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# Assessment of Irrigation Water Management and Demonstration of Irrigation Scheduling Tools in the Full Service Area of the Dolores Project: 1996-2000

## Part I: Survey Results

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*Knowledge to Go Places*

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Trade names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the products by the authors or Colorado State University.

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**Assessment of Irrigation Water Management and Demonstration of Irrigation Scheduling Tools in the Full Service Area of the Dolores Project: 1996-2000**[¶]

**Part I: Survey Results**

Abdelfettah (Abdel) Berrada, Mark W. Stack, and Grant E. Cardon

## ABSTRACT

A survey was conducted in the fall of 1996 to assess irrigation water management in the Full Service Area (FSA) of the Dolores Project. Forty four percent of the farm operators in the FSA responded to the survey. The majority of the respondents (88%) reported using siderolls to irrigate their fields. Twenty one percent of the respondents reported using sprinkler nozzles of nine gallons per minute (gpm) or larger. This far exceeds the FSA system capacity and could lead to significant runoff if not carefully managed. Water runoff was observed by 63% of the respondents. Runoff can be minimized through proper irrigation system design, management, and maintenance. This is particularly important in the FSA due to the erosive nature of the soils (low organic matter, low to moderate infiltration rate, hilly terrain). Several respondents suggested using deep tillage and catch basins to increase soil water infiltration. Seventy-four percent of the respondents reported using more than their water allocation in 1996, which was a particularly dry year. About half of the respondents reported using a shovel or soil probe to check soil moisture before irrigating, but it is not clear how this information was used to schedule irrigations. Only five percent of the respondents reported using crop consumptive use (ET) information to schedule irrigation. An encouraging outcome of the survey was the large number of respondents who indicated the need for information on irrigation equipment innovations, irrigation scheduling, and other information that could help them conserve water and get the most out of their water allocation. Several workshops and field demonstrations have been organized since 1997 to provide such information.

## GENERAL INTRODUCTION

A study was initiated in 1996 to assess irrigation water management in the Full Service Area (FSA) of the Dolores Project, demonstrate irrigation-scheduling tools, and disseminate information related to these topics. This report contains relevant information gathered between 1996 and 2000 and recommendations on irrigation water management and the use of the Watermark sensor and ETgage atmometer for scheduling irrigation. The recommendations are intended to meet the needs of FSA irrigators, but some are general in nature.

The Dolores Project was built in the 1980s to provide a dependable supply of water for irrigation, municipal and industrial use, recreation, fish and wildlife, and for the production of hydroelectric power. The main feature of the Dolores Project is McPhee reservoir on the Dolores River, formed by McPhee Dam and the Great Cut Dike. The total storage capacity of McPhee is 381,000 acre-feet, of which 229,000 acre-feet is active capacity. The reservoir was designed to hold two years of water supply in case of drought (one normal year and one dry year). According to the Dolores Water Conservation District (DWCD), the annual water supply from McPhee reservoir is fully allocated. Current allocation is 92,500 acre-feet for irrigation, 8,700 acre-feet for municipal and industrial (M&I) uses, and 29,300 acre-feet for fish and wildlife habitat. Allocation details are shown in Table 1.

The area where this study was conducted, the FSA encompasses Fairview, Pleasant View, Cahone, Hovenweep, Dove Creek, and Ruin Canyon in Dolores and Montezuma counties in southwestern Colorado. Its allocation is 55,200 acre-feet corresponding to 28,000 acres of irrigable land. The FSA allocation was based on an ideal crop rotation of 55% alfalfa, 20% small grains, 15% dry bean, 3% pasture, and 7% corn (U.S. Department of the Interior, 1977). Diversion requirement is 1.97 acre-feet/acre and farm delivery requirement is 1.72 acre-feet/acre based on a weighted crop consumptive use of 1.76 acre-feet/acre and farm irrigation efficiency of 70%. Conveyance and operational losses have been lower than expected, in effect raising the on-farm allocation to 1.88 acre-feet/acre. Four pumping plants along the Dove Creek Canal and one along the south canal deliver pressurized water to FSA farmers through a series of pipe lateral systems. The Hovenweep sub-area receives irrigation water under gravity pressure. The majority of irrigated fields in FSA are equipped with wheel line sprinkler systems, also called siderolls but center pivots are gaining in popularity due to potential labor savings.

Irrigation water from McPhee reservoir was delivered to dryland farmers in FSA for the first time in 1987. The number of irrigated acres in the FSA jumped from less than 2,000 acres in 1987 to 24,498 acres in 2000, while the amount of irrigation water released at the Great Cut dike increased from 2,116 acre-feet to 57,284 acre-feet during the same period (Fig. 1). Excess Municipal and Industrial (M&I) water[1] was used to supplement FSA allocation in 2000. Average farm delivery was 1.74 acre-feet/acre from 1987 to 2000. It exceeded the original allotment of 1.72 acre-feet/acre eight out of 14 years, but it only exceeded the current allotment of 1.88 acre-feet/acre in 1989, 1996, and 2000, which were exceptionally dry years (Fig. 2). This raises the concern that when most or all the allotted acres in FSA are irrigated (only 87% were in 2000), there may not be enough water to irrigate FSA lands at current usage rates, particularly in dry years. However, Figure 1 shows that the irrigated acreage did not change much since 1996 therefore, it is possible that FSA's full allocation of approximately 28,000 acres may never be reached.

The relatively high water usage in FSA is partly due to the significant alfalfa acreage (Fig. 3), which far exceeds what the project designers had envisioned. Crop consumptive water use and diversion requirements are shown in Table 2. The diversion requirement for FSA as a whole exceeds the original estimate by 12 to 13% when the 1995-1999 acreage is used. Poor management may also be to blame, as evidenced by the results of the 1996 survey and field monitoring in 1997-1999. Figures 4 and 5 further support the need for improvement in irrigation water management at the farm level. These figures show that the fields that had the highest water usage in 1996, which was a particularly dry year, did not necessarily produce the highest alfalfa hay yield. Water management is probably the single most important factor for irrigated crop production in FSA, but water efficiency can be greatly diminished if other production inputs such as pest control and soil fertility are not optimized. The Dolores Water Conservancy District Crop Census for 1990 to 1999 shows a slight increase in alfalfa hay yield in 1992 but not much improvement thereafter (Figure 6). There was a substantial increase in dry bean yield in 1991

[1] M&I water that hasn't been sold or leased.

from the year before. However, except for two good years, 1994 and 1999, dry bean yield only averaged 12 to 14 cwt/acre. Small grains (primarily oat and spring wheat) averaged 27 cwt/acre in 1990-1994, spiked at 45 cwt/acre in 1995 and varied from 31 cwt/acre to 37 cwt/acre in 1996-1999. Large variations in crop yield among irrigated fields and/or producers (data not shown) and experimental results at the Southwestern Colorado Research Center (SWCRC) indicate the potential for improvement. The accuracy of DWCD crop census is not known. Colorado Agricultural Statistics (2000) data for Dolores and Montezuma counties for 1995-1999 shows slightly higher crop yields than DWCD estimates.

Full Service Area irrigators have been able to supplement their water allocation by leasing water from the 'water bank', which is the unused water from undeveloped land or underutilized water allocations. The DWCD also has "excess" M&I water that can be added to the water bank and leased by irrigators on a temporary basis. This system has worked well so far but it might be stretched to the limit, as was clearly the case in 2000. Strategies need to be developed at the District and farm levels to manage severe water shortages.

The objectives of this study were to:

1. Assess irrigation water management in the FSA of the Dolores Project.
2. Demonstrate the use of the Watermark moisture sensor and the ETgage atmometer for irrigation scheduling purposes.
3. Initiate research and educational programs to address specific constraints.

Objective 1 is addressed in this report (Part I) and also in Part III (Berrada et al., 2001). Objective 2 is specifically addressed in Part III. In addition, both the Watermark sensor and ETgage atmometer were calibrated for local conditions and the results are reported in Part II (Berrada et al., 2001). The outreach activities associated with this study are listed in Appendix A of this report.

## 1996 IRRIGATION WATER MANAGEMENT SURVEY

### INTRODUCTION

The Dolores Project is a young project as none of the lands in the Full Service Area (FSA) were irrigated prior to 1987. It is also a sophisticated project where irrigation water is delivered to each field at 45 to 60 psi with minimum conveyance and operational losses. As with any new endeavor, there is a learning curve associated with mastering the technology, which, in the case of the Dolores Project entails irrigation system design and management, irrigation scheduling, and crop allocation and management.

The objective of the 1996 irrigation water management survey was to obtain increased understanding of irrigation water management practices in the FSA and to identify areas of concern that might be addressed through research and education.

### METHODOLOGY

A questionnaire was developed by Colorado State University scientists in cooperation with the DWCD and mailed to landowners and farm operators in FSA in November 1996. The questionnaire consisted of a cover letter and three pages of questions grouped under the headings (1) Land use, (2) Irrigation system, and (3) Irrigation Management. It was designed for ease of use without compromising the quantity and quality of information sought. The entire questionnaire is in Appendix B.

A total of 178 questionnaires were mailed out[2] and 45 were returned but only 42 were usable. At the time of the survey, there were approximately 174 individual landowners, 101 irrigator pools, and 95 farm operators. An irrigator pool is the sum of irrigation water managed by one farm operator, who typically operates several fields belonging to one or more landowners. Some of the land in FSA belongs to absentee landowners. Not all the allocated land was irrigated in 1996. In fact, only 87% was irrigated, according to DWCD Crop Census (Fig. 1). A 44% survey return was achieved (42/95). The percentages in this summary are based on the 42 completed responses. Detailed results are shown in Tables C1, C2, and C3 in Appendix C.

[2] The questionnaire was mailed to all landowners and four businesses.

## SURVEY RESULT SUMMARY

1. Land use

The total acreage reported was 12,616 acres or 52% of the land that was irrigated in 1996 (Table C1). The respondents owned 70% of the reported acreage and leased the rest. On average, each respondent owned 221.5 acres and leased 97.5 acres. Three of the respondents did not report any owned or leased land, although one reported 150 acres of pasture in a separate category. Total irrigation water allocation was 11,011 acre-feet, which did not match the reported acreage since each acre is allotted 1.97 acre-feet (net diversion requirement) in FSA. Several of the respondents did not report their water allocation. Those who did averaged 380 acre-feet.

Of the total irrigated crop acreage that was reported (10,189 acres), 69% was in alfalfa, 14% in spring wheat, 8% in dry bean (primarily pintos), and the rest in oat (3%), winter wheat (2%), grass pasture, alfalfa/grass mix, corn, and onion (only 2.4 acres). The reported alfalfa hay yield averaged 4.3 tons/acre and ranged from 2.3 to 6.0 tons/acre. Dry beans averaged 1470 lbs/acre (900 to 2191 lbs/acre) with only nine entries. Spring wheat and oat faired much better than winter wheat. The 1996 DWCD Crop Census shows a larger percentage of the irrigated acreage in alfalfa (77% vs. 69%) and slightly lower crop yields in FSA as a whole than what the survey shows. The wide range in reported crop yields indicates the potential for improvement as well as differences in land productivity.

2. Irrigation equipment

2.1. Mainline

The survey revealed deficiencies in the design of the main line. Eighty-one percent of the respondents reported air-vacuum release valves installed, while only 52% reported having a pressure relief valve in the mainline. In areas of high pressure, some systems have experienced pipe failure while other systems have been under designed, i.e. pipe diameter too small to carry desired flow or to allow for future development. It is important that the irrigation delivery system be correctly designed to provide for trouble-free operation.

### 2.2. Sprinkler system

Sideroll systems were reported as being used by 88% of the respondents. Seventy-eight per-cent of the systems in use were 1/4 mile systems. Flow control nozzles were reported used by only 10 irrigators (26%). Flow control nozzles should be used when the pressure along the sprinkler line varies by plus or minus 10%. The flow control nozzle provides for constant flow rate the length of the system with a resulting improvement in sprinkler uniformity. Cost has been the obstacle to widespread adoption of flow control nozzles. Pressure regulators were reported as not being used by any respondent, but most center pivot sprinkler packages include either a pressure regulator or flow control nozzle.

Center pivot systems were used by 40% of the respondents. Of those who reported using center pivots, 82% (14/17) also had siderolls. Twenty-three center pivots were 1/4-mile systems while 14 center pivots were shorter in length. The majority of the pivots were equipped with drop tubes and spray nozzle packages. Only five center pivots were equipped with overhead impact sprinklers. One center pivot was designed as a LEPA (Low Energy Precision Application) system. Drop tubes are used to increase irrigation efficiency by placing the water closer to the crop and thus avoiding the wind. The drawback to this system is that the wetted diameter of the spray pattern is smaller which may result in the water application rate exceeding the soil intake rate. Overhead impact sprinklers, on the other hand, have a greater wetted diameter but are subject to the wind resulting in lower irrigation efficiencies.

The respondents who reported the irrigated acreage averaged 30.7 acres per sideroll and 115.5 acres per center pivot. No other irrigation system was reported.

### 2.3. Sprinkler nozzle size

Forty-one per cent of the respondents reported using 6 gallons per minute (GPM) or smaller nozzles on some of their systems, while 21% reported using 9 GPM or larger nozzles. The smaller nozzles approximate the Dolores Project pumping capacity (5.6 GPM during peak usage) while larger nozzles may result in low irrigation efficiencies (deep percolation or runoff) if not carefully monitored.

3. Irrigation management

3.1. Irrigation frequency

In 1996, growers irrigated alfalfa at least twice before each cutting. Dry beans were irrigated four to eight times (6.7 avg.), winter wheat four to seven times (4.9 avg.), spring wheat seven to nine times (7.7 avg.), and oat three to five times (4.0 avg.). Other crops were irrigated four to eleven times. Crops were irrigated more frequently in 1996 compared to previous years due to the dry winter and spring of 1996. Irrigation frequency is usually higher with center pivots than with siderolls.

3.2. Sideroll management

The majority of the siderolls were moved twice per day with a move length of three turns. Six respondents reported that they employed 24-hour sets. Alfalfa growers sometimes use 24-hour sets to reduce labor costs, which require more than one sideroll per 40 acres i.e., three siderolls per 80 acres.

3.3. Irrigation timing

Twenty-two respondents reported that they based their decision on when to irrigate by checking the soil moisture with a shovel or soil probe. Dry soil surface and crop stress were other reasons checked to determine when to begin irrigating. However, 19 respondents reported that they continuously moved their siderolls. If irrigation is begun without checking the soil moisture or employing sound irrigation scheduling techniques, continuously moving siderolls may result in applying excess water to the crop.

3.4. Nozzle size

Eleven respondents reported that they have changed nozzle sizes depending on the crop, and nine respondents reported using different nozzle sizes at different crop growth stages. Fourteen respondents (38%) reported that they do not change nozzle sizes. Reasons listed on how to select a nozzle are crop water use, water intake rate, soil moisture holding capacity, crop growth stage, and field slope. A practical guide for selecting a nozzle cited by several people was the amount of runoff from the field. Center pivots require larger nozzles as the distance from the pivot point increases.

3.5. Sideroll set time per run

Twenty-two respondents reported that they vary the sideroll set time depending on the crop and at different times during the irrigation season. Twelve respondents reported that they do not vary their sideroll set time. Irrigators indicated that set times vary depending on crop water use, crop growth stage, precipitation, temperature, wind, soil moisture, and topography. It was pointed out that set time is related to nozzle size.

3.6. Irrigation water used

Ten out of 38 respondents (26%) who answered Question #36 did not use more than their water allotment in 1996. Forty-seven percent used slightly more than their allotment and 26% used significantly more than their allotment. The year 1996 was very dry, which led to higher than average water usage as shown by DWCD records (Figures 2 & 7).

3.7. Runoff

Sixty three percent (26/41) of the respondents noticed irrigation water runoff on their fields while 37% respondents did not. Strategies for dealing with runoff included checking the irrigation system for leaks and making repairs, using smaller nozzles or shorter set times, and increasing the speed of the center pivot. A frequent suggestion for reducing runoff listed was using tillage (V-ripper, soil aerator, and catch basins) to increase water infiltration. Another suggestion was that an irrigator should be cognizant of a field's topography. Five respondents reported that they did not plan to do anything about their runoff.

3.8. Irrigation metering and timing devices

Only four out of 36 respondents reported that they use a metering or timing device. It is noted that each Dolores Project delivery box is equipped with a meter (gallons, flow rate) used by the Dolores Water Conservancy District for billing purposes. Also, most center pivots are equipped with control panels to automatically control pivot speed and thus application rate. Water shut-off valves (gallons or time) could save sideroll operators valuable time since water is turned off automatically and siderolls are allowed to drain before they are moved. These devices are commercially available but may be suitable only for small operations or high value crops due to cost.

3.9. Irrigation information needed

Information requested by irrigators included crop water use and irrigation scheduling guidelines, soil management guidelines, and crop management guidelines. Twelve respondents requested information on irrigation equipment innovations (a linear move system was cited as an example).

3.10. Additional comments

Other comments listed by respondents not covered elsewhere in this report are:

- Better techniques are needed to monitor soil moisture.
- Farmers should be allowed to use their allocated water and then be shut-off until everyone has had a chance to use their own allocated water.
- Crop water use should be printed in local newspapers.
- For spring crops (including alfalfa), water needs to be available earlier in the spring to avoid starting out behind and playing catch-up all summer.
- Would like work done with tillage implements to measure the effect on soil water intake rate.
- Need information on center pivots getting stuck!

## DISCUSSION AND CONCLUSIONS

As expected, the majority of the respondents (88%) reported using siderolls to irrigate their fields. In 1986, the Soil Conservation Service found that siderolls were the least costly irrigation system for FSA (SCS, 1986). Siderolls were thought to be better suited to the rolling topography and irregular fields of FSA. There was also the concern that the application rate of the standard i.e., ¼ mile center pivots might exceed soil intake rate. This could be overcome by using shorter-length center pivots but the investment cost per acre would increase.

Since the survey was completed, several center pivot systems have been installed on newly or previously developed FSA land. More and more used siderolls are replaced with center pivots due to potential labor savings and the greater flexibility offered by center pivots. Automation, the possibility of growing tall crops under pivots, and chemigation are some of the advantages of center pivots over siderolls. The trend toward more center pivots has been encouraged by several years of good alfalfa hay markets, advances in center pivot technology, and the narrowing of the price differential (on a per-acre basis) between center pivots and siderolls.

Probably the most significant findings of the survey relate to water management. Twenty one percent of the respondents reported using sprinkler nozzles of 9 GPM or larger. This far exceeds the FSA system capacity and could lead to significant runoff if not carefully managed. Water runoff was observed by 63% of the respondents. Runoff can be minimized through proper irrigation system design, management, and maintenance. This is particularly important in FSA due to the erosive nature of the soils (low organic matter, low to moderate infiltration rate, hilly terrain). Several respondents suggested using deep tillage and catch basins to increase soil water infiltration. Runoff does not appear to be as serious of a problem as the survey results would indicate, possibly because of the large acreage in alfalfa. A well-established alfalfa stand provides good ground cover and helps retain the soil in place due to alfalfa's deep and extensive root system. However, soil compaction (leads to runoff) can become a problem in irrigated alfalfa fields after several years of wheel traffic and the use of heavy equipment( e.g., for making one-ton bales).

Seventy-four percent of the respondents reported using more than their water allocation in 1996. Nineteen ninety six was a particularly dry year but the numbers in Figures 5 and 7 suggest that poor management may also be to blame for the high water usage. About half of the respondents reported using a shovel or soil probe to check soil moisture before irrigating, but it is not clear how this information was used to schedule irrigations. Only two of the respondents reported using crop consumptive use (ET) information to schedule irrigation. There is generally less flexibility in scheduling irrigation with siderolls than with center pivots (Berrada et al., 2001).

An encouraging outcome of the survey is the large number of respondents who indicated the need for information on irrigation equipment innovations, irrigation scheduling, and other information that could help them conserve water and get the most out of their water allocation. Several workshops and field demonstrations were organized in 1997-1999 to provide such information.

This survey provided a useful means of assessing irrigation water management in FSA. It was biased toward siderolls and did not lend itself to a separate analysis of water management with siderolls and center pivots. It reflected to some extent, the main authors' level of knowledge of local irrigation issues at the time the survey was done. Nevertheless, this was the first step in a successful attempt to gain a better understanding of irrigation water management in FSA, identify constraints to efficient water use in FSA, and initiate research and educational programs to address these constraints.

A more comprehensive survey may be warranted by the Year 2005. Its objectives would be to:

- Assess progress made since 1996
- Identify new concerns/constraints, especially in light of the proposed expansion of FSA
- Assess the impact of irrigation on:
  - The region's economy
  - FS irrigators' (and their families) quality of life.

A panel made up of university scientists, FSA irrigators, DWCD staff and board member representatives, and other interested parties should design the survey. The survey should be tested before it is mailed out and available DWCD crop census and water use information should be analyzed to help focus the survey.

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## TABLES AND FIGURES

Table 1. Dolores project water allocation[1]

| Water/Entity | Acres | Acre-feet | Comments |
|---|---|---|---|
| Irrigation water | | | |
| Full Service Area | 27920 | 55200 | |
| Ute Mountain Utes | 7634 | 22900 | |
| MVIC[2] | 26300 | 13700 | Supplemental |
| Subtotal | 61854 | 91800 | |
| Municipal and Industrial | | | |
| (M&I) water | | 1000 | |
| Towac | | 2200 | |
| Cortez | | 280 | |
| Dove Creek | | 5220 | |
| DWCD | | 8700 | |
| Subtotal | | | |
| Recreation, Fish & Wildlife | | | Plus water that McPhee cannot store or "spill", plus up to 3900AF in senior water rights |
| Reservoirs | | 1600 | |
| Downstream fishery | | 29300 | |
| Subtotal | | 30900 | |
| Total allocation | 61854 | 131,400 | |

[1]Source: Dolores Water Conservancy District (DWCD)
[2]Montezuma Valley Irrigation Company

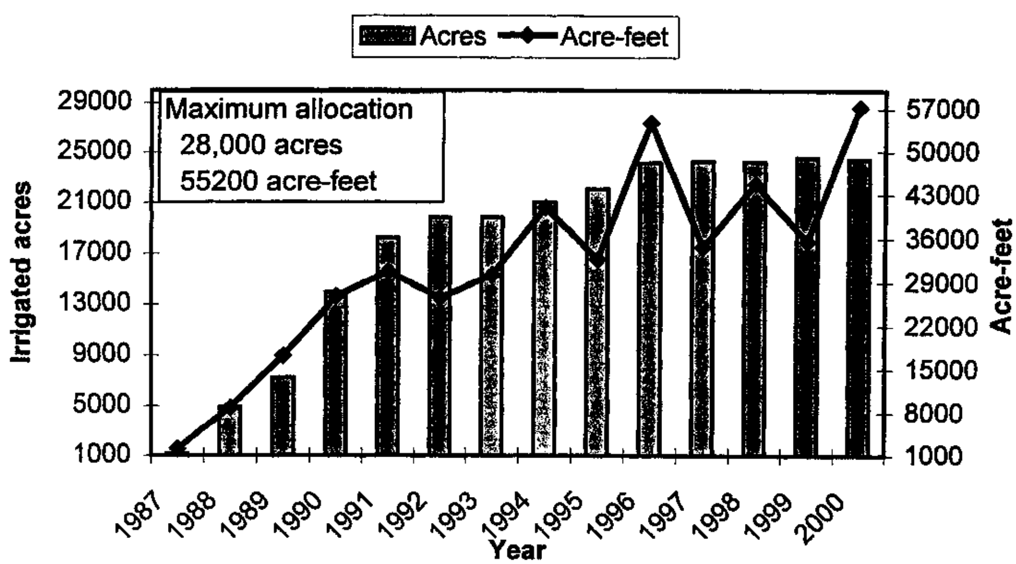


Figure 1. Irrigated acreage in FSA and water release in 1987-2000[1]

[1]Dolores Water Conservancy District Crop Census

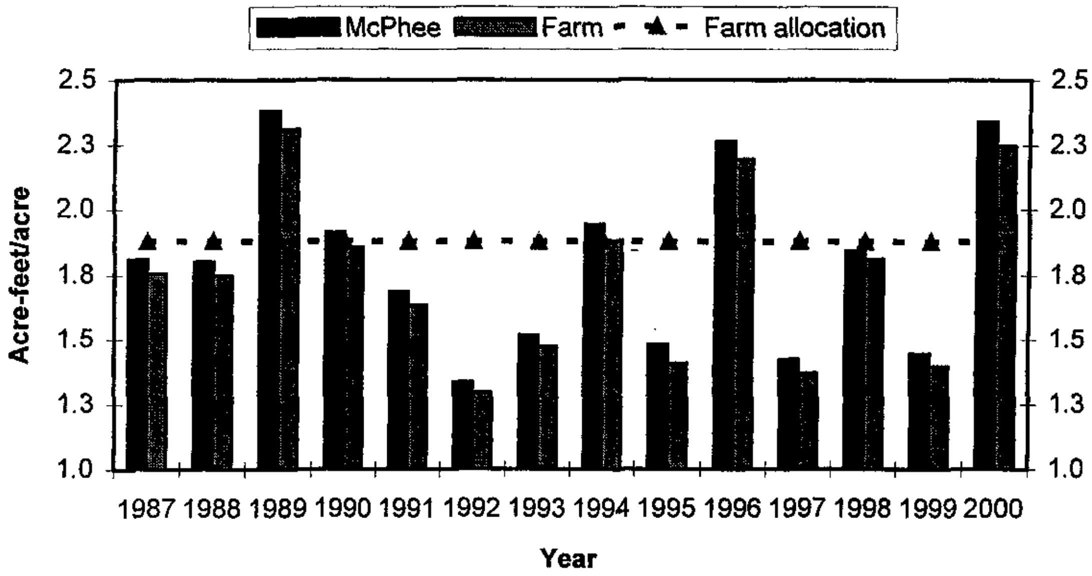


Figure 2. Water use per irrigated acre at FSA in 1987-2000[1]

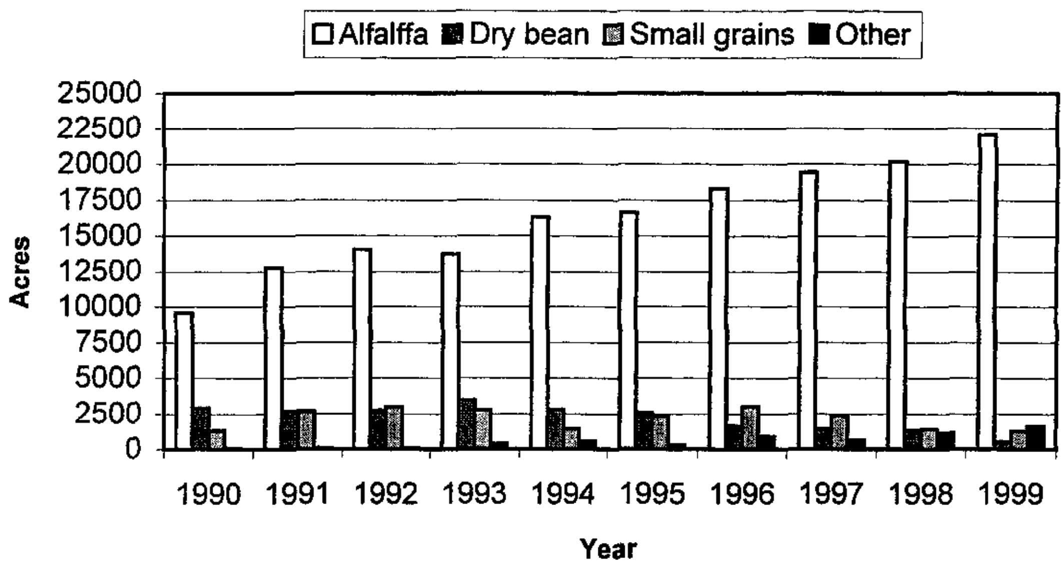


Figure 3. Crop acreage at FSA in 1990-1999[1]

[1]Dolores Water Conservancy District Crop Census

Table 2. Water requirements for FSA

| | Cahone Pleasant View Ruin Canyon | Fairview | Hovenweep | Monument Creek Cross Canyon | Weighted average |
|---|---|---|---|---|---|
| Crop consumptive use (CU)[1] | Acre-feet | | | | |
| Ideal rotation[2] | 1.75 | 1.75 | 1.88 | 1.75 | 1.76 |
| 1995-1999 average | 1.96 | 1.96 | 2.12 | 1.96 | 1.97 |
| Effective precipitation[3] | 0.49 | 0.49 | 0.48 | 0.49 | |
| Water to be supplied by irrigation per acre | | | | | |
| Per irrigated acre | 1.26 | 1.26 | 1.40 | 1.26 | |
| Per irrigable acre (95%) | 1.20 | 1.20 | 1.33 | 1.20 | |
| Farm irrigation Efficiency (%) | 70 | 70 | 70 | 70 | |
| Farm loss | 0.51 | 0.51 | 0.57 | 0.51 | |
| Farm delivery requirement | 1.71 | 1.71 | 1.90 | 1.71 | |
| Reuseable return flow | 0.00 | 0.00 | 0.00 | 0.00 | |
| Net farm delivery requirement | | | | | |
| Ideal rotation | 1.71 | 1.71 | 1.90 | 1.71 | 1.72 |
| 1995-1999 average | 1.91 | 1.91 | 2.13 | 1.91 | 1.93 |
| Conveyance loss | 0.15 | 0.08 | 0.15 | 0.39 | |
| Operational loss requirement (5%) | 0.09 | 0.09 | 0.10 | 0.09 | |
| Net diversion requirement at McPhee Reservoir | | | | | |
| Ideal rotation | 1.95 | 1.88 | 2.15 | 2.19 | 1.97 |
| 1995-1999 average | 2.15 | 2.08 | 2.38 | 2.39 | 2.18 |
| Allocated acres | Acres | | | | Total acres |
| DPR (1977)[4] | 15110 | 7700 | 2000 | 3050 | 27860 |
| 1995-1999 average[5] | 13913 | 8013 | 2649 | 3353 | 27928 |

Crop acreage (%) and CU:

| Crop | Acreage (%) Ideal rotation | CU (DPR/Ideal rotation) Hovenweep | other | Acreage (%) 1995-1999 | CU (DPR/1995-99 acreage) Hovenweep | other |
|---|---|---|---|---|---|---|
| | | Acre-feet | | | Acre-feet | |
| Alfalfa | 55.0 | 2.25 | 2.08 | 81.1 | 2.25 | 2.08 |
| Small grains | 20.0 | 1.30 | 1.21 | 6.3 | 1.30 | 1.21 |
| Dry bean | 15.0 | 1.40 | 1.31 | 8.7 | 1.40 | 1.31 |
| Pasture | 3.0 | 2.30 | 2.12 | 3.9 | 2.30 | 2.12 |
| Corn | 7.0 | 1.51 | 1.42 | 0.0 | 1.51 | 1.42 |
| Total/Weighed | 100.0 | 1.88 | 1.75 | 100.0 | 2.12 | 1.96 |

[1]Crop consumptive use was computed by the Jensen-Haise method. CU and Peff (Effective Precipitation) are cumulative monthly totals for April through October (DPR, 1977).
[2]Ideal crop rotation: Alfalfa (55%), small grains (20%), dry bean (15%), other (10%)
[3]Effective precipitation (DPR, 1977): To allow for evaporation losses, 0.15" was substracted from each monthly precipitation before applying the following percentages: 1" (95%), 2" (90%), 3" (82%).
[4]DPR: Dolores Project Colorado. Definite Plan Report. Appendix B: Water Supply. April 1977
[5]Sandstone (596 acres) was added in 1995-1999.

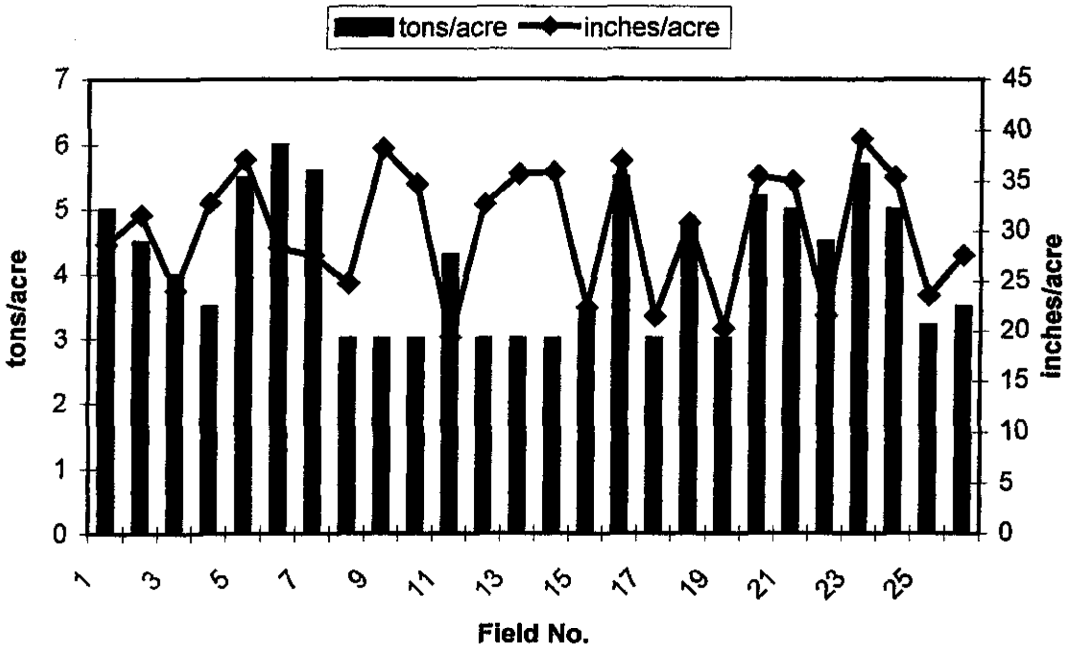


Figure 4. Alfalfa hay yield and water use at FSA (Fairview Block) in 1996[1]

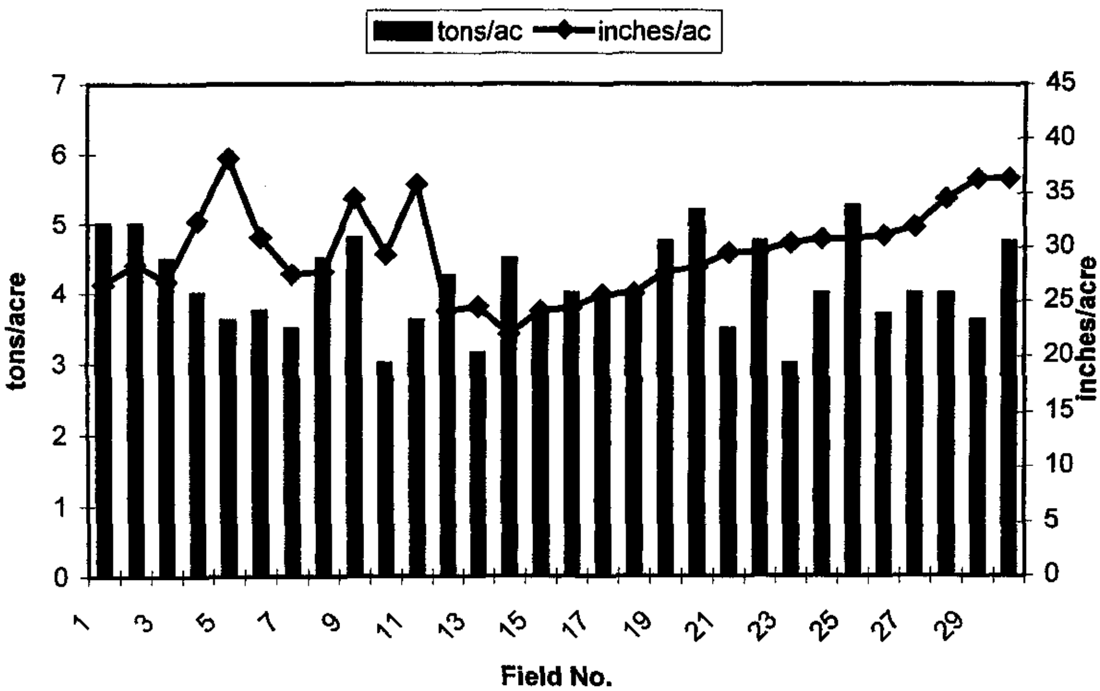


Figure 5. Alfalfa hay yield and water use at FSA (Cahone Block) in 1996[1]

[1]Inches/acre is the amount of irrigation water at the delivery box divided by alfalfa acreage. Source: Dolores Water Conservancy District

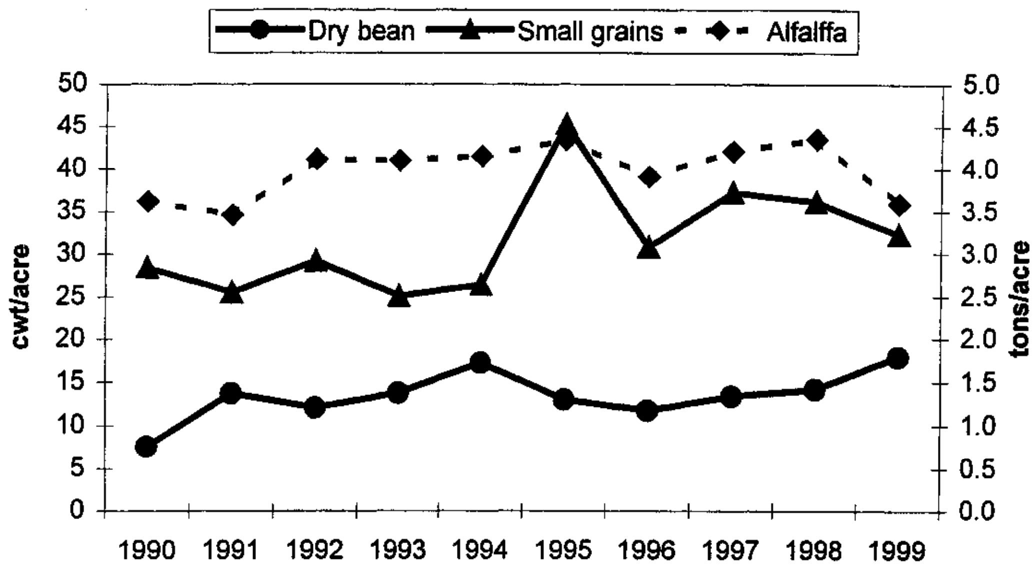


Figure 6. Crop yield at FSA in 1990-1999[1]

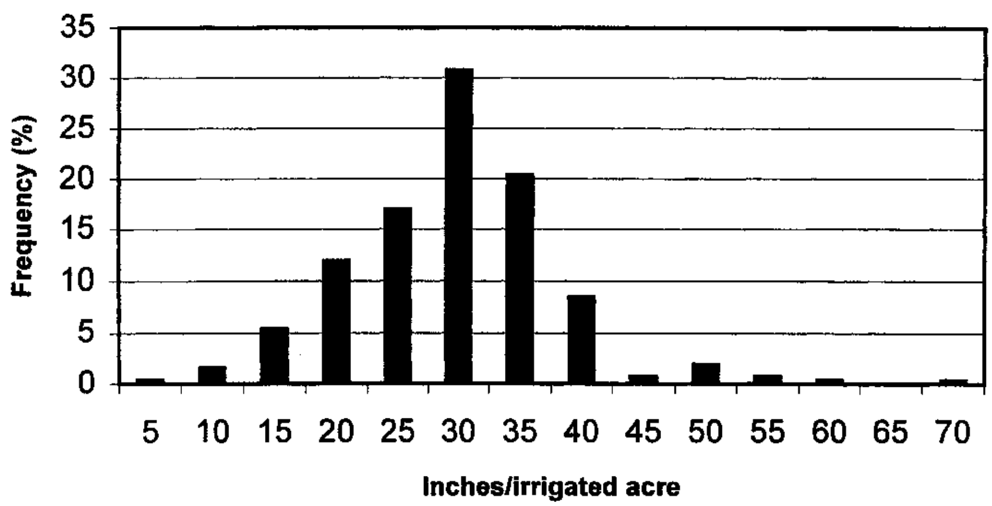


Figure 7. Irrigation water use histograms in 1996 at FSA

[1]Source: Dolores Water Conservancy District

APPENDIX A

**Outreach activities and publications associated with the irrigation water management demonstration (IWMD) project**

Workshops and presentations

3/10/00: Soil, Crop, and Water Management for Optimum Production in SW Colorado. Presented by Abdel Berrada at the Four States Agricultural Exposition in Cortez, CO.

2/17/00: Demonstration of Irrigation Scheduling Tools. Presented by Abdel Berrada and Thomas Hooten at the Four Corners Irrigation Workshop in Cortez, CO

2/17/00: Four Corners Irrigation Workshop in Cortez, CO.

3/18/99: Irrigation Management Research and Demonstration Study. Presented by Abdel Berrada at the Soil, Water, And Groundwater Management (SWAGMAN II) Symposium at the Ute Mountain Ute Tribe Farm & Ranch Enterprise.

3/13/99: Making the Most of Your Irrigation Allocation. Presented by Abdel Berrada at the Four States Agricultural Exposition in Cortez, CO.

3/13/99: Seminar on Irrigation Water Management at the Four States Agricultural Exposition in Cortez, CO.

6/09/98: Irrigation Demonstration project. Presented by Abdel Berrada at the Irrigation Field Day organized by the Intermountain Farmers Association (IFA) West of Pleasant View.

3/18/98: Highlights of the Irrigation Management Study in the Full Service Area of the Dolores Project. Presented by Abdel Berrada at the Irrigation Management Workshop.

3/18/98: Irrigation Management Workshop at the Arriola Fire Station in Montezuma County.

Other: Various aspects/results of the irrigation water management demonstration study were presented by Abdel Berrada at the Annual Advisory Committee meetings for SWCRC and at the Annual Research Center Conferences.

Field days/tours: Oral and poster presentations related to the IWMD project and demonstration of irrigation scheduling tools and water conservation methods were made at the August 21, 1997 and August 19, 1999 at SWCRC. The IWMD project was also highlighted at the Leadership Montezuma- Agriculture and Natural Resources Days on September 2, 1997 and October 1, 1998. In addition, field plots were set up during the summer of 1999 to demonstrate the use of PAM and dammer diker to conserve water and reduce soil erosion.

Publications

Abdel Berrada. 2000. Crops, Soil, and Irrigation Research. Colorado Water 17(1): 11-13. Newsletter of the Water Center of Colorado State University. February 2000. Colorado State Univ., Fort Collins.

Berrada, A., G.E. Cardon, I. Broner, T.M. Hooten, and M.W. Stack. 1999. Evaluation of irrigation water management in southwestern Colorado. Agron. Abstracts p. 278 Amer. Soc. of Agron., Madison, WI.

'Irrigation check now will prevent headaches later' by Abdel Berrada. Page 9B, Cortez Sentinel, 05/08/99

'Highlights of the irrigation management survey in the full service area of the Dolores Irrigation Project' by Abdel Berrada. Section B of the Montezuma Valley Journal, 4/10/97

'Farmers may use technology to survive severe drought' by Jim Mimiaga. Page 2B, Cortez Journal, 2/12/00. Account of interview with Abdel Berrada and Tom Hooten relating to IWMD project.

Progress reports were submitted to CAES & CE in June '99 and to BOR in Sept. '99 and Nov. '00.

Related publications

Mahdi M. Al-Kaisi, Abdel Berrada, and Mark Stack. 1997. Evaluation of irrigation scheduling program and spring wheat yield response in southwestern Colorado. Agric. Water Management 34 (1997) 137-148. Elsevier Science Inc.

Mahdi M. Al-Kaisi, Abdel F. Berrada, and Mark W. Stack. 1999. Dry bean yield response to different irrigation rates in southwestern Colorado. J. Prod. Agric. 12:422-427

APPENDIX B

## Irrigation Survey Questionnaire

Cover letter

October 28, 1996

**Irrigation Management Survey**

Dear Irrigator:

The objective of this survey is to assess irrigation management practices in the Dolores Water Project area. The information obtained will help Colorado State University scientists and extension specialists plan future research and outreach efforts in irrigation management in southwestern Colorado.

This survey is being conducted under guidelines established by Colorado State University. Your participation is strictly voluntary, and confidentially is guaranteed. All replies are anonymous; only summaries of the compiled results will be made public.

**Please complete the questionnaire forms as indicated and return it in the envelope provided by December 1, 1996.** The results of the survey will be compiled by the Southwestern Colorado Research Center, and copies of the results will be available to the public. If you would like a copy, or have any questions or concerns, please contact Abdel Berrada or Mark Stack at 562-4255.

We appreciate your cooperation and prompt reply. Thank you.

Sincerely,

Abdel Berrada
Research Scientist/Superintendent
Southwestern Colorado Research Center

John Porter, Chairman
Advisory Committee for the Southwestern Colorado Research Center & the San Juan Basin Research Center

**Irrigation Management Survey**
**Southwestern Colorado Research Center**
**P.O. Box 233, Yellow Jacket, CO 81335**

Please mark all that apply to your operation.

**1. Land use**

11. How many irrigated acres do you own or lease/rent in your operation?
    a. Acres owned ________
    b. Acres leased/rented ________

12. Please specify the irrigated crops you grew in 1995-96 and their average yield.
    a. Alfalfa: ________ acres ________ t/ac.
    b. Dry bean: ________ acres ________ lb/ac.
    c. Winter wheat: ________ acres ________ bu/ac.
    d. Spring wheat: ________ acres ________ bu/ac.
    e. Oats: ________ acres ________ bu/ac.
    f. Other (specify) ________________________________________

13. What is your irrigation allocation? __________ acre-feet

**2. Irrigation system**

21. Please specify the buried pipe you use
    a. Material: ___ PVC ___ 80 psi ___ 100 psi ___ 120 psi Other (specify) ___
    b. Pipe diameter: ___ 4" pipe___ 6" pipe ___ 8" pipe
    ___ 10" pipe Other (specify) ____________________________

    c. Do you use ___ pressure relief or ___ air vac valves with your pipe? ___ YES ___NO

22. What irrigation systems do you use?
    221. Siderolls
    a. Pipe and wheel size
    ___ 5" pipes & 7' wheels ___ 4" pipes & 5' wheels Other (specify)________

    b. Length and number of siderolls

| Length | How many? | Length | How many? |
|---|---|---|---|
| ____ 1/4 mile | ____ | ______ ft | _____ |
| ______ ft | ____ | ______ ft | _____ |

    c. Total acres irrigated with Siderolls _______

    222. Center Pivots

a.

| Length | How many? | Length | How many? |
|---|---|---|---|
| ____ 1100 ft | ____ | _______ ft | _____ |
| ____ 1300 ft | ____ | _______ ft | _____ |

b. Total acres irrigated with Center Pivots ________

223. Other irrigation systems: Drip ______ acres Other (specify) __________ acres

224. Please specify the type of sprinklers and sprinkler nozzles you use

a. with siderolls
____ Single nozzles
____ Double nozzles
____ Flow control nozzles
____ Pressure regulators
Other (specify) ___________

b. with center pivots
____ Rotators
____ Impact (overhead)
____ Low Drift Nozzle Sprinklers (LDN)
____ Low Energy Precision Applicator (LEPA)
Other (specify) ______________________

c . Nozzle size

| | | | |
|---|---|---|---|
| ____ 9/64 | ____ 5/32 | ____ 9/64 x 3/32 | ____ 5/32 x 3/32 |
| ____ 11/64 | ____ 3/16 | ____ 11/64 x 3/32 | ____ 3/16 x 3/32 |
| ____ 7/32 | ____ 1/4 | ____ 3/16 x 1/8 | ____ 7/32 x 1/8 |
| Other (specify) ___________ | | Other (specify) ______________ | |

____ 5 gpm ____ 6 gpm ____ 7 gpm ____ 8 gpm ____ 9 gpm Other (specify) ___

**3. Irrigation Management**

31. How often do you usually move your siderolls in 24 hours and how far do you move them?

_____ Once _____ Two turns
_____ Twice _____ Three turns
_____ Three times Other (specify) ______________________

32. How do you decide when to irrigate?

a. _____ When the soil surface is dry
b. _____ When the crop shows signs of stress
c. _____ I keep moving the siderolls from the start of the irrigation season until the crop is mature or ready to cut/harvest
d. _____ I sample the soil with a ____ probe or ____ shovel and feel how dry/moist it is
e. I rely on crop water use information obtained from ____ CoAgmet ____ Weather station ___ Newspaper ____ Cooperative Extension, Other (specify) ______________
f. Other (specify) ______________________________

33. How often do you irrigate the following crops?

| Crop | Number of irrigations in 1996 | a normal year |
|---|---|---|
| a. Alfalfa | | |
| Before the first cutting | ____ | ____ |
| 1st - 2nd cutting | ____ | ____ |
| 2nd - 3rd cutting | ____ | ____ |
| 3rd. - 4th cutting | ____ | ____ |
| b. Dry beans | ____ | ____ |

| | | |
|---|---|---|
| c. Winter wheat | ___ | ___ |
| d. Spring wheat | ___ | ___ |
| e. Oats | ___ | ___ |
| f. Other (specify) | ___ | ___ |

34. Do you use different nozzle sizes? ___ NO ___ YES
    a. ___ For different crops
    b. ___ At different crop growth stages
    c. How do you decide what nozzle size to use? ______________________

35. Do you use different sideroll settings (number of hours per run)? ___ NO ___ YES
    a. ___ For different crops
    b. ___ At different times of the irrigation season
    c. How do you decide what setting to use? ______________________

    ______________________________________________

36. How much water did you use in 1996?
    a. ___ My allocated amount
    b. ___ Less than my allocated amount
    c. ___ Slightly more than my allocated amount
    d. ___ Much more than my allocated amount
    e. Other (specify) ______________________

37. Did you notice any runoff on your irrigated fields? ___ YES ___ NO

38. If the answer to question 37 is yes, what do you plan to do about it?
    a. ___ Nothing Why? ______________________
    b. ___ Check my pipes and sprinklers for leaks and fix them
    c. ___ Use smaller nozzle sizes
    d. ___ Run the siderolls for less hours
    e. ___ Increase the speed of center pivot
    e. Other (specify) ______________________

39. Do you use irrigation metering and/or timing devices? ___ YES ___ NO

40. What type of information do you think will help you better manage your irrigated land?
    ___ Irrigation equipment innovations
    ___ Crop water requirements & irrigation scheduling guidelines
    ___ Soil management guidelines
    ___ Crop management guidelines
    Other (specify) ______________________

    ______________________________________________

41. Additional comments: Please provide any additional information, comments, or suggestions, which may be useful in assessing irrigation water management in the Dolores Project Area. Thank you. ______________________

## APPENDIX C
## **Detailed Survey Results**

Table C1. Irrigation Survey Results I: Land Use

| | Irrigated crops grown in 1995-96 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | | | Alfalfa | | Dry bean | | Winter wheat | | |
| ID | Owned | Leased | Total | acres | t/a | acres | lb/a | acres | bu/a | Comments |
| 1 | 140.0 | 0.0 | 140.0 | 140.0 | 4.5 | | | | | |
| 2 | 154.0 | 0.0 | 154.0 | 71.0 | - | | | | | |
| 3 | 525.0 | - | 525.0 | | | | | | | |
| 4 | 0.0 | 498.0 | 498.0 | 368.0 | 4.0 | | | | | |
| 5 | | | | | | | | | | |
| 6 | 50.0 | 0.0 | 50.0 | 50.0 | | | | | | |
| 7 | 40.0 | - | 40.0 | 33.0 | 3.5 | | | | | |
| 8 | 0.0 | 70.0 | 70.0 | 70.0 | 3.0 | | | | | |
| 9 | 32.0 | - | 32.0 | 16.0 | 6.0 | | | | | |
| 10 | 90.0 | 40.0 | 130.0 | | | 100.0 | 900.0 | 30.0 | 25.0 | |
| 11 | 105.0 | 0.0 | 105.0 | | 2.7 | | | - | 55.0 | |
| 12 | 280.0 | 0.0 | 280.0 | 280.0 | 4.0 | | | | | |
| 13 | 160.0 | 0.0 | 160.0 | 110.0 | 3.0 | | | | | |
| 14 | 53.0 | 106.0 | 159.0 | | 2.3 | | | | | |
| 15 | 27.0 | 0.0 | 27.0 | 12.0 | 2.8 | | | | | |
| 16 | 300.0 | 0.0 | 300.0 | 100.0 | 7.0 | 105.0 | 1900.0 | | | |
| 17 | 300.0 | 0.0 | 300.0 | 300.0 | 5.0 | | | | | |
| 18 | 231.0 | 440.0 | 671.0 | 590.0 | 6.0 | | | | | |
| 19 | 288.0 | 271.0 | 559.0 | 316.0 | 4.8 | 102.0 | 1818.0 | | | |
| 20 | 235.0 | 90.0 | 325.0 | 325.0 | 5.0 | | | | | |
| 21 | | | 150.0 | | | | | | | pasture |
| 22 | 118.1 | 391.4 | 509.5 | 215.4 | 4.0 | | | | | |
| 23 | 600.0 | 0.0 | 600.0 | 310.0 | 4.1 | | | | | |
| 24 | 150.0 | 286.0 | 436.0 | 397.0 | 4.0 | 6.0 | 1600.0 | | | |
| 25 | 110.0 | 0.0 | 110.0 | 110.0 | 3.0 | | | | | |
| 26 | 225.0 | 0.0 | 225.0 | 150.0 | - | | | | | |
| 27 | 0.0 | 89.3 | 89.3 | | | 61.3 | 2191.0 | | | |
| 28 | 73.0 | 23.0 | 96.0 | | | 73.0 | 1700.0 | | | |
| 29 | 130.0 | 68.0 | 198.0 | 189.0 | 3.5 | | | | | |
| 30 | 158.0 | 0.0 | 158.0 | 110.0 | - | | | 37.0 | 42.5 | |
| 31 | 580.0 | 220.0 | 800.0 | 560.0 | - | | | | | |
| 32 | 156.8 | 0.0 | 156.8 | 68.0 | 4.6 | 68.0 | 1000.0 | | | |
| 33 | 1900.0 | 0.0 | 1900.0 | 1000.0 | 5.8 | | | | | |
| 34 | 280.0 | 0.0 | 280.0 | | | | | | | |
| 35 | 57.0 | 0.0 | 57.0 | 40.0 | - | | | | | |
| 36 | 137.0 | 160.0 | 297.0 | 195.0 | 6.0 | 72.0 | 1000.0 | | | |
| 37 | 73.8 | 0.0 | 73.8 | 73.8 | 4.0 | | | | | |
| 38 | 350.0 | 400.0 | 750.0 | 270.0 | 4.0 | | | | | |
| 39 | 200.0 | 0.0 | 200.0 | 200.0 | 4.0 | | | | | |
| 40 | 100.0 | 0.0 | 100.0 | 10.0 | 5.4 | | | | | |
| 41 | 186.0 | 157.0 | 343.0 | 112.0 | - | 77.0 | | 152.0 | - | |
| 42 | 264.0 | 298.0 | 562.0 | 240.0 | 3.3 | 113.0 | 1125.0 | | | |
| Entries | 41 | 38 | 42 | 34 | 29 | 11 | 10 | 4 | 4 | |
| Total | 8858.7 | 3607.7 | 12616.4 | 7031.2 | | 777.3 | | 219.0 | | |
| Mean | 221.5 | 97.5 | 307.7 | 213.1 | 4.3 | 77.7 | 1470.4 | 73.0 | 40.8 | |

Table C1. Irrigation Survey Results I: Land Use (Continued)

| | Irrigated crops grown in 1995-96 | | | | | | Irrigation | |
|---|---|---|---|---|---|---|---|---|
| | Spring wheat | | Oat | | Other crops | | allocation | |
| ID | acres | bu/a | acres | bu/a | acres | crop | acre-feet | Comments |
| 1 | | | | | | | 178.4 | |
| 2 | | | | | | | | |
| 3 | | | | | | | 890.0 | |
| 4 | 130 | 80 | | | | | | |
| 5 | | | | | 1 | ? | 6.6 | Could be M&I water |
| 6 | | | 5 | - | | | 228.0 | |
| 7 | | | | | | | | |
| 8 | | | | | | | 103.5 | |
| 9 | | | | | | | | |
| 10 | | | | | | | 84.1 | |
| 11 | | | | | | | 84.0 | |
| 12 | | | | | | | 459.0 | |
| 13 | | | | | | | 115.0 | |
| 14 | | | | | | | | |
| 15 | | | | | | | 20.5 | |
| 16 | | | 60 | 70 | | | 510.4 | |
| 17 | | | | | | | | |
| 18 | | | | | | | | |
| 19 | | | 141 | 95 | | | 1028.4 | |
| 20 | | | | | | | 555.0 | |
| 21 | | | | | 150 | Pasture | 247.0 | |
| 22 | 163.8 | 76 | | | | | 643.8 | |
| 23 | | | | | 150 | Corn | 4.0 | Could be M&I water |
| 24 | 40 | 100 | | | | | | |
| 25 | | | | | | | 135.0 | |
| 26 | 75 | 70 | | | | | 436.0 | |
| 27 | 28 | 90 | | | | | 136.3 | |
| 28 | | | | | | | | |
| 29 | | | | | | | | |
| 30 | | | | | | | 133.0 | |
| 31 | | | 100 | - | 100 | Grass | 1360.0 | |
| 32 | | | | | | | 268.0 | |
| 33 | 360 | 70 | | | | | 1300.0 | |
| 34 | 150 | 65 | | | | | 478.0 | |
| 35 | | | | | 17 | Alf/grass | | |
| 36 | | | | | | | | |
| 37 | | | | | | | 144.6 | |
| 38 | 360 | 80 | | | | | 465.0 | |
| 39 | | | | | | | 260.0 | |
| 40 | | | | | | | 179.0 | |
| 41 | | | | | 2.4 | Oinons | | |
| 42 | 128 | 83.7 | | | | | 562.0 | |
| Entries | 10 | 10 | 5 | 3 | 7 | | 30.0 | |
| Total | 1434.8 | 714.7 | 306 | | 420.4 | | 11014.6 | |
| Mean | 159.4 | 79.4 | 76.5 | 82.5 | 70.1 | | 379.8 | |

Table C2. Irrigation Survey Results II: Irrigation System

| Item | Tally[1] | | Tally[1] |
|---|---|---|---|
| 21. Mainline/buried pipe | 38 | | |
| Rating | | Pressure relief valve (PRV) | 22 |
| 80 – 100 psi | 36 | Air-vacuum release valve (ARV) | 34(20) |
| 120-160 psi | 7(4) | PRV or ARV | 37 |
| Other | 1(1) | None | 0 |
| Mainline diameter | 40 | 22. Irrigation system/Siderolls | 37 |
| 4" | 7 | Sideroll length | |
| 6" | 26 | Less than ¼ mile (38 systems) | 15 |
| 8" | 28(19) | ¼ mile (168 systems) | 35(13) |
| 10" | 20(18) | 1440' to 1600' (10 systems) | 6(5) |
| Other | 6(4) | | |
| Sideroll sprinklers | 38 | Sideroll pipe and wheel diameter | 37 |
| Single nozzle | 24 | 5" x 7' | 31 |
| Double nozzle | 20(7) | 4" x 5' | 9(5) |
| Flow control nozzle | 10(6) | Other | 5(3) |
| Pressure regulator | 0 | Total sideroll acres: 5887 | 33 |
| Center Pivots | 17 | Center pivot sprinklers | 13 |
| 1300 ft (23 systems) | 10(1) | Rotator | 9 |
| 1200-1300 ft (6 systems) | 3 | Overhead impacts | 5(1) |
| 1100-1200 ft (4 systems) | 3 | LEPA | 1(1) |
| 600 - 900 ft (4 systems) | 2 | Total CP acres: 2888 | 15 |
| Other irrigation systems | 0 | Nozzle size | |
| | | 4-5 GPM | 12 |
| | | 5-6 GPM | 11 |
| | | 6-7 GPM | 11 |
| | | 7-8 GPM | 5 |
| | | 8-9 GPM | 2 |
| | | > 9 GPM | 12 |
| | | Unspecified | 3 |

[1]Number of respondents. Numbers between parentheses indicate number of respondents who marked more than one choice.

Table C3. Irrigation Survey Results III: Irrigation Management

| Item | Tally[1] | | Tally[1] |
|---|---|---|---|
| 31. Sideroll set time | 39 | Sideroll move length | 9 |
| 24-hour set | 6 | 3 turns | 27 |
| 12-hour set | 34(2) | Other | 3 |
| Other | 2(1) | | |
| 32. How do you decide when to irrigate? | | | 40 |
| Soil surface is dry | | | 7 |
| Crop stress | | | 6(2) |
| Continuously move siderolls | | | 19(3) |
| Sample with shovel or probe | | | 22(11) |
| Crop water use information | | | 1 |
| Other | | | 5 |
| Precipitation, runoff | | | |
| Every 10 to 11 days before crop stress | | | |
| Precipitation, once before 1st cut, twice between cuttings | | | |
| Checkbook, ET, crop consumptive use. | | | |

| 33. Irrigation frequency | Number of irrigations | | | |
|---|---|---|---|---|
| | 1996 | Range ('96) | Normal | Range |
| Alfalfa | | | | |
| Early spring | 2.7 | 1-4 | 1.5 | 1-5 |
| 1st – 2nd cut | 2.8 | 1-6 | 2.5 | 1-5 |
| 2nd – 3rd cut | 2.6 | 1-7 | 2.3 | 1-5 |
| 3rd – 4th cut | 2.1 | 1-7 | 2.0 | 1-5 |
| Dry bean | 6.7 | 4-8 | 5.3 | 4-6 |
| Winter wheat | 4.9 | 4-7 | 3.8 | 3-5 |
| Spring wheat | 7.7 | 7-9 | 6.7 | 4-9 |
| Oat | 4.0 | 3-5 | 3.7 | 3-4 |
| Other crops | 6.4 | 4-11 | 6.8 | 4-11 |

| | | | |
|---|---|---|---|
| 34. Do you use different nozzle sizes? | 37 | 36. Water use in 1996 | 38 |
| Yes | 23 | | |
| No | 14 | Allocated amount (AA) | 5 |
| | | Less than AA | 5 |
| With different crops | 11 | Slightly more than AA | 18 |
| At different crop growth stages | 9(6) | Much more than AA | 10 |

[1]Number of respondents. Numbers between parentheses indicate number of respondents who marked more than one choice.

Table C3. Irrigation Survey Results III: Irrigation Management (Continue)

| Item | Tally[1] |
|---|---|
| 35. Do you vary the sideroll set time? | 34 |
| Yes | 22 |
| No | 12 |
| For different crop | 10 |
| During the irrigation season | 14(7) |
| How do you decide set time? | |
| • In order to germinate crop 4 to 6-hour sets are used. | 2 |
| • In 1996, 24-hour sets were used between cuttings of alfalfa due to the dry soil. | 1 |
| • Crop maturity | 2 |
| • Chemigation requires different set times. | 1 |
| • Crop use | 3 |
| • Wind, rain, temperature | 3 |
| • Nozzle size, runoff, and crop stage | 1 |
| • What crop needs and soil will take. | 1 |
| • Crop appearance or probe soil for moisture | 1 |
| • When changes in the nozzle size are not sufficient to control the water. | 1 |
| • In late summer when the temperature is lower and water starts to runoff, I may move siderolls more frequently or change the nozzle size. | 1 |
| • Crop condition and availability of labor | 1 |
| • Wind (turn off if too windy), crop, growth stage, topography, infiltration rate, soil texture, time of year | 1 |
| • Soil moisture, precipitation, temperature | 1 |
| 37. Did you notice runoff in your field? | 41 |
| Yes | 26 |
| No | 15 |
| 38. What did you do about it? | |
| Nothing | 5 |
| Check for leaks | 6(1) |
| Use smaller nozzles | 10 |
| Shorter set time | 6(3) |
| Increase CP speed | 13(4) |
| Other | 10 |
| I'm going to rip my alfalfa with 1" shanks. The ground is too hard. | |
| Check for leaks. | |
| I plugged the spreader nozzle on each double sprinkler. | |
| Maybe aerate center pivot. | |
| Roll aerator across alfalfa field. | |
| Re-engineer nozzles to slope and pressure, try aeration. | |
| Steep hillside | |
| I have cut ditches and dug holes to slow runoff. | |
| Replaced drains and old impact sprinklers. | |
| Try new tillage programs. | |

Table C3. Irrigation Survey Results III: Irrigation Management (Continued)

| Item | Tally[1] |
|---|---|
| 39. Do you use irrigation metering/timing devices | 36 |
| Yes | 4 |
| No | 32 |
| 41. Additional comments | 12 |
| • Aeration is needed to help water infiltration on established fields (alfalfa). | |
| • Farmers should be allowed to use their allocated water and then be shut- off until everyone has had a chance to use their own allocated water. | |
| • Thank you for all your help. | |
| • Interested in a linear move irrigation system. Would like a linear system tested under our rolling terrain. | |
| • My runoff was mostly from lower or wetter areas, because I was putting more water on the higher areas due to the dry year. | |
| • I would like work done with tillage tools to measure the effect on soil water intake rates. | |
| • Crop water use should be printed in local newspapers. | |
| • Most irrigators use nozzles that are too large. | |
| • Excessive runoff helps no one. | |
| • For spring crops (including alfalfa), water needs to be available earlier in the spring to avoid starting out behind and playing catch-up all summer. | |
| • Need information on center pivots getting stuck. | |
| • I would like to have a better way of monitoring water in the field (storage capacity) i.e. gypsum blocks, probe, or new technology. | |

[1]Number of respondents. Numbers between parentheses indicate number of respondents who marked more than one choice.