Impact of Utilizing Water Supplies from the South Platte Water Conservation Project on Crop Production

Report made to the
Northern Colorado Water Conservancy District

data from a distance
reasonable report
Given the data given
to him

incomplete
no soil conditions
cursory

By
Dr. Glenn J. Hoffman respected

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INTRODUCTION

At the request of the Northern Colorado Water Conservancy District and in connection with the water court applications filed in Consolidated Case No. 92CW130 for the South Platte Water Conservation Project (Project or SPWCP), I have assembled crop and water data, analyzed the data with respect to the impact of the salinity of the applied water in the proposed Project area on crop production, and drawn conclusions and made several management recommendations. I wish to thank Mr. Andrew Pineda and others at the District office for providing data and acquainting me with the proposed Project. This analysis draws heavily upon the information provided in the Reference Section and information provided by the District.

This report presents the salt tolerance of the major crops in the project area, summarizes the potential sources of applied water and their approximate level of salinity for this project, and describes how these water sources can be weighted by the amount applied from each source to estimate an average salinity of the applied water. These results are then applied to a crop salt tolerance equation to predict the crop yield with various scenarios of applying the several sources of water. The report concludes with an analysis of which crops will not be and which may be at risk of suffering a yield loss from utilizing the various water sources. Several recommendations are presented for managing waters and crops to avoid yield losses from excess salinity.

CROP SALT TOLERANCE

Crops differ in their response to salinity. The most distinct signs of injury from excess salts are reduced plant growth and loss of yield. Crops can tolerate salinity up to certain levels without a measurable loss in yield. This is called the salinity threshold. As the salt tolerance of crops increases, the threshold also increases. At salinity levels greater than the threshold, crop yield is typically reduced linearly as salinity increases. The relationship between soil salinity and crop yield in equation form is:

$$Yr = 100 - S\,(ECe - T), \qquad (1)$$

where Yr is crop yield relative to the same conditions without salinity, S is the linear rate of yield decline with increasing salinity beyond the threshold (slope of the line), T is the threshold salinity, and ECe represents the average root zone salinity measured as the electrical conductivity of a saturated soil extract (Maas and Hoffman, 1977). The threshold and slope values for the major crops in the project area are presented in Table 1. The crops in Table 1 are also rated as sensitive (S), moderately sensitive (MS), moderately tolerant (MT), or tolerant (T) of soil salinity.

Table 1. Threshold (T) and slope (S) values to calculate crop yields as a function of soil salinity and the crop's qualitative salt tolerance rating. (Adapted from Maas and Hoffman, 1977)

Crop	Threshold (T) dS/m	Slope (S) %/dS/m	Qualitative Salt Tolerance Rating
Alfalfa	2.0	7.3	MS
Barley for grain	8.0	5.0	T
Bean	1.0	19	S
Carrot	1.0	14	S
Corn for grain	1.7	12	MS
Corn for silage	1.8	7.4	MS
Grass hay/pasture			
Brome, smooth	----*	-----	MS
Orchard grass	1.5	6.2	MS
Rye	----*	-----	MS
Onion	1.2	16	S
Sorghum for grain	6.8	16	MT
Sugar Beet	7.0	5.9	T
Wheat for grain	6.0	7.1	MT

*These values are not published.

The salt tolerance data presented in Table 1 are based upon the average soil salinity of the root zone reported as the electrical conductivity of saturated soil extracts (ECe). This can be seen in the relationship given in equation (1). For this proposed project the only estimate of salinity is that of the applied water (see section on Applied Water Salinity). When the actual relationship between average soil salinity and the salt content of the applied water is not known, ECe is assumed to be 1.5 times larger than the salinity of the applied water (Ca). This relationship has been shown to be a reasonable estimate for many situations and the basic assumption is that 15% of the applied water leaches (drains) through the root zone to control soil salinity (G. Hoffman, 1997). If more water is applied than is needed to satisfy the crop's evapotranspiration and provide a leaching fraction of 0.15, the leaching fraction will increase and the ratio of ECe to Ca of 1.5 will become smaller. Conversely, applying less water results in a leaching fraction less than 0.15 and the ratio between ECe and Ca will become larger. If the leaching fraction is known to be different than 0.15 then a more accurate relationship can be applied to the analysis presented in this report.

APPLIED WATER SALINITY

There are four potential sources of water that could be available for crop production. These four sources are: rainfall, surface water currently provided by the irrigation and reservoir companies, well water, and proposed water supplies from diversion of Cache la Poudre River and South Platte River water. The amount of precipitation that may be effectively used by crops is discussed in the next section, followed by sections on probable salinity levels of ditch company surface waters after the project is initiated, and projected salt levels in the supplies from the South Platte Water Conservation Project (SPWCP). There is limited information on well water supplies in the Project area. If more information on the salt content of well water is available, the accuracy of analysis considering well water as an irrigation source can be improved.

Effective Rainfall

Even in regions of low to moderate rainfall, precipitation can be an effective source of water for crops. Any precipitation used by the crop will obviously reduce the irrigation requirement. How much of the recorded rainfall can be utilized by crops is not well understood. As a result, many estimate that 75% of the recorded rainfall can satisfy a portion of the crop's ET requirement. The 75% figure is to take into account small, low intensity rainfalls that may not penetrate into the crop root zone and high intensity and/or long duration rains that result in surface runoff. Thus, to be conservative, 75% of the recorded rainfall will be assumed to offset irrigation requirements. With respect to water quality, rainwater, which is salt free, permits the use of more saline irrigation water than would otherwise be permissible in the absence of rain. For the purposes of this study, recorded rainfall records were used from station number 53553 at Greeley, Colorado, for 1967 through 2003.

For an overall analysis of rainfall in the project area, the 26-year rainfall record was utilized. Later in this report, the effective rainfall for each major crop was considered. For overall comparisons, the typical growing period was considered to be from March 1 through September 30 of each year. This time period is a compromise considering that planting dates vary from March to late May for many crops and some crops are planted in the fall (alfalfa) or winter (seed onions). Likewise, harvest dates among crops range from July to October. After this initial analysis, if certain crops appear to be in jeopardy of yield loss because of excess salinity, a detailed analysis for any crops threatened by salinity will be conducted. Taking recorded rainfall at Greeley from March 1 until September 30 and multiplying by 0.75 yields the values in Table 2 for effective rain from 1967 to 2003.

Also of interest are drought years. Data for the driest year and an average of the five driest years are presented in Table 2.

Table 2. Rainfall at Greeley, Colorado, from 1967 to 2003

	Inches
Average Values	
Annual rainfall	14.1
Effective seasonal rainfall (Mar. 1 to Sept. 30)	8.3
Drought Values	
Lowest value on record (1968)	
Annual rainfall	8.4
Effective seasonal rainfall	4.4
Average of 5 driest years (1968, 1986, 1994, 2000, & 2002)	
Annual rainfall	9.6
Effective seasonal rainfall	5.0

As a check on the effective rainfall data, a comparison was made with the values reported by Broner and Schneekloth (2003) from Colorado State University. The time period for their rainfall records was not specified but they reported an average seasonal precipitation for Greeley of 12.2 inches and an average effective seasonal precipitation of 7.3 inches. The ratio of effective to total was 0.60 for Broner and Schneekloth and 0.59 for the data in Table 2.

Existing and Projected Ditch and Reservoir Company Irrigation Water

The NCWCD Water Quality Sampling Report (2003) on the presents the salinity of water delivered in the Larimer and Weld irrigation canal (LW) and to the New Cache la Poudre Irrigation Company (NC) from 1999 through 2002 during the irrigation season along with a number of other areas. For the purposes of this study, measurements from the sampling sites designated, as LW8, NC5, and NC7 will be used because they are in the proposed project area and four years of data were collected throughout the irrigation season at each site. The four years of sampling include data for two years of above average rainfall (1999 and 2001) and two drought years (2000 and 2002). Salinities of LW and NC irrigation waters will be considered separately because the values from the 2003 report are different for the two supplies and it is projected that the project will have different impacts on the water quality to these two suppliers.

Larimer and Weld Irrigation Canal (LW). The average electrical conductivity (EC) for the LW8 sampling site for the two high annual rainfall years (1999 and 2001) and the two dry years are both 0.52 dS/m. Thus, this value was used for predicting the current impact of water quality on crop yield. NCWCD personnel have estimated that the EC of the water at the LW8 location may increase because of withdrawals of water at upstream locations for exchange purposes. Thus, the EC value of 0.52 dS/m was increased by 15 %. This resulted in a projected EC of 0.60 dS/m. This value will be used when calculating crop yields after the project begins.

New Cache la Poudre Irrigation Company (NC). For NC, the average values for sampling sites NC5 and NC7 were utilized. For the above average rainfall years (1999 and 2001), the average EC was 0.83 dS/m and for the two dry years the average was 0.88 dS/m. Although the EC value is higher for the dry years, the difference is not considered to be significant. Thus, an average of 0.86 dS/m was taken as the current average condition. With the initiation of the project, NCWCD personnel have projected that the EC of water supplied to this company will increase 7 %. Thus, an EC value of 0.92 dS/m was assumed for after the project is started.

South Platte Water Conservation Project Water Supplies

Two sets of data were made available to estimate the salinity of the water pumped to Galeton Reservoir from the South Platte River to be used in the proposed project. The NCWCD provided data on the relationship between water salinity and flow rate at the Kersey gauging station on the South Platte River near where water will be diverted for the SPWCP. The maximum EC was about 1.3 dS/m when flow rate was at its lowest. The second set of data is from a USGS report (1995) where salinity was measured in five off-stream reservoirs along the South Platte River. Measurements from the Riverside Reservoir during the irrigation season of 1995 indicated an average of about 1.3 dS/m. The 1.3 dS/m value will be used here for the SPWCP. The actual value will depend on flow in the river, which is controlled by snowmelt, diversions, return flows, evaporation rates, and runoff from rainfall.

Well Water

Well water is another potential source of applied water and many farmers use wells to supplement their other sources of water. Data on the salt concentration of well water in the

Project area are lacking. District personnel have measured only a few irrigation wells in the Project area to date. The salinity of these measurements ranges from an EC of 1.2 to 2.7 dS/m. wells

In the Project area the use of well water is more predominant under the New Cache la Poudre system than for the Larimer and Weld system. The salinity of the well water used for this analysis was assumed to be 2.0 dS/m.

Projected Salinity of Applied Water

The average salinity of the applied water (irrigation and seasonal rainfall), Ca, can be calculated based upon the equation from Hoffman (1997) as:

$$Ca = [(Cr \times Dr) + (Cdi \times Ddi) + (Csp \times Dsp) + (Cw \times Dw)] / (Dr + Ddi + Dsp + Dw) \quad (2)$$

The variable C can be expressed as concentration (mg/L or ppm) or electrical conductivity (dS/m or mmhos/cm). D is depth of water (inches). The symbols a, r, di, sp, and w indicate weighted average, rainfall, ditch company irrigation water, SPWCP water, and well water, respectively.

In addition to the salinity of the various water sources, the amount of each source applied must be estimated. In Table 3 the amount of irrigation water required to satisfy the crop water requirements in the District is presented. The water requirement for each major crop was taken from Broner and Schneekloth (2003) for Greeley. The average effective seasonal rain was then subtracted to arrive at the net irrigation requirement. The gross irrigation requirements for center pivot irrigation systems and for gravity irrigation systems (furrow or flood) are presented in the last two columns of Table 3 assuming the irrigation efficiency is 85% for center pivots and 55% for gravity irrigation.

Table 3. Estimated water requirement and the net and gross irrigation requirements for crops near Greeley, Colorado, with center pivot and gravity irrigation systems.

Crop	Water Required* Inches	Average Effective Rainfall Inches	Net Irrigation Required Inches	Gross Irrigation Requirement Center Pivot Inches	Gross Irrigation Requirement Gravity Inches
Alfalfa	32	11	21	25	38
Barley	16**	6	10	12	18
Bean	18	4	14	16	25
Carrot	18	5	13	15	24
Corn, grain	22	7	15	18	27
Corn, silage	22***	6	16	19	29
Grass, hay/pasture	27	11	16	19	29
Onion	18	7	11	13	20
Sorghum	20	5	15	18	27
Sugar Beet	29	8	21	25	38
Wheat	16	9	7	8	13

* Data taken from Broner and Schneekloth (2003).
** Value assumed equal to wheat.
*** Value assumed equal to corn for grain.

To calculate Ca from equation (2), the depth of water to be applied from ditch water and SPWCP water must be known. Until better values are available, the gross irrigation will be assumed to be provided equally from these two sources. If quantities and qualities are known from well water the proportions of water from each of the three sources could be entered into equation (2) for the determination of Ca. For example, Ca for alfalfa can be calculated for the Larimer and Weld irrigation canal once the project is initiated assuming no well water is applied from equation (2) for center pivots as follows:

Ca = [(0 X 11) + (0.60 X 12.5) + (1.3 X 12.5)] / (11 + 12.5 + 12.5)
Ca = (7.5 +16.2) / 36
Ca = 0.66 dS/m

For gravity irrigation systems:

Ca = [(0 X 11) + (0.60 X 19) + (1.3 X 19) / (11 + 19 + 19)
Ca = (11.4 + 24.7) / 49
Ca = 0.74 dS/m

The average values for the salt concentration of the applied water (Ca) for each ditch system are summarized in Tables 4 through 9 using average rainfall conditions and by type of delivery application (gravity or sprinkler). For the Larimer and Weld system it was assumed that no well water was applied to crops in the Project area. For the New Cache system two scenarios were analyzed: 1) no well water applied and 2) combined surface and well water supplies. Under the combined water supply scenario it is assumed that well water makes up 30% of the total water supply.

Results of the calculations are shown with varying concentrations of SPWCP in the total water supply deliverable to the ditch systems. For this report, the ratio of SPWCP water to existing surface water analyzed are assumed to be 25%, 50% and 75%. These ratios represent varying levels of SPWCP development. The Project will most likely be developed in phases, as water is needed for upstream exchange purposes. The 50% ratio approximately represents a full-scale project as described in the Project Completion Study Report and operated under firm yield conditions (NCWCD, 2002). The 75% ratio represents a full-scale project operated under maximum potential yield conditions.

Table 4. Larimer and Weld System – Surface Supplies Only – Gravity Systems
Salinity of the applied water [Ca, (dS/m)] after the SPWCP project is started.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	0.40	0.60	0.74	0.87
Barley	0.39	0.58	0.71	0.85
Bean	0.45	0.67	0.82	0.97
Carrot	0.43	0.64	0.78	0.93
Corn, grain	0.41	0.62	0.76	0.90
Corn, silage	0.43	0.64	0.79	0.93
Grass, hay/pasture	0.38	0.56	0.69	0.82
Onion	0.39	0.57	0.70	0.83
Sorghum	0.44	0.65	0.80	0.95
Sugar Beet	0.43	0.64	0.79	0.93
Wheat	0.30	0.45	0.56	0.66

Table 5. Larimer and Weld System – Surface Supplies Only – Sprinkler Systems
Salinity of the applied water [Ca, (dS/m)] after the SPWCP project is started.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	0.36	0.54	0.66	0.78
Barley	0.34	0.51	0.63	0.75
Bean	0.42	0.62	0.76	0.91
Carrot	0.39	0.58	0.72	0.85
Corn, grain	0.37	0.55	0.68	0.81
Corn, silage	0.39	0.59	0.72	0.85
Grass, hay/pasture	0.33	0.49	0.60	0.71
Onion	0.34	0.50	0.62	0.73
Sorghum	0.41	0.60	0.74	0.88
Sugar Beet	0.39	0.59	0.72	0.85
Wheat	0.25	0.37	0.45	0.54

Table 6. New Cache System – Surface Supplies Only – Gravity Systems
Salinity of the applied water [Ca, (dS/m)] after the SPWCP project is started.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	0.67	0.79	0.86	0.94
Barley	0.65	0.76	0.83	0.91
Bean	0.74	0.88	0.96	1.04
Carrot	0.71	0.84	0.92	0.99
Corn, grain	0.68	0.81	0.88	0.96
Corn, silage	0.71	0.84	0.92	1.00
Grass, hay/pasture	0.62	0.74	0.81	0.87
Onion	0.64	0.75	0.82	0.89
Sorghum	0.73	0.86	0.94	1.02
Sugar Beet	0.71	0.84	0.92	1.00
Wheat	0.50	0.59	0.65	0.71

Table 7. New Cache System – Surface Supplies Only – Sprinkler Systems
Salinity of the applied water [Ca, (dS/m)] after the SPWCP project is started.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	0.60	0.70	0.77	0.83
Barley	0.57	0.67	0.74	0.80
Bean	0.69	0.82	0.89	0.97
Carrot	0.65	0.76	0.84	0.91
Corn, grain	0.62	0.73	0.79	0.86
Corn, silage	0.65	0.77	0.84	0.91
Grass, hay/pasture	0.54	0.64	0.70	0.76
Onion	0.56	0.66	0.72	0.78
Sorghum	0.67	0.79	0.86	0.94
Sugar Beet	0.65	0.77	0.84	0.91
Wheat	0.41	0.48	0.53	0.58

Table 8. New Cache System – Surface and Well Water Supplies – Gravity Systems Salinity of the applied water [Ca, (dS/m)] after the SPWCP project is started.

Crop	Existing Conditions 70% Ditch 30% Wells	53% Ditch 17% SPWCP 30% Wells	35% Ditch 35% SPWCP 30% Wells	17% Ditch 53% SPWCP 30% Wells
Alfalfa	0.93	1.02	1.07	1.12
Barley	0.90	0.98	1.04	1.09
Bean	1.04	1.13	1.19	1.25
Carrot	0.99	1.08	1.14	1.19
Corn, grain	0.96	1.04	1.10	1.15
Corn, silage	1.00	1.08	1.14	1.20
Grass, hay/pasture	0.87	0.95	1.00	1.05
Onion	0.89	0.97	1.02	1.07
Sorghum	1.02	1.11	1.16	1.22
Sugar Beet	0.99	1.08	1.14	1.20
Wheat	0.70	0.77	0.81	0.85

Table 9. New Cache System – Surface Supplies and Well Water Supplies – Sprinkler Systems Salinity of the applied water [Ca, (dS/m)] after the SPWCP project is started.

Crop	Existing Conditions 70% Ditch 30% Wells	53% Ditch 17% SPWCP 30% Wells	34% Ditch 34% SPWCP 30% Wells	17% Ditch 53% SPWCP 30% Wells
Alfalfa	0.83	0.91	0.95	1.00
Barley	0.80	0.87	0.91	0.96
Bean	0.97	1.05	1.11	1.16
Carrot	0.91	0.99	1.04	1.09
Corn, grain	0.86	0.94	0.99	1.03
Corn, silage	0.91	0.99	1.04	1.10
Grass, hay/pasture	0.76	0.83	0.87	0.91
Onion	0.78	0.85	0.89	0.94
Sorghum	0.94	1.02	1.07	1.13
Sugar Beet	0.91	0.99	1.04	1.09
Wheat	0.57	0.63	0.66	0.69

PREDICTED CROP YIELD

After multiplying Ca times 1.5 to convert from the average salinity of the applied water to the average value of soil salinity in the crop root zone (ECe), equation (1) can be used to predict the yield of the major crops in the proposed project area. Relative crop yields can be estimated based on the salt tolerance of each crop from Table 1 and the salinity values for the two ditch company irrigation waters with the two major irrigation systems envisioned in the project area from Tables 4 through 9. Relative crop yields under average rainfall conditions are presented in Tables 10 through 15. A value of 100% indicates that no yield loss is expected under these conditions.

Table 10. Larimer and Weld System – Surface Supplies Only – Gravity Systems
Relative crop yields based upon projected water qualities from ditch company waters and SPWCP waters being applied and average rainfall conditions.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	100%	100%	100%	100%
Barley	100%	100%	100%	100%
Bean	100%	100%	96%	91%
Carrot	100%	100%	98%	95%
Corn, grain	100%	100%	100%	100%
Corn, silage	100%	100%	100%	100%
Grass, hay/pasture	100%	100%	100%	100%
Onion	100%	100%	100%	99%
Sorghum	100%	100%	100%	100%
Sugar Beet	100%	100%	100%	100%
Wheat	100%	100%	100%	100%

Table 11. Larimer and Weld System – Surface Supplies Only – Sprinkler Systems
Relative crop yields based upon projected water qualities from ditch company waters and SPWCP waters being applied and average rainfall conditions.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	100%	100%	100%	100%
Barley	100%	100%	100%	100%
Bean	100%	100%	97%	93%
Carrot	100%	100%	99%	96%
Corn, grain	100%	100%	100%	100%
Corn, silage	100%	100%	100%	100%
Grass, hay/pasture	100%	100%	100%	100%
Onion	100%	100%	100%	100%
Sorghum	100%	100%	100%	100%
Sugar Beet	100%	100%	100%	100%
Wheat	100%	100%	100%	100%

Table 12. New Cache System – Surface Supplies Only – Gravity Systems
Relative crop yields based upon projected water qualities from ditch company waters and SPWCP waters being applied and average rainfall conditions.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	100%	100%	100%	100%
Barley	100%	100%	100%	100%
Bean	98%	94%	92%	89%
Carrot	99%	96%	95%	93%
Corn, grain	100%	100%	100%	100%
Corn, silage	100%	100%	100%	100%
Grass, hay/pasture	100%	100%	100%	100%
Onion	100%	100%	99%	98%
Sorghum	100%	100%	100%	100%
Sugar Beet	100%	100%	100%	100%
Wheat	100%	100%	100%	100%

Table 13. New Cache System – Surface Supplies Only – Sprinkler Systems
Relative crop yields based upon projected water qualities from ditch company waters and SPWCP waters being applied and average rainfall conditions.

Crop	Existing Conditions	75% Ditch 25% SPWCP	50% Ditch 50% SPWCP	25% Ditch 75% SPWCP
Alfalfa	100%	100%	100%	100%
Barley	100%	100%	100%	100%
Bean	99%	96%	94%	91%
Carrot	100%	98%	96%	95%
Corn, grain	100%	100%	100%	100%
Corn, silage	100%	100%	100%	100%
Grass, hay/pasture	100%	100%	100%	100%
Onion	100%	100%	100%	100%
Sorghum	100%	100%	100%	100%
Sugar Beet	100%	100%	100%	100%
Wheat	100%	100%	100%	100%

Table 14. New Cache System – Surface and Well Water Supplies – Gravity Systems
Relative crop yields based upon projected water qualities from ditch company waters, well waters, and SPWCP waters being applied and average rainfall conditions.

Crop	Existing Conditions 70% Ditch 30% Wells	53% Ditch 17% SPWCP 30% Wells	35% Ditch 35% SPWCP 30% Wells	17% Ditch 53% SPWCP 30% Wells
Alfalfa	100%	100%	100%	100%
Barley	100%	100%	100%	100%
Bean	89%	87%	85%	83%
Carrot	93%	91%	90%	89%
Corn, grain	100%	100%	100%	100%
Corn, silage	100%	100%	100%	100%
Grass, hay/pasture	100%	100%	100%	100%
Onion	98%	96%	95%	94%
Sorghum	100%	100%	100%	100%
Sugar Beet	100%	100%	100%	100%
Wheat	100%	100%	100%	100%

Table 15. New Cache System – Surface Supplies and Well Water Supplies – Sprinkler
Relative crop yields based upon projected water qualities from ditch company waters, well waters, and SPWCP waters being applied and average rainfall conditions.

Crop	Existing Conditions 70% Ditch 30% Wells	53% Ditch 17% SPWCP 30% Wells	34% Ditch 34% SPWCP 30% Wells	17% Ditch 53% SPWCP 30% Wells
Alfalfa	100%	100%	100%	100%
Barley	100%	100%	100%	100%
Bean	91%	89%	87%	86%
Carrot	95%	93%	92%	91%
Corn, grain	100%	100%	100%	100%
Corn, silage	100%	100%	100%	100%
Grass, hay/pasture	100%	100%	100%	100%
Onion	100%	99%	98%	97%
Sorghum	100%	100%	100%	100%
Sugar Beet	100%	100%	100%	100%
Wheat	100%	100%	100%	100%

From the results in Tables 10 through 15, slight yield losses can be expected for salt sensitive crops like bean, carrot, and onion under the conditions considered in the preceding sections. The yield loss for salt sensitive crops is directly proportional to the concentration of SPWCP water introduced to the Project area. All of the other crops studied should give full potential yields. It should be noted that a slight yield loss for salt sensitive crops probably already exists under present operations for the New Cache system.

As shown in Tables 10 and 11 the relative yield loss for salt sensitive crops such as beans grown under Project delivery area of the Larimer and Weld system would range from 7 to 9% if the Project was providing 75% of the irrigation water.

For the New Cache system greater yield loss may be expected depending on the management of existing water supplies (Tables 12 through 15). Some farms have well water available at varying EC concentrations. For the scenarios with the SPWCP providing 75% of the water supply and where well water is also applied, the yield loss for beans ranges about 6% less than existing conditions. For the scenarios where only existing surface supplies with SPWCP water is used shows a yield loss for beans ranging from 3 to 9% more than existing conditions.

Based on the rainfall data presented in Table 2, however, about 20% of the time a drought can be expected. In drought years, on average, only about 60% of the average rainfall can be expected. When making calculations like those for the expected yields reported in Tables 10 through 15greater yield losses may be experienced during a drought. Table 16 shows the predicted relative yields during a drought for those crops likely to be impacted. In Table 16 the total water requirement not provided by rain is assumed to be available in equal amounts from ditch company water and SPWCP water. In some drought situations water from other sources may not be available to satisfy crop water conditions. Under these conditions, even larger yield reductions can be expected.

Table 16. Relative yields of crops relatively sensitive to salinity under drought conditions (60% of average effective rainfall) in the project area. These calculations assume any lack of rainfall is supplied from other sources.

	Relative Yield, %			
	Sprinkler systems		Gravity systems	
Crop	Larimer & Weld	New Cache	Larimer & Weld	New Cache
Bean	95	91	94	90
Carrot	97	95	96	93
Corn, grain	100	100	100	100
Onion	100	99	100	97

Comparing results in Tables 10 through 13 for the 50% ditch supply and 50% SPWCP supply with Table 16 shows that yields for sensitive crops are reduced only slightly more than in typical drought years than in years of average rainfall (1 to 3 % more). However, these calculations are based on the salt content of the water sources not increasing and sufficient quantities of irrigation water being available.

CONCLUSIONS AND RECOMMENDATIONS

From the data presented and the assumptions and calculations made in this report, the following conclusions can be made:

- Crops that are moderately sensitive, moderately tolerant, or tolerant of salinity will not suffer yield losses from the water qualities considered.

- Under maximum operation of the Project crops that are salt sensitive may suffer losses in yield (up to 9%) under the average conditions considered in this report. In typical drought years, yield losses for salt sensitive crops may be as high as 11 %.

- If the appropriate amount of water is applied to compensate for differences in irrigation efficiency, the response of crops to the salinity of the applied water is not significantly impacted by the irrigation method.

- Effective rainfall is a significant source of water for crops in the project area and should be considered in irrigation requirement and water quality considerations.

With these findings, the following are recommendations to minimize or prevent yield losses of salt sensitive crops:

- The proportion of irrigation water from the ditch company's supply should be increased and the water from the SPWCP reduced when growing salt sensitive crops where ever possible.

- Crops are more sensitive to salinity in their early growth stages. Thus, ditch company water should be applied early in the irrigation season in preference to SPWCP water where feasible.

- If high quality well water is available it should be used in place of SPWCP water for salt sensitive crops.

- If the proportion or timeliness of applying ditch company water are not options then additional water should be applied to increase leaching, thereby reducing soil salinity.

The following are general recommendations to assist where salinity is a concern:

- Monitor selected fields at least annually to ensure soil salinity is not becoming excessive.

- Continue to measure the salt content of water sources to be sure the qualities used in this report are reasonable.

- Measure the salt content of well waters to assess their suitability as irrigation water sources.

- If needed to reduce soil salinity, apply excess irrigation water in the off-season to leach the crop root zone.

- Management practices can be implemented to alleviate the potential for crop yield losses due to salinity increases.

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