AGRO ENGINEERING

"COMPREHENSIVE AGRICULTURAL AND WATER RESOURCE CONSULTING"

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TO: RGDSS Ground water Modeling Team
FROM: Kirk Thompson
SUBJECT: StateCU Crop Irrigation Requirements
DATE: 3/10/2011

At our January 21, 2011 workgroup teleconference/meeting, a lot of discussion centered around the accuracy of the 2009 crop irrigation requirements (CIR) that James illustrated for the different NOAA meteorological stations that are calculated by StateCU, and subsequently used to determine ditch system wide potential CU demand. Jim Slattery asked if we could provide some insight by comparing against Agro Engineering's meteorological stations and the 2009 ET/CIR calculations that we relied on for irrigation scheduling. The purpose of this memo is two-fold, 1) to use the AGRO stations to see if StateCU's estimation of ET for 2009 is still well-calibrated to the Modified Hargreaves method of estimating ET, and 2) to use the AGRO stations to evaluate the reasonableness of the NOAA stations for estimating CIR.

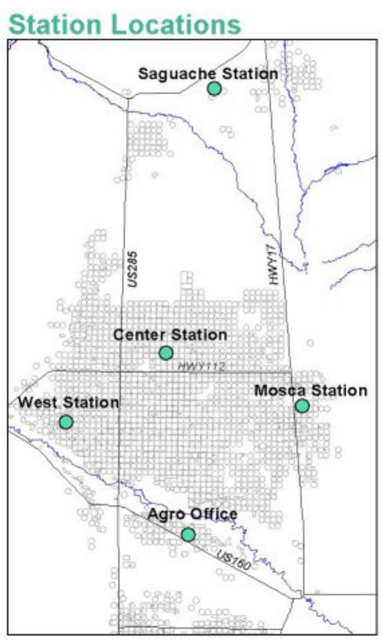

Figure 1. Agro Engineering Meteorological Station Locations

Agro Engineering maintains five meteorological stations throughout the SLV used to calculate cultivar ET on individual fields. We use this information for irrigation scheduling. Shown in Figure 1, our five stations are located: 1) at the Agro Engineering office (about half-way between Alamosa and Monte Vista), 2) near Center, 3) near Mosca, 4) near Saguache, and 5) near Del Norte. We use the modified Hargreaves radiation method (as described in the RGDSS Historic Crop Consumptive Use Analysis documentation) to calculate potential evapotranspiration (ET). Table 1 shows the 2009 ET/CIR values for the Agro Stations as calculated using the modified Hargreaves method. The daily weather data and ET calculations are included in the accompanying AgroStations2009.xls spreadsheet. In terms of spatial variation, the stations show a 3.5 inch difference in CIR for alfalfa from west to east. This variation is considerably less than the 9.4 inch difference that James showed between the NOAA stations for alfalfa (excluding Hermit). In comparison to the three stations that run through the middle of the valley (Agro, Center, and Saguache), the station further west (Del Norte) tends to be lower in CIR and the station further east (Mosca) tends to have a higher CIR. This is predominantly because cloud-cover tends to build from the west and consequently, solar radiation and temperature are lower. These clouds tend to dissipate as they move across the valley.

Table 1. 2009 ET and CIR Calculated Using Modified Hargreaves Radiation Method for the Agro Engineering Meteorological Stations.

POTENTIAL EVAPOTRANSPIRATION

Crop	Crop ET Near Agro AGRO1 (inches/acre)	Crop ET Near Center AGRO2 (inches/acre)	Crop ET Near Mosca AGRO3 (inches/acre)	Crop ET Near Saguache AGRO4 (inches/acre)	Crop ET Near Del Norte AGRO5 (inches/acre)	Crop ET Avg of AGRO Stations (inches/acre)
Alfalfa	32.43	32.90	35.23	32.49	32.56	33.12
Grass Pasture	27.73	28.22	30.16	27.78	27.90	28.36
Potatoes	15.83	16.18	17.63	16.14	15.78	16.31
Small Grains	19.07	19.41	21.09	19.33	19.20	19.62

EFFECTIVE PRECIPITATION

Crop	Effective Precipitation Near Agro AGRO1 (inches/acre)	Effective Precipitation Near Center AGRO2 (inches/acre)	Effective Precipitation Near Mosca AGRO3 (inches/acre)	Effective Precipitation Near Saguache AGRO4 (inches/acre)	Effective Precipitation Near Del Norte AGRO5 (inches/acre)	Effective Precipitation Avg of AGRO Stations (inches/acre)
Alfalfa	1.87	3.38	3.27	3.25	4.10	3.17
Grass Pasture	2.77	4.15	4.57	4.07	5.80	4.27
Potatoes	1.35	2.58	2.00	2.46	3.03	2.28
Small Grains	1.42	2.66	2.03	2.59	3.22	2.38

CROP IRRIGATION REQUIREMENT

Crop	CIR Near Agro AGRO1 (inches/acre)	CIR Near Center AGRO2 (inches/acre)	CIR Near Mosca AGRO3 (inches/acre)	CIR Near Saguache AGRO4 (inches/acre)	CIR Near Del Norte AGRO5 (inches/acre)	CIR Avg of AGRO Stations (inches/acre)
Alfalfa	30.56	29.52	31.95	29.24	28.46	29.95
Grass Pasture	24.96	24.07	25.59	23.71	22.10	24.09
Potatoes	14.48	13.60	15.63	13.67	12.75	14.03
Small Grains	17.65	16.75	19.06	16.74	15.98	17.24

Table 2. Difference Between Modified Hargreaves Radiation and StateCU's Blaney Criddle Method (using default crop characteristics) for AGRO Meteorological Stations in 2009.

Potential Crop Evapotranspiration

Crop	Difference in ET Methods AGRO1 (inches/acre)	Difference in ET Methods AGRO2 (inches/acre)	Difference in ET Methods AGRO3 (inches/acre)	Difference in ET Methods AGRO4 (inches/acre)	Difference in ET Methods AGRO5 (inches/acre)	Average Difference in ET Methods (inches/acre)
Alfalfa	2.8	3.3	3.9	2.0	1.4	2.7
Grass	1.5	1.8	2.3	0.8	-0.3	1.2
Potatoes	3.7	-0.4	4.6	3.7	-2.0	1.9
Grain	3.1	0.6	4.1	3.1	-0.5	2.1

Effective Precipitation

Crop	Difference in ET Methods AGRO1 (inches/acre)	Difference in ET Methods AGRO2 (inches/acre)	Difference in ET Methods AGRO3 (inches/acre)	Difference in ET Methods AGRO4 (inches/acre)	Difference in ET Methods AGRO5 (inches/acre)	Average Difference in ET Methods (inches/acre)
Alfalfa	0.1	0.0	0.3	0.0	-0.1	0.1
Grass	1.0	0.9	1.4	1.0	1.5	1.1
Potatoes	0.3	0.2	0.6	0.5	-0.3	0.3
Grain	0.2	0.0	0.2	0.2	-0.2	0.1

Crop Irrigation Requirement

Crop	Difference in ET Methods AGRO1 (inches/acre)	Difference in ET Methods AGRO2 (inches/acre)	Difference in ET Methods AGRO3 (inches/acre)	Difference in ET Methods AGRO4 (inches/acre)	Difference in ET Methods AGRO5 (inches/acre)	Average Difference in ET Methods (inches/acre)
Alfalfa	2.7	3.3	3.7	2.0	1.5	2.6
Grass	0.5	1.0	0.9	-0.2	-1.8	0.1
Potatoes	3.3	-0.5	4.0	3.1	-1.8	1.6
Grain	2.9	0.7	3.9	2.9	-0.4	2.0

Calibration Between ET Methods

To compare ET methods, the average 2009 monthly temperature, total monthly precipitation and frost date data from the five Agro stations were input into StateCU. The StateCU files are included for comparison. Results are included in the accompanying 2009StateCU.xls spreadsheet. Comparing the potential ET calculated by StateCU using the modified Blaney Criddle method to the modified Hargreaves radiation method, StateCU is underestimating ET fairly consistently by 1 to 4 inches. This is shown in Table 2. In my opinion this is not a problem with the crop coefficients. Instead it is a problem with the season length as dictated by the crop characteristics file. The default crop characteristics specify that growing season will begin at a mean temperature of 45 F for alfalfa, grass pasture, and small grains and at a mean temperature of 50 F for potatoes. The default crop characteristics specify that the growing season will end at the first 32 F frost date for potatoes and grain and 28 F frost date for alfalfa. Grass pasture ends at a mean temperature of 45 F. In 2009, there was a light frost (just under 32 F) on August 9th across part of the valley. This frost did not hurt alfalfa badly (a few burnt leaves before third cutting). Grass pasture and small grains were untouched. Potatoes, as a generality were not hurt badly either. One cultivar of potatoes, called Blazers, which is very susceptible to frost damage, were burnt badly and went downhill fast after the frost. The Norkotah cultivar, which was the primary cultivar grown in 2009, had some burnt leaves but kept on growing for another month. The cultivars with larger canopies, such as Nuggets and Rio Grandes, were untouched. The frost was spotty from location to location with many potato fields untouched. The majority of those potato fields that were hurt did not die the next day but continued to grow for another month and yielded decently. However, the default crop characteristic settings result in a short growing season of 95 days for potatoes and 106 days for grain in this circumstance. Similarly the 28 F frost date cuts alfalfas growing season short on September 22. Alfalfa continued to be irrigated (and was using water) until mid October. Table 3 shows the season lengths resulting from the default crop characteristics.

Table 3. 2009 Season Length Using Default Crop Characteristics

DEFAULT SEASON LENGTH

Crop	Season Length M Hargreaves All AGRO Stations	Season Length Blaney Criddle AGRO1	Season Length Blaney Criddle AGRO2	Season Length Blaney Criddle AGRO3	Season Length Blaney Criddle AGRO4	Season Length Blaney Criddle AGRO5
Alfalfa	4/15 - 10/10	4/26 - 9/22	4/26 - 9/22	4/25 - 9/22	4/27 - 9/22	4/24 - 9/22
Grass	4/15 - 10/15	4/26 - 10/3	4/26 - 10/4	4/25 - 10/4	4/27 - 10/3	4/24 - 10/6
Potatoes	5/5 - 9/4	5/7 - 8/9	5/8 -9/14	5/6 - 8/9	5/8 - 9/9	5/7 - 9/13
Grain	4/24 - 9/1	4/26 - 8/9	4/26 - 9/2	4/25 - 8/9	4/27 - 8/9	4/24 - 8/31

DEFAULT SEASON DAYS

Crop	Season Days M Hargreaves All AGRO Stations (days)	Season Days Blaney Criddle AGRO1 (days)	Season Days Blaney Criddle AGRO2 (days)	Season Days Blaney Criddle AGRO3 (days)	Season Days Blaney Criddle AGRO4 (days)	Season Days Blaney Criddle AGRO5 (days)
Alfalfa	178	150	150	151	149	152
Grass	183	161	162	163	160	166
Potatoes	122	95	130	96	125	130
Grain	130	106	130	107	105	130

In examining the past 30 years of minimum temperature data from the Center CoAgMet station, the window of opportunity for growing crops without any risk of frost is short, as shown in Figure 2, between June 20th and August 3rd; and even this record is punctuated by a July 7 frost in 1982. Nonetheless farmers in the San Luis Valley still manage to raise crops. At this station, there is a 4% chance of having a frost any day throughout August. These early light frosts can hurt crops (particularly potatoes), but they seldom kill the crop outright. On the other hand, hard frosts can kill potatoes outright. I have seen fields of potatoes burned back clear to the ground after a 26 F hard frost. The risk of a hard frost is still fairly high through the majority of the early and late growing season as shown in Figure 3.

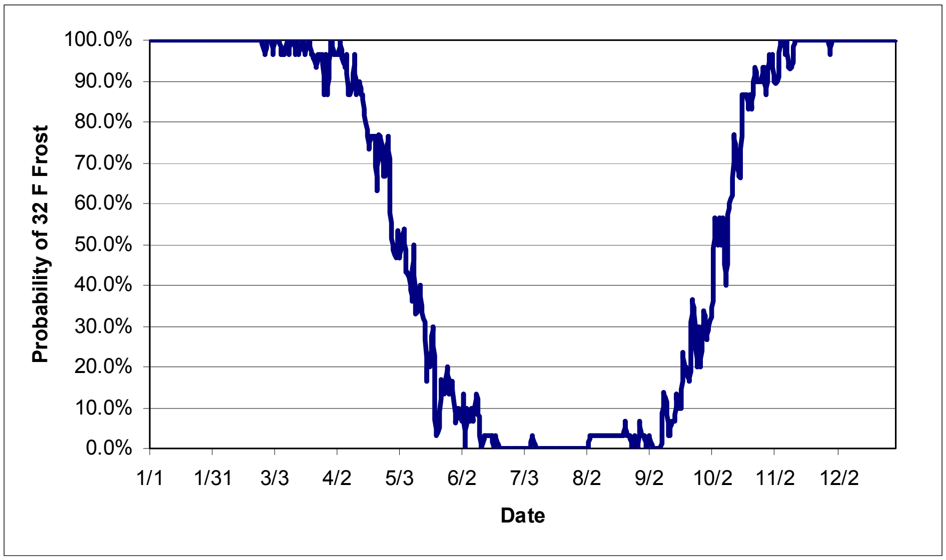

Figure 2. Probability of a 32F Frost (1980–2009 data from Center CoAgMet Station)

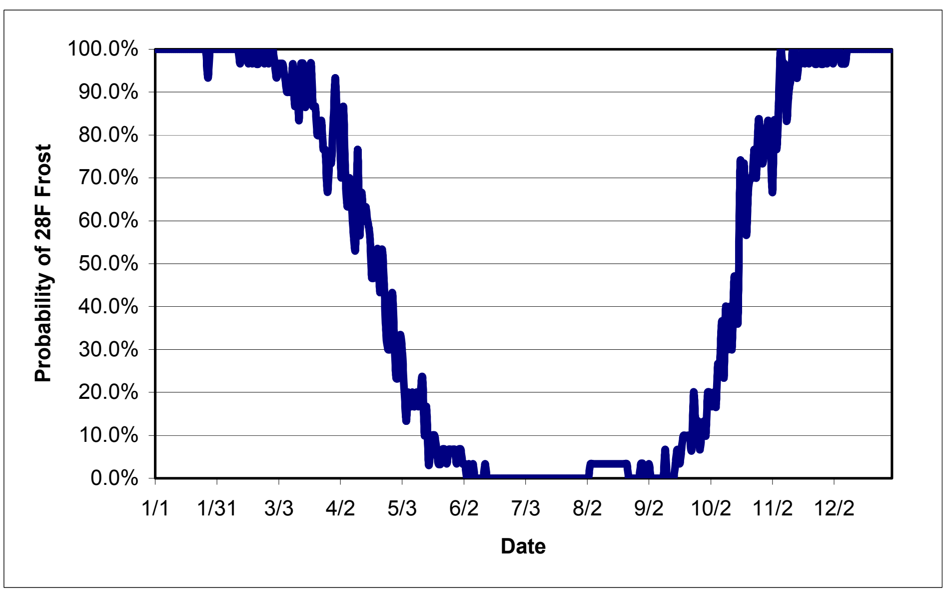

Figure 3. Probability of a 28F Frost (1980–2009 data from Center CoAgMet Station)

For potatoes and small grains, I would recommend changing the end of growing season specification to a 28 F frost date. Lowering the frost date to 28 F will still allow hard frosts to cut a growing season short, but will provide a slightly greater probability that the model allows potatoes and small grain crops to grow to their maximum season length. I would also suggest changing the maximum length of growing season for potatoes from 130 days to 120 days. 110 to 120 day potato cultivars are much more common than 120 to 130 day cultivars. This is true today and has been true in the past as well.

I would also suggest changing the beginning of season specification for potatoes to a hard date of May 8. Using a beginning of season specification of a mean temperature of 50 F results in an average planting date of May 12. However it also results in a 37 day range of planting dates, with cold years having a planting date as late as June 2. This range is too large and June planting dates are too late to be representative of actual cropping practices, even in years with cool springs. Farmers tend to plant potatoes at nearly the same time each year. Since the potatoes are underground for about a month before emergence, soil temperature is more important than air temperature. Farmers do not delay planting to wait and see if the air temperature will be cool at the end of May. On the other hand, the planting date for small grains is more variable. Barley tends to be planted before wheat. Using a beginning of season specification of a mean temperature of 45 F seems reasonable as it results in an average planting date of April 23. This beginning of season specification allows the planting date to vary by 30 days (April 12 to May 12) and the fields around the edges of the valley to plant on average 10 days later than the middle of the valley when spring temperatures are cooler at the stations closer to the mountains.

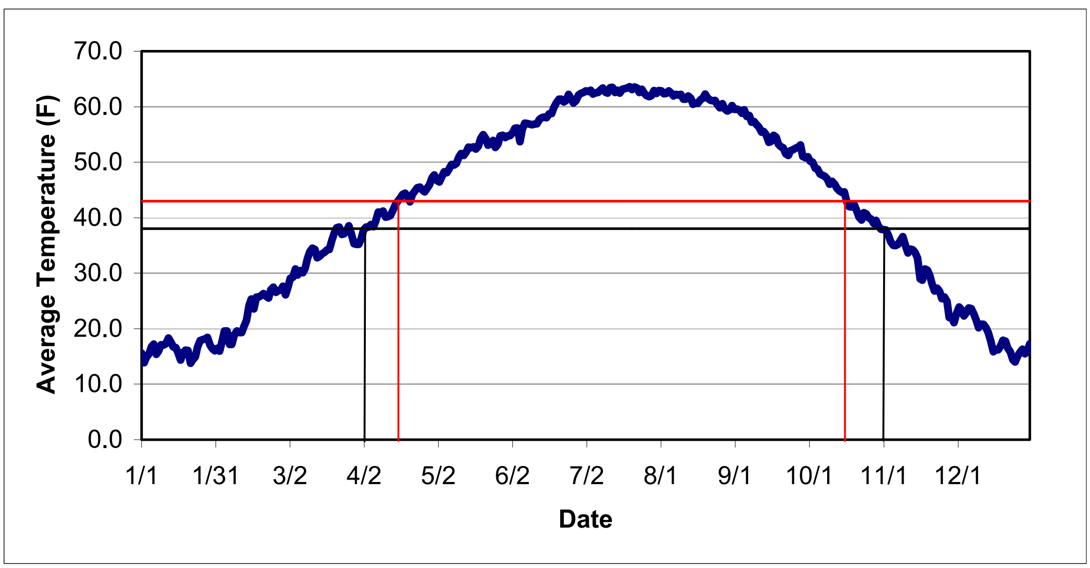

Figure 4. Long Term Average Daily Temperature (1980–2009 from Center CoAgMet Station)

For alfalfa and grass pasture, I would recommend changing the beginning of the growing season specification and the end of growing season specification to a mean of 43 F. The official irrigation season runs from April 1 to October 31. Alfalfa and grass pasture begin breaking dormancy by early April and they green up and start using water in earnest by mid April, depending obviously on the temperature. Likewise, they stop using water by mid to late October. In examining the 30-year record at the Center CoAgMet station, long-term average daily temperature is very symmetric in April and October. The long-term average temperature is 38 F at the beginning of April and the end of October. The long-term average temperature is 43 F at the middle of both months. The long-term average temperature is 49 F at the end of April and the beginning of October. The default beginning and ending season specification of 45 F for grass pasture results in the model predicting that, on average, grass pasture will not start using water until late April and will stop using water by early October. I would propose changing these season specifications to 43 F so that, on average, it will start in mid April and end in mid October. Furthermore, I do not think we can differentiate alfalfa from grass pasture in terms of its season length.

To summarize, in order to improve the calibration of ET methods I would suggest the changes shown in Table 4 to the crop characteristics for the Rio Grande calibrated crops.

Table 4. Suggested Revisions to Crop Characteristics

DEFAULT CROP CHARACTERISTICS

Crop	Beginning of Growing Season Specification (Farenheit)	End of Growing Season Specification (Farenheit)	Maximum Length of Growing Season (days)
Alfalfa	Mean 45	28 frost date	365
Grass	Mean 45	Mean 45	365
Potatoes	Mean 50	32 frost date	130
Grain	Mean 45	32 frost date	130

REVISED CROP CHARACTERISTICS

Crop	Beginning of Growing Season Specification (Farenheit)	End of Growing Season Specification (Farenheit)	Maximum Length of Growing Season (days)
Alfalfa	Mean 43	Mean 43	365
Grass	Mean 43	Mean 43	365
Potatoes	8-May	28 frost date	120
Grain	Mean 45	28 frost date	130

Utilizing these revised crop characteristics for 2009 results in season lengths that seem more reasonable for all four crop types, as shown in Table 5. It prevents the light frost that occurred on August 9 from cutting the season short for potatoes and small grains. Utilizing these revised crop characteristics also improves the agreement between potential ET as calculated using the Modified Hargreaves method and StateCU's Modified Blaney Criddle method to within 1.5 inches. The StateCU model's calculation of the crop irrigation requirements for the AGRO stations is shown in Table 6. The difference in the comparison of methods is shown in Table 7.

Table 5. 2009 Season Length Using Revised Crop Characteristics

REVISED SEASON LENGTH

Crop	Season Length M Hargreaves All AGRO Stations	Season Length Blaney Criddle AGRO1	Season Length Blaney Criddle AGRO2	Season Length Blaney Criddle AGRO3	Season Length Blaney Criddle AGRO4	Season Length Blaney Criddle AGRO5
Alfalfa	4/15 - 10/10	4/22 - 10/7	4/22 - 10/8	4/21 - 10/8	4/23 - 10/7	4/19 - 10/10
Grass	4/15 - 10/15	4/22 - 10/7	4/22 - 10/8	4/21 - 10/8	4/23 - 10/7	4/19 - 10/10
Potatoes	5/5 - 9/4	5/8 - 9/4	5/8 -9/4	5/8 - 9/4	5/8 - 9/4	5/8 - 9/4
Grain	4/24 - 9/1	4/26 - 9/2	4/26 - 9/2	4/25 - 9/1	4/27 - 9/3	4/24 - 8/31

REVISED SEASON DAYS

Crop	Season Days M Hargreaves All AGRO Stations (day)	Season Days Blaney Criddle AGRO1 (days)	Season Days Blaney Criddle AGRO2 (days)	Season Days Blaney Criddle AGRO3 (days)	Season Days Blaney Criddle AGRO4 (days)	Season Days Blaney Criddle AGRO5 (days)
Alfalfa	178	169	170	171	168	175
Grass	183	169	170	171	168	175
Potatoes	122	120	120	120	120	120
Grain	130	130	130	130	130	130

Table 6. 2009 ET and CIR Calculated Using StateCU Modified Blaney Criddle Method (and Revised Crop Characteristics) for the AGRO Stations.

Potential Crop Evapotranspiration

Crop	Crop ET AGRO1 Near AGRO (inches/acre)	Crop ET AGRO2 Near Center (inches/acre)	Crop ET AGRO3 Near Mosca (inches/acre)	Crop ET AGRO4 Near Saguache (inches/acre)	Crop ET AGRO5 Near Del Norte (inches/acre)	Crop ET Average of AGRO Stations (inches/acre)
Alfalfa	31.21	31.33	33.04	32.14	33.17	32.18
Grass	27.02	27.20	28.66	27.83	29.12	27.97
Potatoes	16.24	16.17	17.23	17.06	17.06	16.75
Grain	18.89	18.78	20.25	19.86	19.72	19.50

Effective Precipitation

Crop	Effective Precipitation AGRO1 Near AGRO (inches/acre)	Effective Precipitation AGRO2 Near Center (inches/acre)	Effective Precipitation AGRO3 Near Mosca (inches/acre)	Effective Precipitation AGRO4 Near Saguache (inches/acre)	Effective Precipitation AGRO5 Near Del Norte (inches/acre)	Effective Precipitation Average of AGRO Stations (inches/acre)
Alfalfa	1.98	3.62	3.52	3.47	4.77	3.47
Grass	1.88	3.40	3.34	3.24	4.59	3.29
Potatoes	1.23	2.29	1.68	2.16	3.11	2.09
Grain	1.41	2.68	2.02	2.57	3.39	2.41

Crop Irrigation Requirement

Crop	CIR AGRO1 Near AGRO (inches/acre)	CIR AGRO2 Near Center (inches/acre)	CIR AGRO3 Near Mosca (inches/acre)	CIR AGRO4 Near Saguache (inches/acre)	CIR AGRO5 Near Del Norte (inches/acre)	CIR Average of AGRO Stations (inches/acre)
Alfalfa	29.23	27.71	29.52	28.67	28.40	28.71
Grass	25.14	23.80	25.32	24.59	24.53	24.68
Potatoes	15.01	13.88	15.55	14.90	13.95	14.66
Grain	17.48	16.10	18.23	17.29	16.33	17.09

Table 7. Difference Between Modified Hargreaves Radiation and StateCU's Blaney Criddle Method (using revised crop characteristics) for AGRO Meteorologic Stations

Potential Crop Evapotranspiration

Crop	Difference in ET Methods AGRO1 (inches/acre)	Difference in ET Methods AGRO2 (inches/acre)	Difference in ET Methods AGRO3 (inches/acre)	Difference in ET Methods AGRO4 (inches/acre)	Difference in ET Methods AGRO5 (inches/acre)	Average Difference in ET Methods (inches/acre)
Alfalfa	1.2	1.6	2.2	0.4	-0.6	0.9
Grass	0.7	1.0	1.5	0.0	-1.2	0.4
Potatoes	-0.4	0.0	0.4	-0.9	-1.3	-0.4
Grain	0.2	0.6	0.8	-0.5	-0.5	0.1

Effective Precipitation

Crop	Difference in ET Methods AGRO1 (inches/acre)	Difference in ET Methods AGRO2 (inches/acre)	Difference in ET Methods AGRO3 (inches/acre)	Difference in ET Methods AGRO4 (inches/acre)	Difference in ET Methods AGRO5 (inches/acre)	Average Difference in ET Methods (inches/acre)
Alfalfa	-0.1	-0.2	-0.2	-0.2	-0.7	-0.3
Grass	0.9	0.8	1.2	0.8	1.2	1.0
Potatoes	0.1	0.3	0.3	0.3	-0.1	0.2
Grain	0.0	0.0	0.0	0.0	-0.2	0.0

Crop Irrigation Requirement

Crop	Difference in ET Methods AGRO1 (inches/acre)	Difference in ET Methods AGRO2 (inches/acre)	Difference in ET Methods AGRO3 (inches/acre)	Difference in ET Methods AGRO4 (inches/acre)	Difference in ET Methods AGRO5 (inches/acre)	Average Difference in ET Methods (inches/acre)
Alfalfa	1.3	1.8	2.4	0.6	0.1	1.2
Grass	-0.2	0.3	0.3	-0.9	-2.4	-0.6
Potatoes	-0.5	-0.3	0.1	-1.2	-1.2	-0.6
Grain	0.2	0.7	0.8	-0.6	-0.4	0.2

Reasonableness of 2009 Crop Irrigation Requirements from the NOAA Stations

Utilizing the revised crop characteristics results in the calculation of 2009 crop irrigation requirements for the NOAA stations as shown in Table 8. The average crop irrigation requirement for each NOAA station (excluding Hermit) agrees very well with the average CIR from the AGRO stations shown in Table 6. However, the CIR at some of these stations still seems low in comparison to the average.

Table 8. 2009 ET and CIR Calculated Using StateCU Modified Blaney Criddle Method for the NOAA Stations.

Potential Crop Evapotranspiration

Crop	Crop ET Station: 0130 Alamosa (inches/acre)	Crop ET Station: 1458 Center (inches/acre)	Crop ET Station: 0776 Blanca (inches/acre)	Crop ET Station: 5706 Monte Vista (inches/acre)	Crop ET Station: 2184 Del Norte (inches/acre)	Crop ET Station: 3541 Sand Dunes (inches/acre)	Crop ET Station: 5322 Manassa (inches/acre)	Crop ET Station: 7337 Saguache (inches/acre)	Crop ET Station: 3951 Hermit (inches/acre)	Crop ET Average of COAGMET (inches/acre)
Alfalfa	34.32	33.99	37.12	29.55	28.54	35.51	34.53	34.39	23.36	33.49
Grass	29.99	29.86	32.72	25.51	24.54	31.16	30.52	30.50	20.47	29.35
Potatoes	17.76	17.41	19.65	15.77	15.35	19.00	17.74	17.49	9.73	17.52
Grain	20.79	20.38	21.84	19.17	19.00	21.58	20.09	20.20	11.15	20.38

Effective Precipitation

Crop	Effective Precipitation Station: 0130 Alamosa (inches/acre)	Effective Precipitation Station: 1458 Center (inches/acre)	Effective Precipitation Station: 0776 Blanca (inches/acre)	Effective Precipitation Station: 5706 Monte Vista (inches/acre)	Effective Precipitation Station: 2184 Del Norte (inches/acre)	Effective Precipitation Station: 3541 Sand Dunes (inches/acre)	Effective Precipitation Station: 5322 Manassa (inches/acre)	Effective Precipitation Station: 7337 Saguache (inches/acre)	Effective Precipitation Station: 3951 Hermit (inches/acre)	Effective Precipitation Average of COAGMET (inches/acre)
Alfalfa	3.89	5.49	3.96	4.49	5.45	5.42	4.61	4.93	4.56	4.78
Grass	3.72	5.26	3.75	4.29	5.19	5.11	4.44	4.74	4.43	4.56
Potatoes	2.03	3.38	2.42	2.66	3.52	2.71	2.61	3.47	2.32	2.85
Grain	2.38	3.77	2.83	3.05	3.99	3.32	2.97	3.50	2.38	3.23

Crop Irrigation Requirement

Crop	CIR Station: 0130 Alamosa (inches/acre)	CIR Station: 1458 Center (inches/acre)	CIR Station: 0776 Blanca (inches/acre)	CIR Station: 5706 Monte Vista (inches/acre)	CIR Station: 2184 Del Norte (inches/acre)	CIR Station: 3541 Sand Dunes (inches/acre)	CIR Station: 5322 Manassa (inches/acre)	CIR Station: 7337 Saguache (inches/acre)	CIR Station: 3951 Hermit (inches/acre)	CIR Average of COAGMET (inches/acre)
Alfalfa	30.43	28.50	33.16	25.06	23.09	30.09	29.92	29.46	18.80	28.71
Grass	26.27	24.60	28.97	21.22	19.35	26.05	26.08	25.76	16.04	24.79
Potatoes	15.73	14.03	17.23	13.11	11.83	16.29	15.13	14.02	7.41	14.67
Grain	18.41	16.61	19.01	16.12	15.01	18.26	17.12	16.70	8.77	17.16

*Average Excludes Hermit

The Hermit station should not be used to estimate crop irrigation requirements on the valley floor. This station is located at a much higher elevation in the mountains. Temperatures at Hermit are too cold to grow potatoes and small grains. Localized weather stations also make it less representative. While the Hermit station may be indicative of alfalfa and grass pastures grown along the small creeks in the mountain, it is not representative of crops grown on the valley floor.

To examine the reasonableness of the NOAA stations, the difference between the crop irrigation requirement at each NOAA station was compared against the closest AGRO station in Table 9. AGRO does not have stations in close proximity to Alamosa, Blanca, or the Manassa stations, so some difference in the comparison of these stations should be expected. Nonetheless, the Monte Vista station and the Del Norte station seem to be underestimating crop irrigation requirement in 2009 as compared to the closest AGRO station.

Table 9. Comparison of NOAA Stations to Agro Stations in 2009

Potential Crop Evapotranspiration

Crop	Difference in ET Comparing Station: 0130 to AGRO1 Alamosa* (inches/acre)	Difference in ET Comparing Station: 1458 to AGRO2 Center (inches/acre)	Difference in ET Comparing Station: 0776 to AGRO3 Blanca* (inches/acre)	Difference in ET Comparing Station: 5706 to AGRO1 Monte Vista (inches/acre)	Difference in ET Comparing Station: 2184 to AGRO5 Del Norte (inches/acre)	Difference in ET Comparing Station: 3541 to AGRO3 Sand Dunes (inches/acre)	Difference in ET Comparing Station: 5322 to AGRO1 Manassa* (inches/acre)	Difference in ET Comparing Station: 7337 to AGRO4 Saguache (inches/acre)
Alfalfa	-3.11	-2.66	-4.08	1.66	4.63	-2.47	-3.32	-2.25
Grass	-2.97	-2.66	-4.06	1.51	4.58	-2.50	-3.50	-2.67
Potatoes	-1.52	-1.24	-2.42	0.47	1.71	-1.77	-1.50	-0.43
Grain	-1.90	-1.60	-1.59	-0.28	0.72	-1.33	-1.20	-0.34

Effective Precipitation

Crop	Difference in Pe Comparing Station: 0130 to AGRO1 Alamosa* (inches/acre)	Difference in Pe Comparing Station: 1458 to AGRO2 Center (inches/acre)	Difference in Pe Comparing Station: 0776 to AGRO3 Blanca* (inches/acre)	Difference in Pe Comparing Station: 5706 to AGRO1 Monte Vista (inches/acre)	Difference in Pe Comparing Station: 2184 to AGRO5 Del Norte (inches/acre)	Difference in Pe Comparing Station: 3541 to AGRO3 Sand Dunes (inches/acre)	Difference in Pe Comparing Station: 5322 to AGRO1 Manassa* (inches/acre)	Difference in Pe Comparing Station: 7337 to AGRO4 Saguache (inches/acre)
Alfalfa	-1.91	-1.87	-0.44	-2.51	-0.68	-1.90	-2.63	-1.46
Grass	-1.84	-1.86	-0.41	-2.41	-0.60	-1.77	-2.56	-1.50
Potatoes	-0.80	-1.09	-0.74	-1.43	-0.41	-1.03	-1.38	-1.31
Grain	-0.97	-1.09	-0.81	-1.64	-0.60	-1.30	-1.56	-0.93

Crop Irrigation Requirement

Crop	Difference in CIR Comparing Station: 0130 to AGRO1 Alamosa* (inches/acre)	Difference in CIR Comparing Station: 1458 to AGRO2 Center (inches/acre)	Difference in CIR Comparing Station: 0776 to AGRO3 Blanca* (inches/acre)	Difference in CIR Comparing Station: 5706 to AGRO1 Monte Vista (inches/acre)	Difference in CIR Comparing Station: 2184 to AGRO5 Del Norte (inches/acre)	Difference in CIR Comparing Station: 3541 to AGRO3 Sand Dunes (inches/acre)	Difference in CIR Comparing Station: 5322 to AGRO1 Manassa* (inches/acre)	Difference in CIR Comparing Station: 7337 to AGRO4 Saguache (inches/acre)
Alfalfa	-1.20	-0.79	-3.64	4.17	5.31	-0.57	-0.69	-0.79
Grass	-1.13	-0.80	-3.65	3.92	5.18	-0.73	-0.94	-1.17
Potatoes	-0.72	-0.15	-1.68	1.90	2.12	-0.74	-0.12	0.88
Grain	-0.93	-0.51	-0.78	1.36	1.32	-0.03	0.36	0.59

*Closest Station for Comparison isn't very close.

Monte Vista Station

Taking a closer look at the Monte Vista NOAA station's data, the CIR for alfalfa and grass pasture was 4 inches less than at the station at Agro Engineering's office. 1.5 inches of this difference occurred because less ET was calculated at the NOAA Monte Vista station early and late in the season. This 1.5 inch difference occurred because the average temperature (and daily minimum and daily maximum temperatures) was slightly lower in April, May, August, September and October. The other 2.5 inches of this difference occurred because more precipitation occurred in each month. For potatoes and small grains, the difference in CIR was about 1.5 inches less at NOAA Monte Vista than the Agro office station. This difference results almost entirely because of more precipitation at Monte Vista.

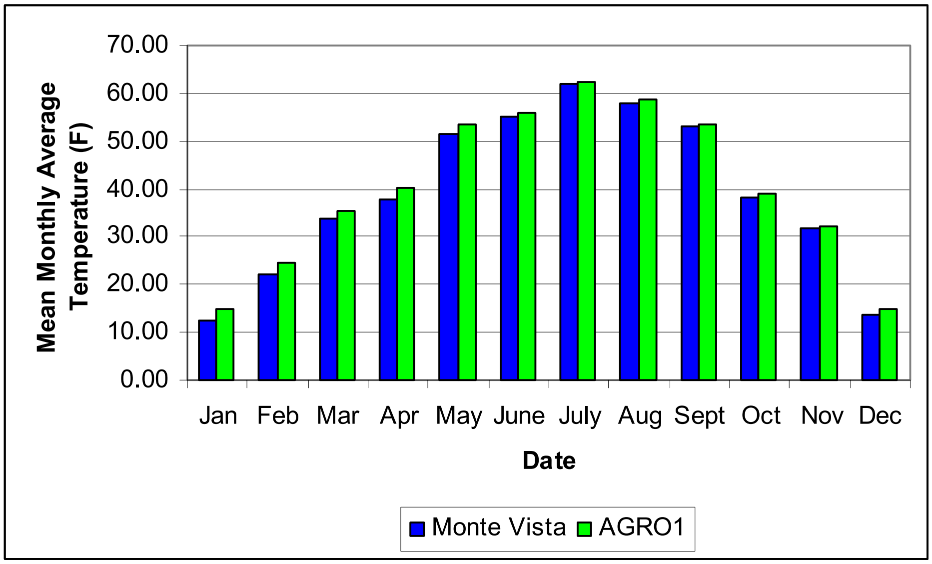

Figure 5. Comparison of Mean Monthly Average Temperature at NOAA Monte Vista station to Agro Engineering's office station.

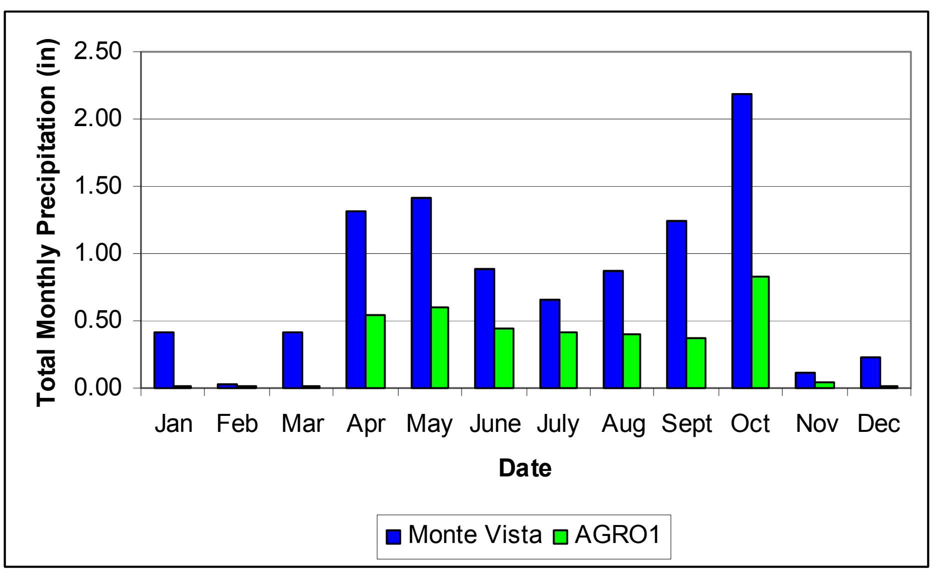

Figure 6. Comparison of Total Monthly Precipitation at NOAA Monte Vista station to Agro Engineering's office station.

The difference in average temperature in 2009 appears to be real and does not indicate a problem with station site location or the crop coefficients used. Comparing the long-term mean of the average daily temperature at Monte Vista (1948 to 2009) to the Center CoAgMet station (1980 to 2009) results in very similar curve, indicating that temperature data from Monte Vista is not consistently low. Comparing the 2009 daily temperature data at Monte Vista against that at the Agro office, results in the same daily trends, suggesting accurate measurement, but slightly lower maximum, minimum, and average temperatures.

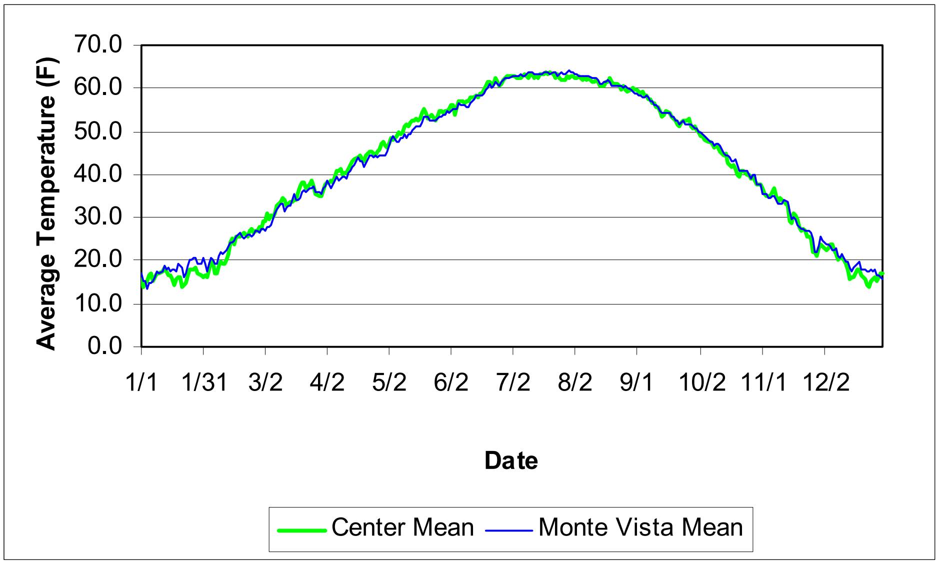

Figure 7. Comparison of Long Term Mean Daily Temperature at NOAA Monte Vista station compared to Center CoAgMet Station.

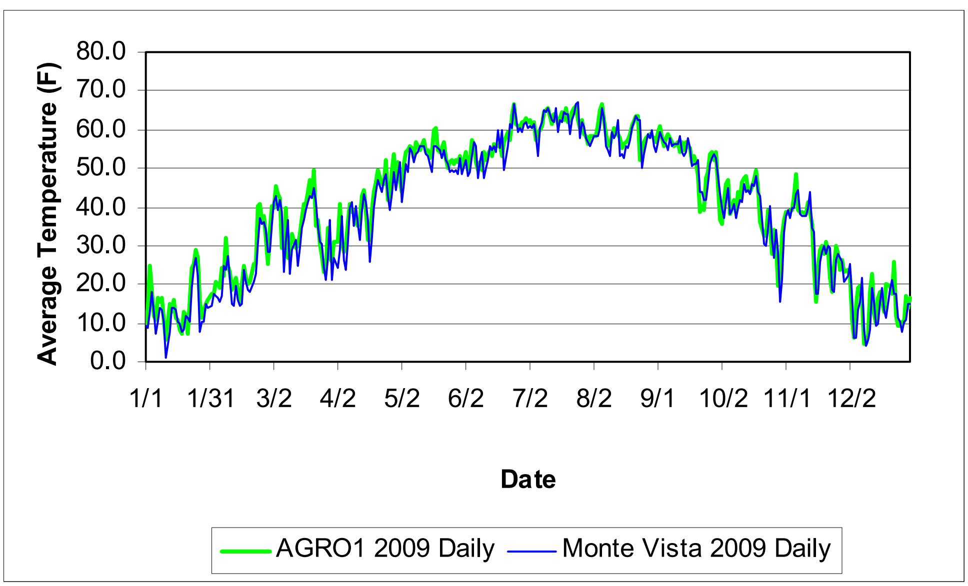

Figure 8. Comparison of 2009 Average Daily Temperature at NOAA Monte Vista station compared to Agro Engineering's office station.

Precipitation at the NOAA Monte Vista station seems reasonable but is higher than at several other stations. The long-term annual precipitation at the Monte Vista station is 7.68 inches. The long-term annual precipitation at the Center CoAgMet station is 5.80 inches. The 2009 precipitation during the growing season (April through October) at the Monte Vista station was 8.57 inches. This is considerably higher than the 3.60 inches of precipitation through the growing season at the Agro station.

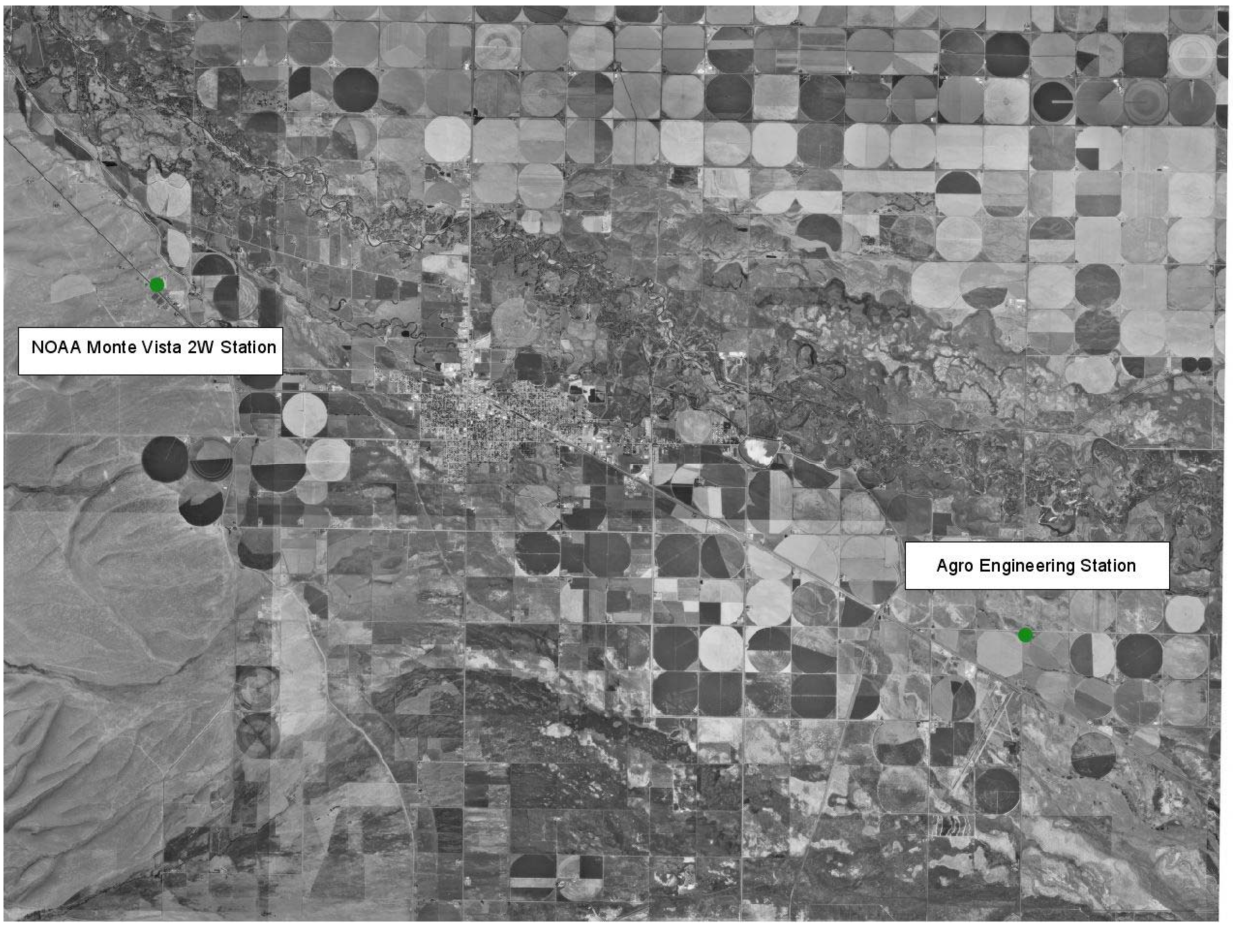

Figure 9. Location of the Monte Vista NOAA station and the Agro office station.

Del Norte Station

Looking in detail at the Del Norte NOAA station's data, the CIR for alfalfa and grass pasture was roughly 5 inches less than at Agro Engineering's station near Del Norte. 4.5 inches of this difference occurred because less ET was calculated at the NOAA Del Norte station. This 4.5 inch difference occurred because the average temperature (and daily minimum and daily maximum temperatures) was consistently lower in every month. The other 0.5 inch of this difference occurred because more precipitation occurred in April, May and September. For potatoes and small grains, the difference in CIR was about 1.5 to 2.0 inches less at the NOAA Del Norte station than at Agro Engineering station near Del Norte. About 1 to 1.5 inches of this difference occurred because less ET was calculated at the NOAA Del Norte station. The remaining 0.5 inch of the difference resulted from more precipitation at the NOAA Del Norte station.

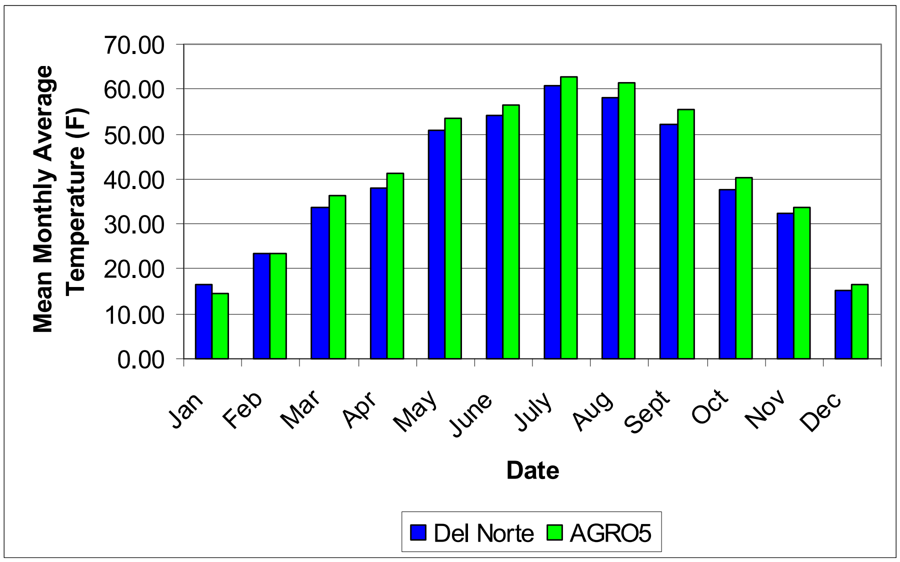

Figure 10. Comparison of Mean Monthly Average Temperature at NOAA Del Norte to Agro station near Del Norte.

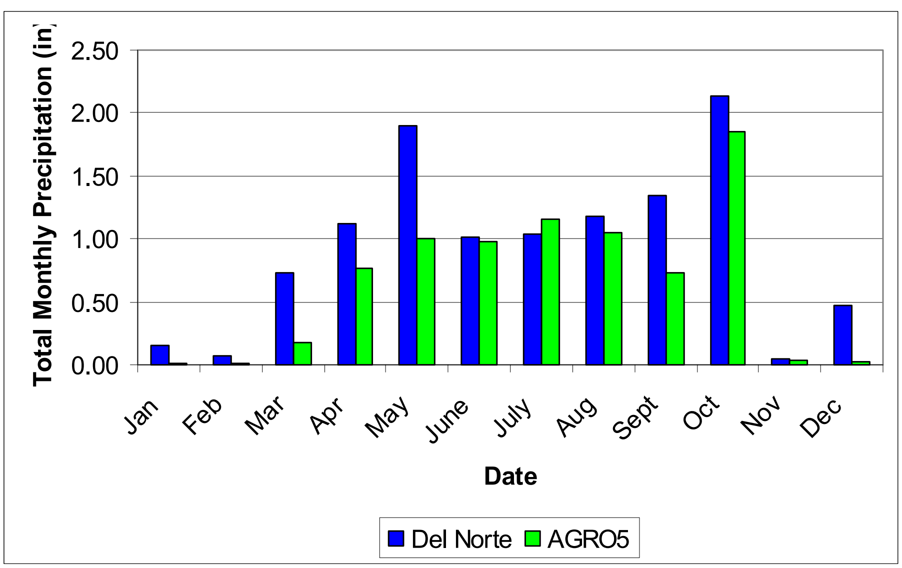

Figure 11. Comparison of Total Monthly Precipitation at NOAA Del Norte to Agro station near Del Norte.

Comparing the long-term mean of the average daily temperature at the NOAA Del Norte station (1948 to 2009) to the Center CoAgMet station (1980 to 2009) results in a very similar curve during the growing season, but cooler temperatures during the winter months. Nonetheless, temperature data from Del Norte station is not consistently low. Comparing the 2009 daily temperature data at the NOAA Del Norte station against that of Agro Engineering's station near Del Norte, results in the same daily trends, suggesting accurate measurement, but the daily maximum, minimum, and average temperatures are consistently lower and offset by 2 F on average.

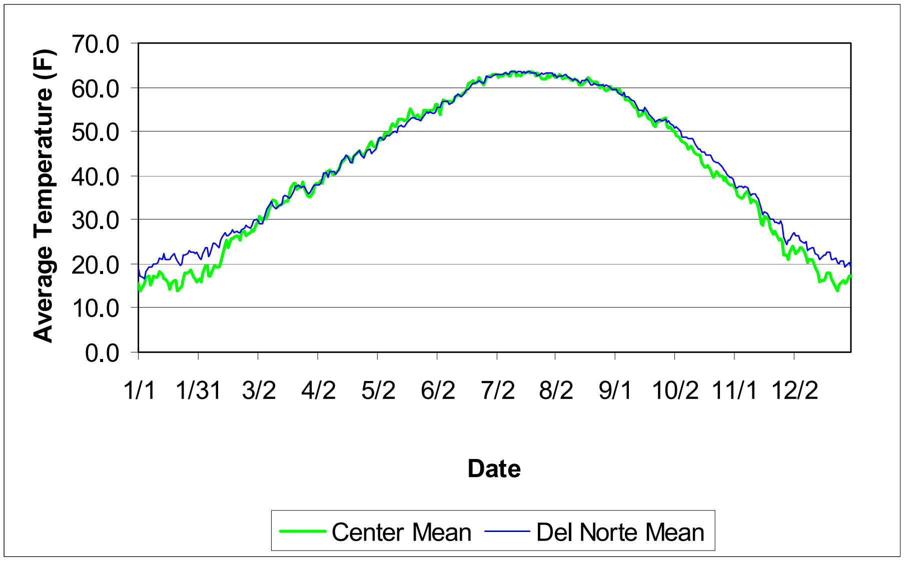

Figure 12. Comparison of Long Term Mean Daily Temperature at NOAA Del Norte station compared to COAGMET Center station

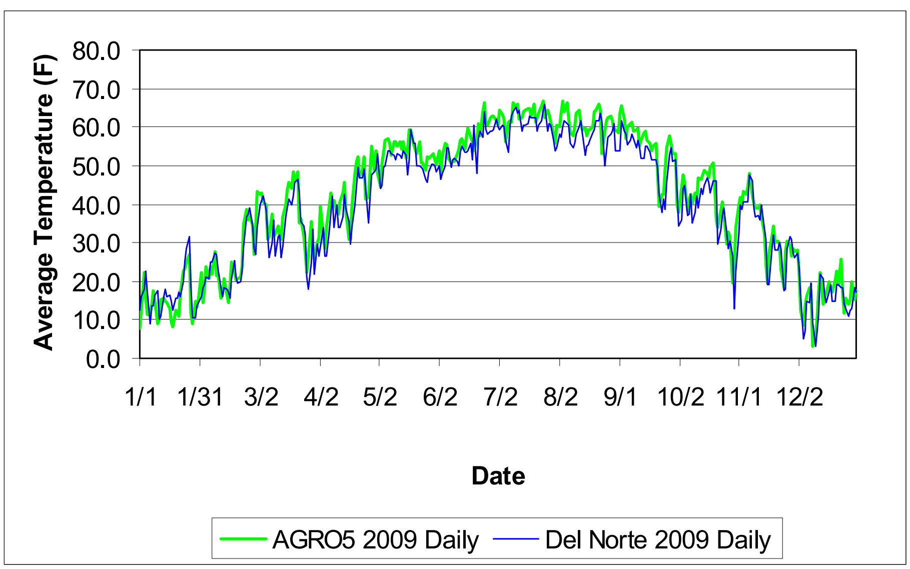

Figure 13. Comparison of 2009 Average Daily Temperature at NOAA Del Norte station compared to Agro station near Del Norte

Precipitation at the NOAA Del Norte station seems erratic. The long-term annual precipitation at the NOAA Del Norte station is 4.78 inches. The long-term annual precipitation at the Center CoAgMet station is 5.80 inches. The 2009 precipitation during the growing season (April through October) at the NOAA Del Norte station was 9.73 inches. This is somewhat higher than the 7.53 inches of precipitation through the growing season at Agro Engineering's station near Del Norte.

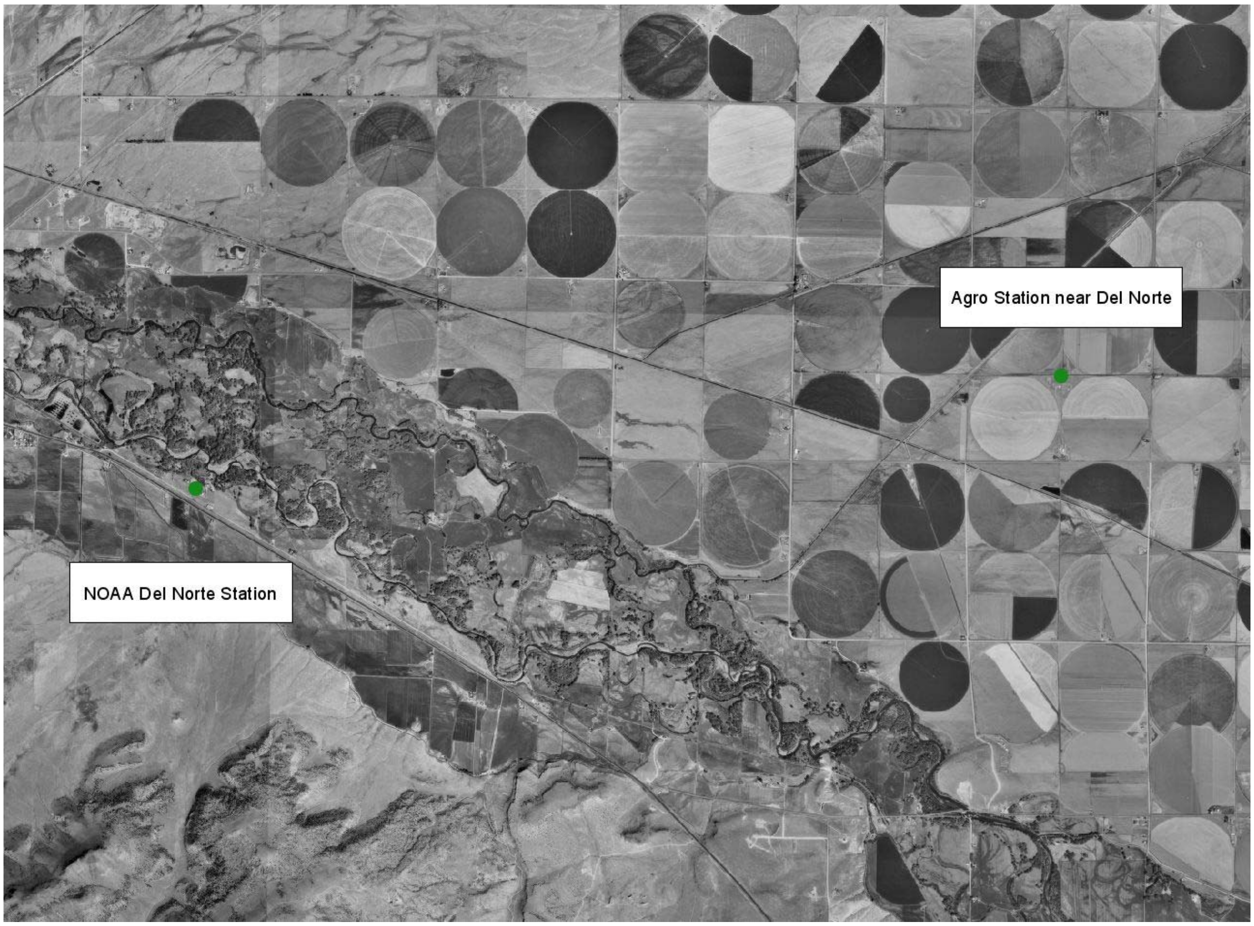

Figure 14. Location of the NOAA Del Norte station and Agro Engineering's station near Del Norte.

In conclusion, I would recommend changing the end of growing season specification to a 28 F frost date for potatoes and small grains. I would also suggest changing the maximum length of growing season for potatoes from 130 days to 120 days. I would recommend changing the beginning of the growing season specification for potatoes to May 8. I would recommend changing the beginning of the growing season specification and the end of growing season specification to a mean of 43 F for both alfalfa and grass pasture. Making these changes to the crop characteristics results in more reasonable season lengths and also results in a better calibration between ET methods.

Table 10. Recommended Revised Crop Characteristics

Crop	Beginning of Growing Season Specification (Farenheit)	End of Growing Season Specification (Farenheit)	Maximum Length of Growing Season (days)
Alfalfa	Mean 43	Mean 43	365
Grass	Mean 43	Mean 43	365
Potatoes	8-May	28 frost date	120
Grain	Mean 45	28 frost date	130

In 2009, the NOAA Monte Vista station and the NOAA Del Norte station had lower calculated crop irrigation requirements than expected. The majority of the discrepancy in crop irrigation requirement at the Monte Vista station was a result of more precipitation at that station's location. Precipitation is highly random and highly variable from location to location. The NOAA Monte Vista station also had slightly lower average temperatures. The majority of the discrepancy in crop irrigation requirement at the Del Norte station was a result of lower average temperatures. The NOAA Del Norte station also had slightly higher precipitation. Both of these stations are located between Monte Vista and Del Norte along Highway 160 and may be influenced by their close proximity to the hills to the south and the Rio Grande to the north. The highly variable precipitation at individual stations provides a strong rationale for the averaging of multiple stations to obtain the crop irrigation requirement for the parcels under different ditch systems. Stations should be weighted in a manner that is representative of the parcels within a given ditch. The Hermit station should not be used.