td>Baca</td>
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<td>2</td>
<td>4</td>
<td>11</td>
<td>19</td>
<td>16</td>
<td>9</td>
<td>61</td>
</tr>
<tr>
<td>Cheyenne</td>
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<td>8</td>
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<td>Douglas</td>
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Western Slope

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* County and farm size identified from National Agricultural Statistics Service (NASS) database prior to mailing.
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*Farm size and county reported by some respondents did not match NASS records, causing response rates to be overstated for some categories (particularly those indicating greater than 100% response) and understated for others. Anonymity of respondents prevents reconciliation of these differences. Pooling across county and farm size should diminish the effect of these errors.*
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<th>Mountains</th>
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% Percent of Respondents

- San Luis Valley
  - System reliability: 63
  - Water availability: 80
  - Yield impact: 67
  - Familiarity with system: 62
  - Timing of labor required: 39
  - Difficulty to operate/manag: 37
  - Soil type: 42
  - Water laws: 52
  - Cropping flexibility: 37

- Mountains
  - System reliability: 57
  - Water availability: 67
  - Yield impact: 59
  - Familiarity with system: 66
  - Timing of labor required: 46
  - Difficulty to operate/manag: 35
  - Soil type: 37
  - Water laws: 55
  - Cropping flexibility: 13

- Western Slope
  - System reliability: 66
  - Water availability: 67
  - Yield impact: 61
  - Familiarity with system: 59
  - Timing of labor required: 51
  - Difficulty to operate/manag: 42
  - Soil type: 35
  - Water laws: 36
  - Cropping flexibility: 23
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*1 = Very Important, 2 = Important, 3 = Slightly Important, 4 = Not Important*
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\(^a\) Average of respondents with a stated opinion of given information source.
Table B8. Average Rating of Quality of Information from Various Sources\textsuperscript{a}

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\textsuperscript{a} Average rating of respondents with a stated opinion of the given information source. (1 = Excellent, 2 = Very Good, 3 = Good, 4 = Fair, 5 = Poor)