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Technical Memorandum – Final

To:	**Blaine Dwyer (AECOM) and Matt Brown (LRE)**
Distribution:	**CWCB Staff**
From:	**Erin Wilson and Mark Mitisek (LRE)**
Subject:	**CRWAS Phase I – Consumptive Use Analysis – Growing Season Adjustment**
Date:	**January 31, 2012**

Introduction

The crop consumptive use analysis to support the Colorado River Water Availability Study (CRWAS) uses the modified Blaney-Criddle method, crop coefficients, and growing season "triggers" as defined in SCS Technical Release 21 (TR-21) for crops grown below 6500 feet in elevation. In addition, an elevation adjustment is applied to the crop coefficients to represent the use of these coefficients at higher elevations than the elevations at which they were developed. Above 6500 feet, the original Blaney-Criddle method is used with grass pasture crop coefficients calibrated to lysimeter data measured in several of Colorado's higher elevation area.

TR-21 has "triggers" that define the start and end growing season for most crops, including grass pasture, based on mean monthly temperature. However, the alfalfa, corn, dry beans, and spring grains growing season trigger for the start of growing season is mean monthly temperature, and growing season ends when the minimum temperature reaches either 28 or 32 degrees Fahrenheit – termed the killing frost.

As part of the CRWAS, crop irrigation requirements are estimated based on temperature and precipitation estimated from global climate models. The down-scaling of these models result in alternate average monthly temperature estimates that can be used directly in the Blaney-Criddle equation to estimate alternate crop irrigation requirements. The down-scale process to minimum daily temperature, and therefore killing frost dates, is much more involved and not necessary for the CRWAS study considering the following analysis and recommendations. Therefore, an analysis was performed to determine an appropriate mean monthly temperature for alfalfa that can be used to represent, on average, the killing frost date.

Approach

In an effort to more accurately model crop irrigation requirements as the result of climate change, the irrigation season needs to be limited based on mean temperature instead of frost dates. The following approach was used to accurately reflect the growing season:

1. Tabulate all crop types modeled in the western slope StateCU models, and determine which crops are limited by fall frost dates.

2. Use the 1993 irrigated land coverage to assess the spatial distributions of crops that are limited by fall frost dates. Select climate stations that are representative of each crop limited by fall frost dates in each division.

3. Using a representative period of record (1995-2005), run the StateCU climate scenario for crops limited by fall frost dates and record average end of growing season and average annual crop irrigation requirement for each climate station and crop combination. Note that at this juncture, it was shown that corn, dry beans, and spring grain have growing seasons that end based on maximum number of days of growth, and that frost date is not reached. Therefore, these crops were not analyzed further.

4. Adjust the mean monthly ending temperature in the crop characteristic file (*.cch) for alfalfa to limit the ending of the growing season until the average end of growing seasons for the 1995 to 2005 period matched the end of growing seasons limited by fall frost date. The goal is to find a mean temperature that best represents the 28 degree Fahrenheit killing frost data for the entire basin. This allows the growing season to vary each year based on mean monthly temperature, removing the need for minimum daily temperature to define frost dates.

5. Further verify the validity of the use of mean monthly temperature by comparing average monthly crop irrigation water requirement resulting from the two end-of-season triggers, and comparing crop irrigation water requirements for high and low consumptive use years.

Results

As discussed above, end of growing season for corn; dry beans; and spring grains was driven by number of days of growing season; these crops are generally harvested in the Colorado River basin prior to the killing frost date. The following climate stations are near areas with significant irrigated alfalfa, therefore were selected for use in the analysis:

- Montrose No 2
- Glenwood Springs No 2
- Meeker 3W
- Yellow Jacket 2W

Several iterations were performed varying the mean monthly ending temperature for alfalfa, beginning with the 50 degrees Fahrenheit recommended by TR-21 to trigger the beginning of growing season. Using 53 degrees Fahrenheit resulted in an average date for the end of growing season that matched the TR-21 recommended 28 degree Fahrenheit killing frost for the four stations combined. This allows alfalfa growing season and associated consumptive use to be determined even if daily minimum temperatures are not available.

Figures 1 through 4 on the following pages show the average monthly crop irrigation requirement of alfalfa for the period 1998 through 2005 for each climate stations using the mean ending temperature of 53 degrees compared to crop irrigated using the killing frost date. Average annual consumptive use using the mean ending temperature of 53 degrees results in the same consumptive use estimated using the killing frost date for the four stations combined. Glenwood and Yellow Jacket consumptive use was essentially the same; whereas Meeker is

slightly over-estimated and Montrose is slightly under-estimated. Consumptive use estimated using 53 degrees for the mean ending temperature results in growing season lengths that correlate well for both high and low consumptive use years.

Figures 5 through 8 show the monthly crop irrigation requirement of alfalfa for each climate stations using the mean ending temperature of 53 degrees compared to crop irrigated using the killing frost date for a representative high consumptive use year (2002). Annual consumptive use for 2002 using the mean ending temperature of 53 degrees resulted in consumptive use slightly lower (1 percent) for each of the four stations.

Figures 9 through 12 show the monthly crop irrigation requirement of alfalfa for each climate stations using the mean ending temperature of 53 degrees compared to crop irrigated using the killing frost date for a representative low consumptive use year (1995). Annual consumptive use for 1995 using the mean ending temperature of 53 degrees results consumptive use within 2 percent of consumptive use estimated using the killing frost date for the four stations combined. Each of the four stations resulted in slightly higher consumptive use.

Recommendation

A mean monthly temperature of 53 degrees Fahrenheit is recommended to determine the end of growing season when estimating alfalfa irrigation requirement for alternate climate scenarios associated with the CRWAS throughout the Colorado River basin in Colorado. Using this mean monthly temperature-based end of growing season trigger provides results that provide a good correlation with results using killing frost trigger and provides a method for representing extended length of growing season under alternate climate scenarios. This approach was adopted to meet the data challenges associated with the CRWAS. The use of frost dates to determine the end of growing season for alfalfa should continue to be used for other CDSS efforts that rely on historical climate data.

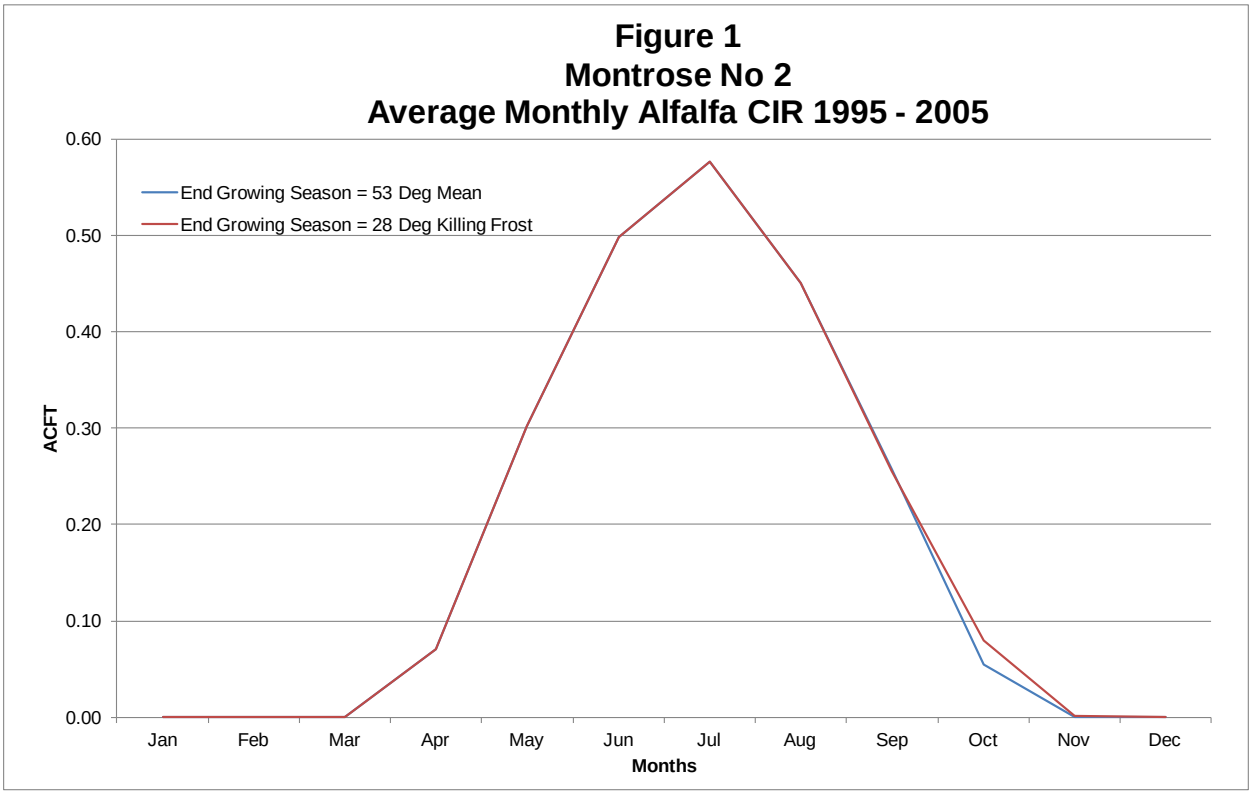
Figure 1
Montrose No 2
Average Monthly Alfalfa CIR 1995 - 2005
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ACFT
End Growing Season = 53 Deg Mean
End Growing Season = 28 Deg Killing Frost
Jan
Feb
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Sep
Oct
Nov
Dec
Months

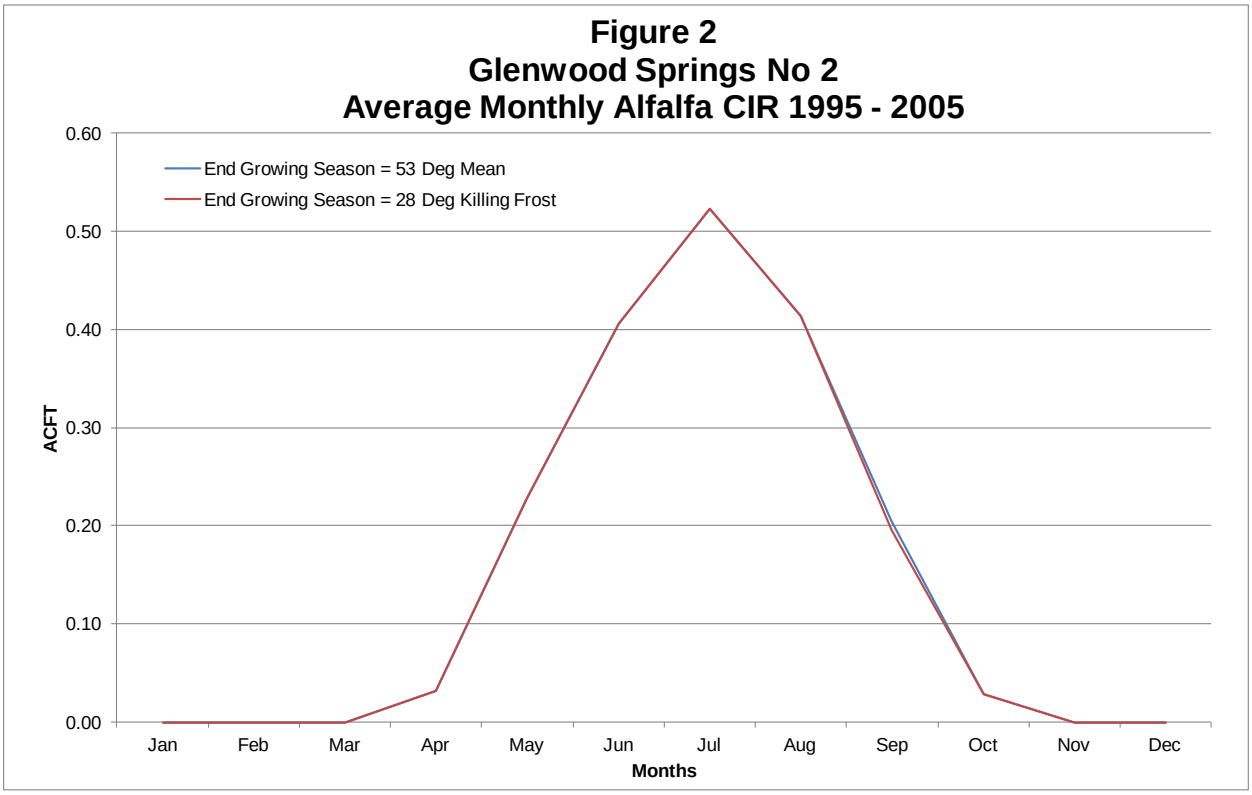
Figure 2
Glenwood Springs No 2
Average Monthly Alfalfa CIR 1995 - 2005
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ACFT
End Growing Season = 53 Deg Mean
End Growing Season = 28 Deg Killing Frost
Jan
Feb
Mar
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Oct
Nov
Dec
Months

Figure 3
Meeker 3W
Average Monthly Alfalfa CIR 1995 - 2005

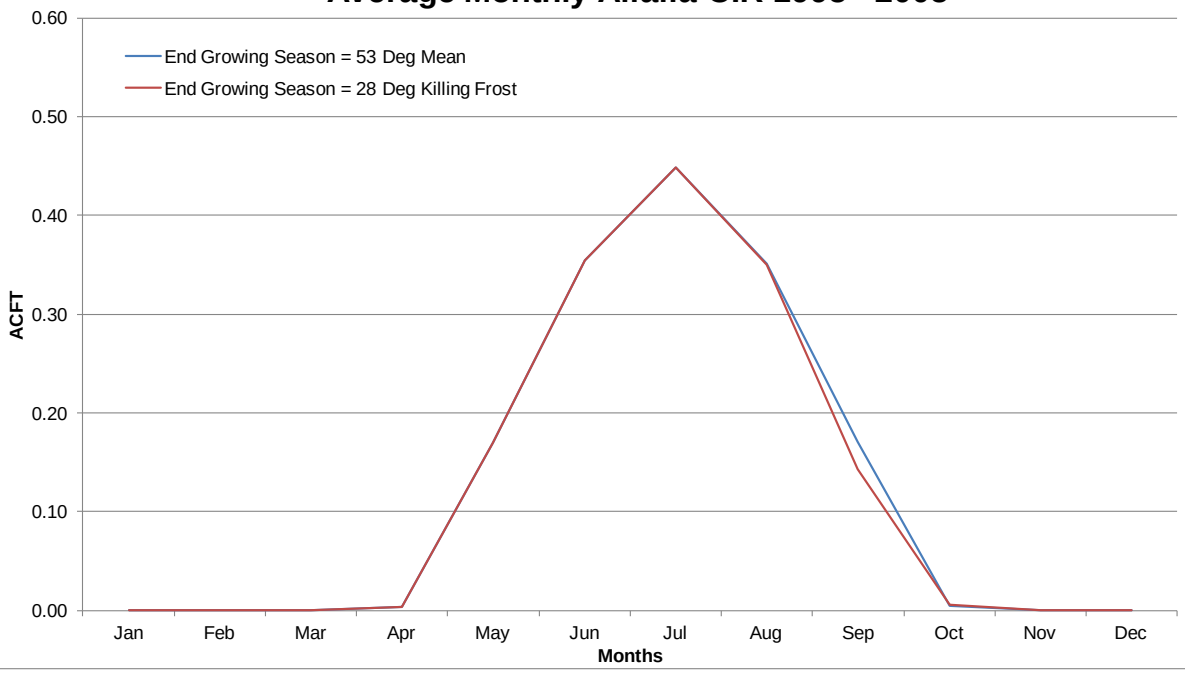


Figure 4
Yellow Jacket 2W
Average Monthly Alfalfa CIR 1995 - 2005

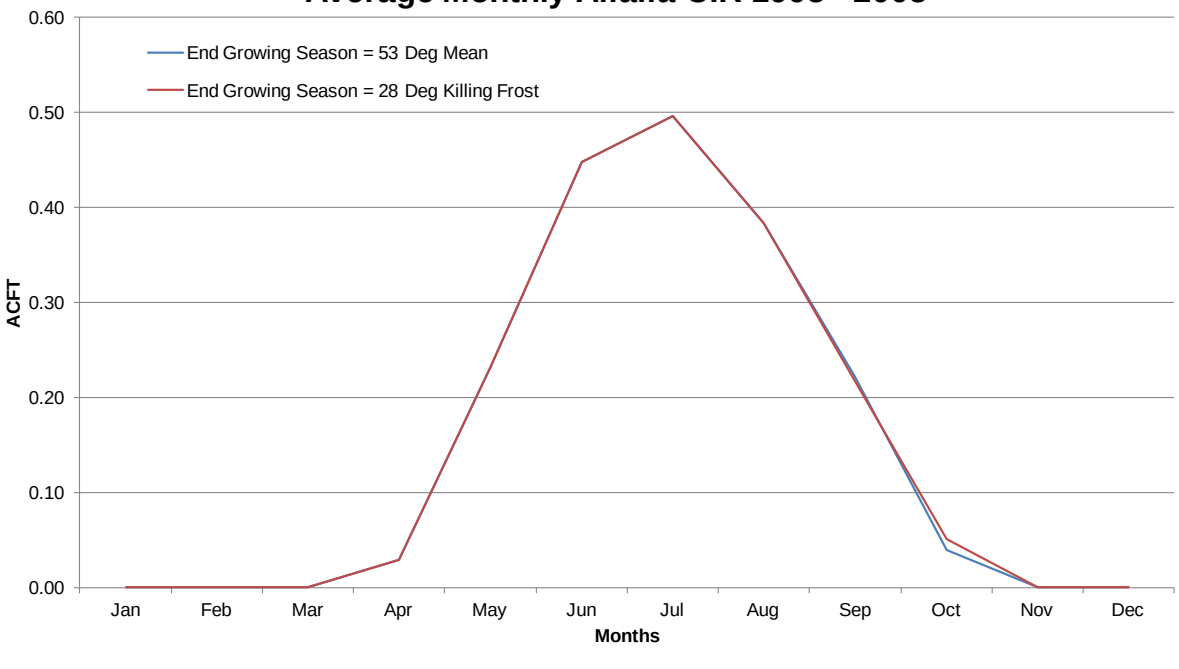


Figure 5
Montrose No 2
High CU Year (2002) Monthly Alfalfa CIR

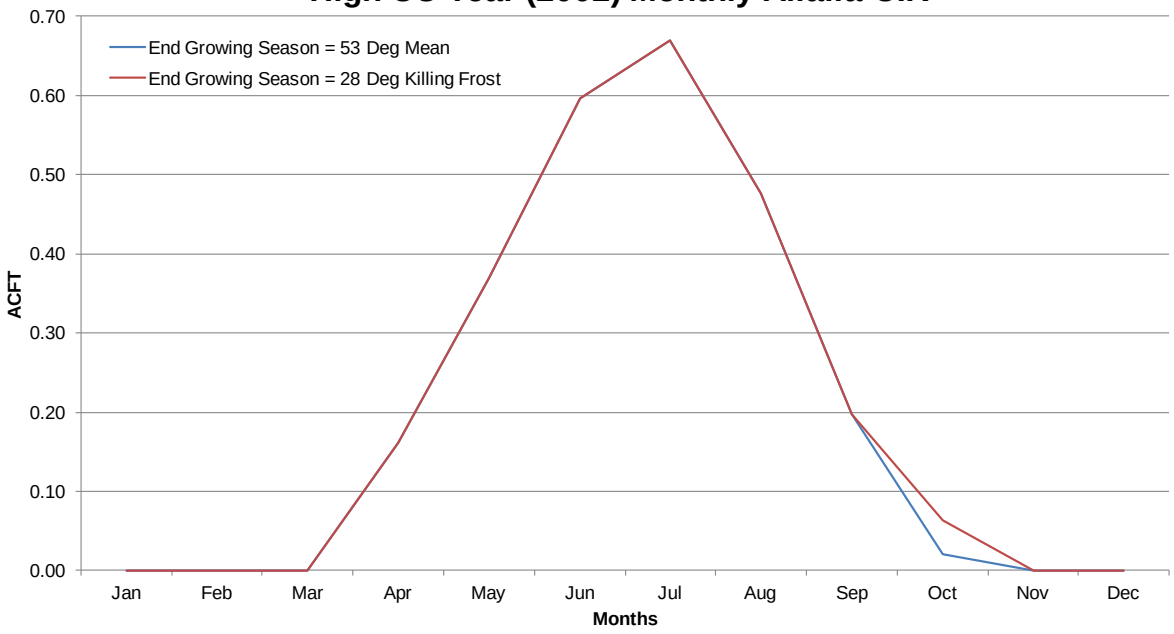
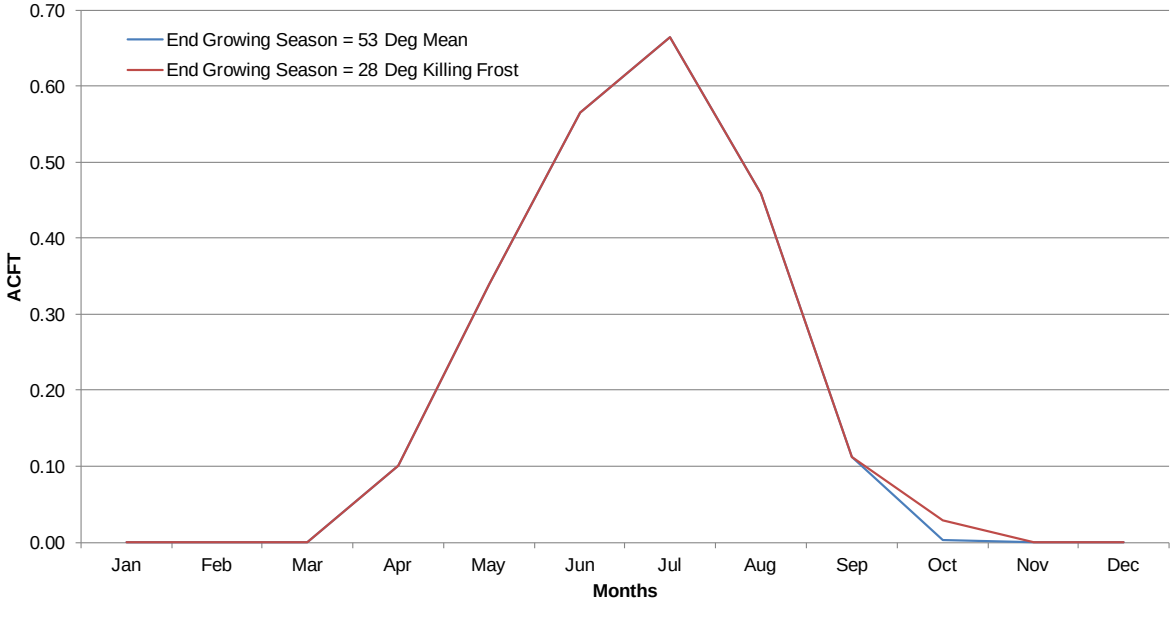


Figure 6
Glenwood Springs No 2
High CU Year (2002) Monthly Alfalfa CIR



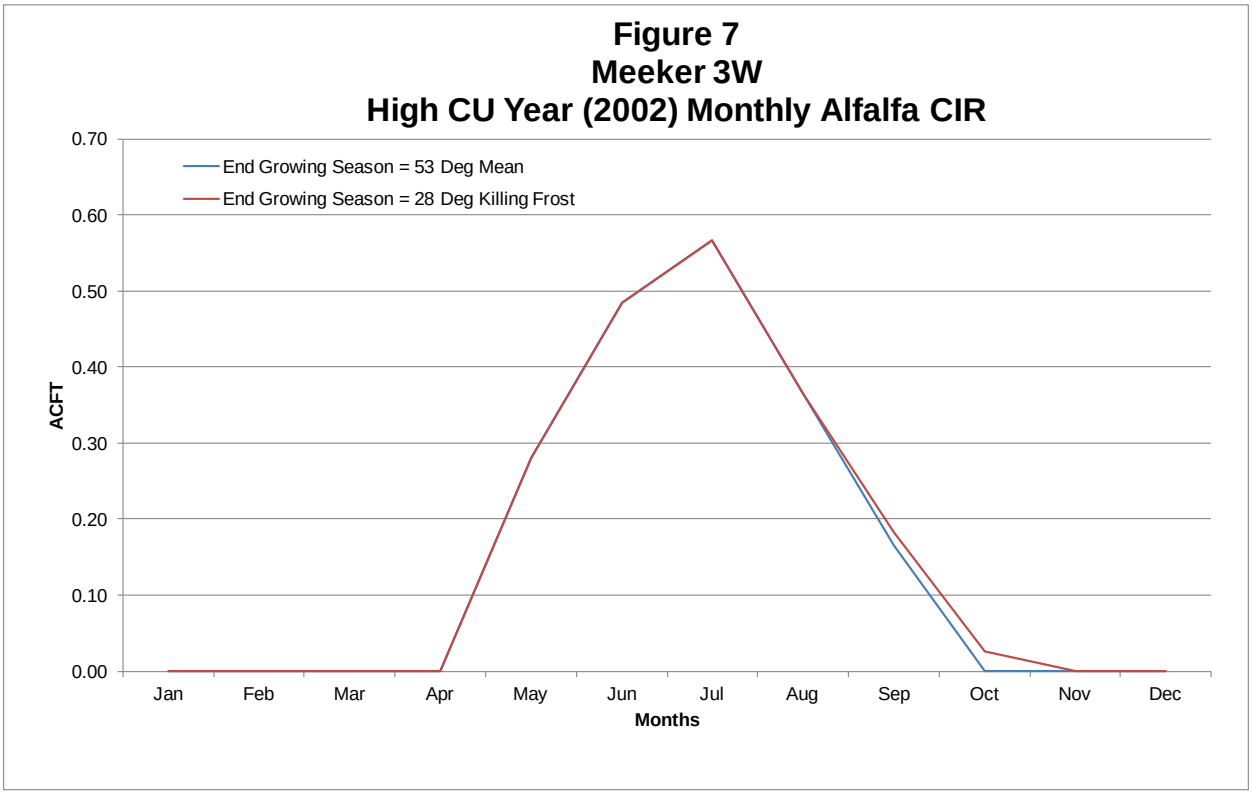


Figure 7
Meeker 3W
High CU Year (2002) Monthly Alfalfa CIR
End Growing Season = 53 Deg Mean
End Growing Season = 28 Deg Killing Frost
ACFT
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jan
Feb
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Nov
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Months

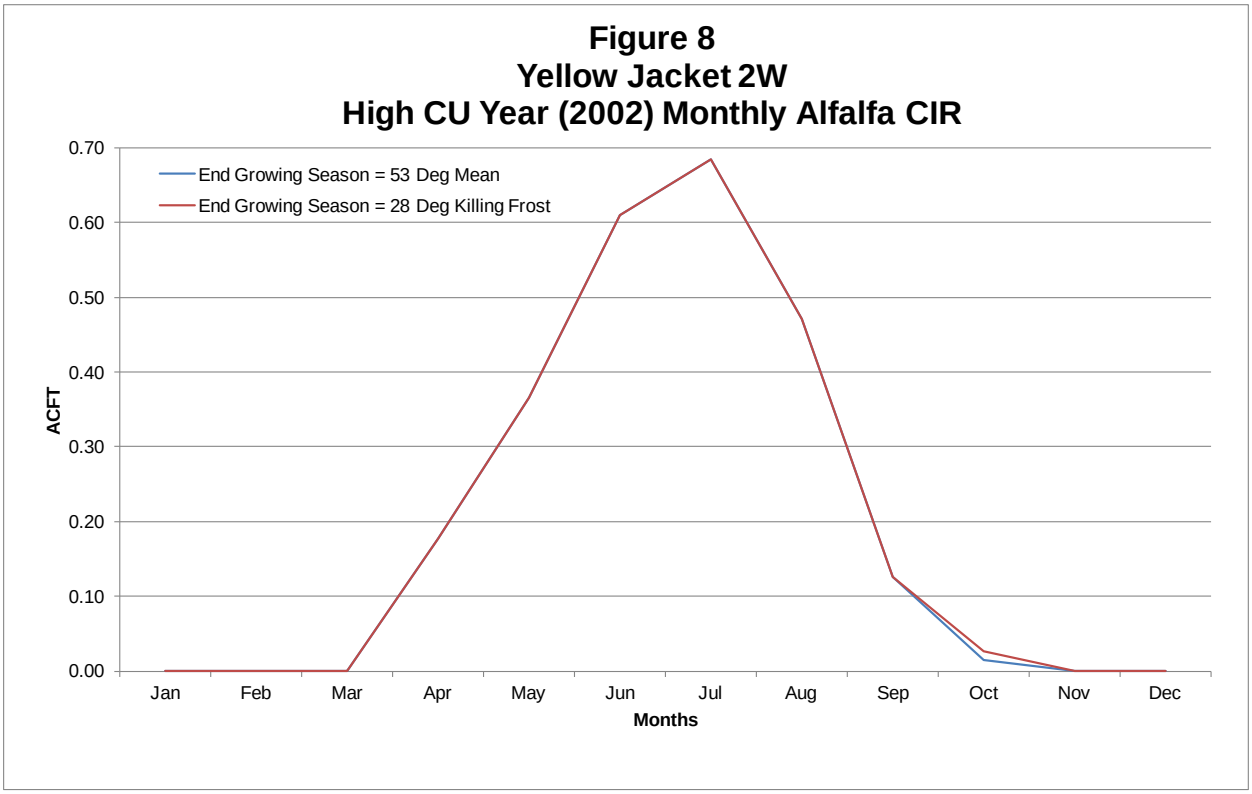
Figure 8
Yellow Jacket 2W
High CU Year (2002) Monthly Alfalfa CIR
End Growing Season = 53 Deg Mean
End Growing Season = 28 Deg Killing Frost
ACFT
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jan
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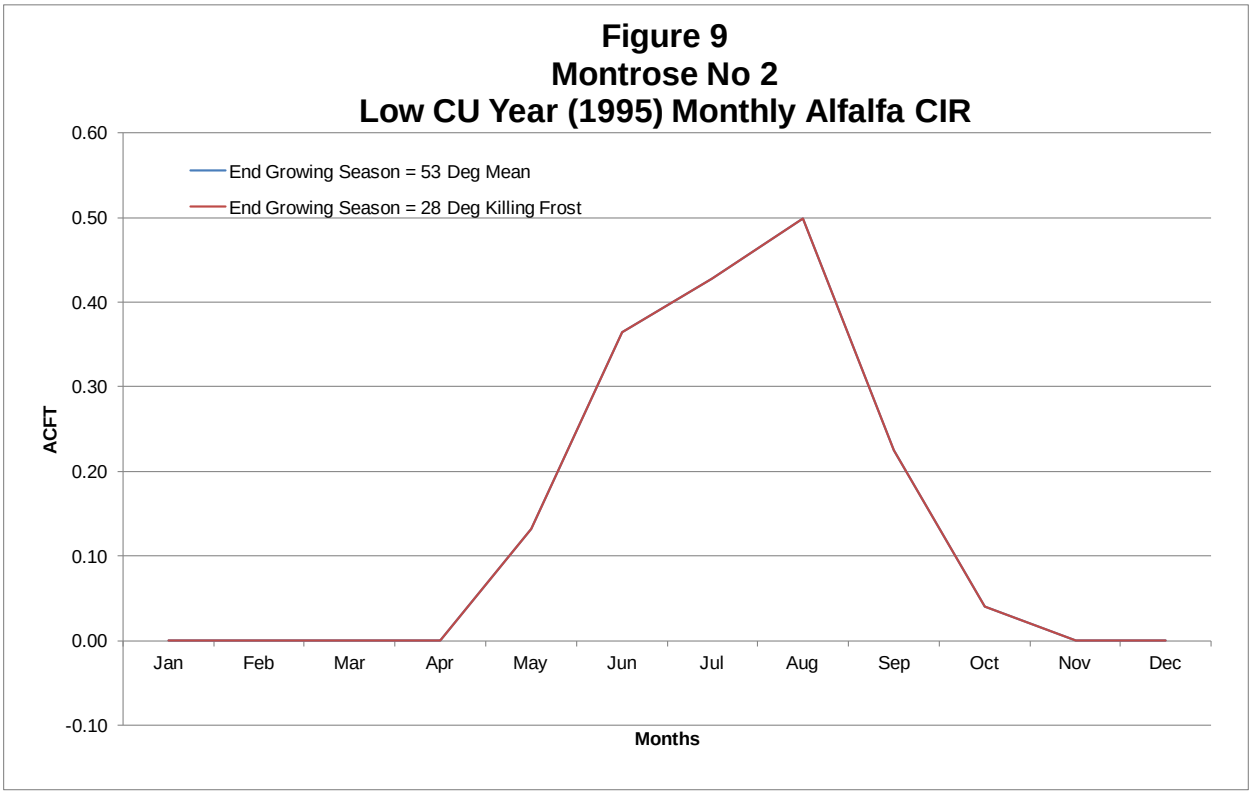
Figure 9
Montrose No 2
Low CU Year (1995) Monthly Alfalfa CIR
End Growing Season = 53 Deg Mean
End Growing Season = 28 Deg Killing Frost
ACFT
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
Jan
Feb
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Nov
Dec
Months

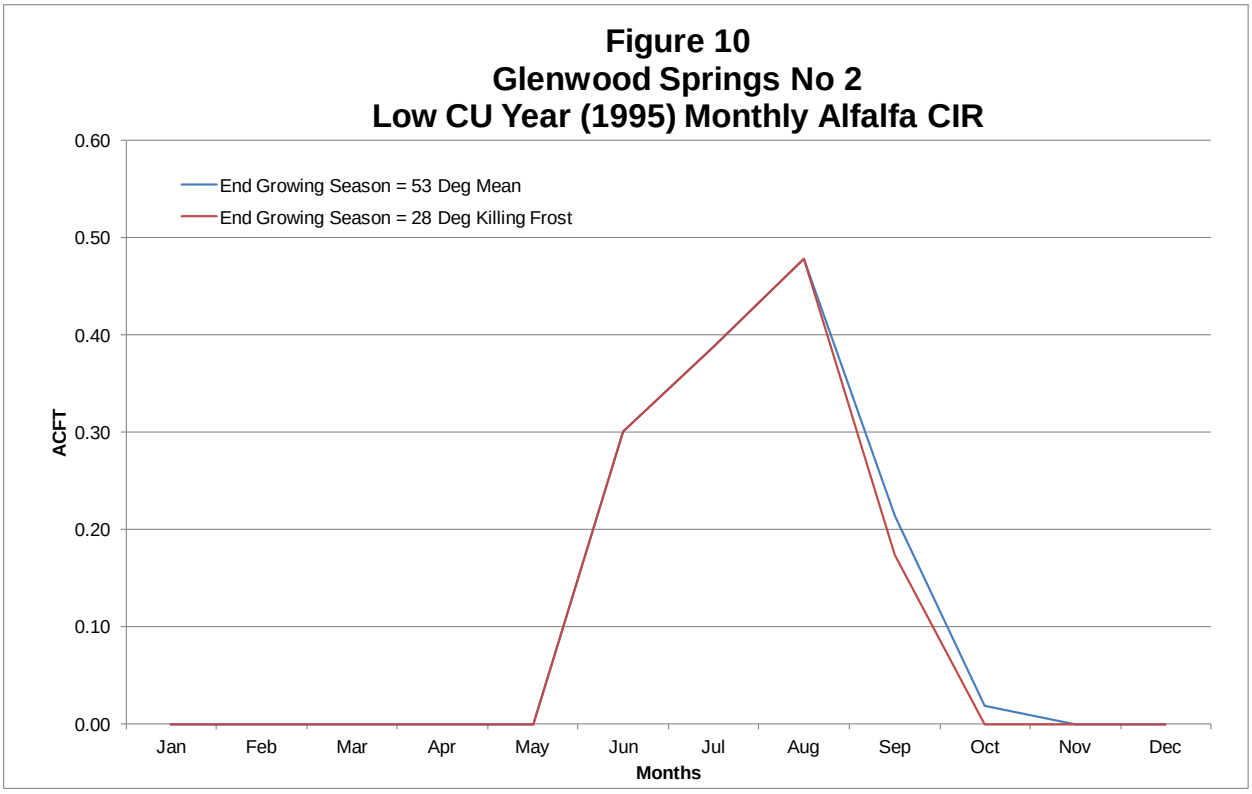
Figure 10
Glenwood Springs No 2
Low CU Year (1995) Monthly Alfalfa CIR
End Growing Season = 53 Deg Mean
End Growing Season = 28 Deg Killing Frost
ACFT
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jan
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Months

Figure 11
Meeker 3W
Low CU Year (1995) Monthly Alfalfa CIR

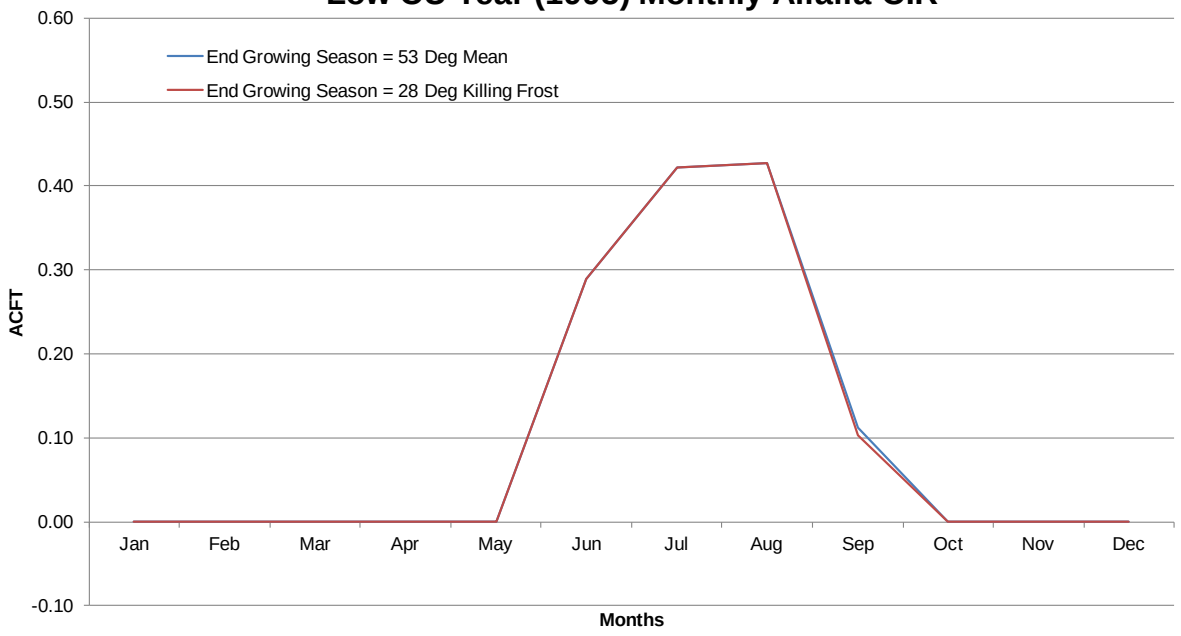

Figure 12
Yellow Jacket 2W
Low CU Year (1995) Monthly Alfalfa CIR