Improved Meteorological Infrastructure for Water Management in the Middle and Lower Rio Grande, New Mexico

Technical Completion Report

Submitted by

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Submitted to:

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Introduction

Management of water in a basin requires an accurate estimate of water budget. For decades, water management agencies such as the Middle Rio Grande Conservancy and Elephant Butte Irrigation districts, US Geological Survey, US Bureau of Reclamation and others have invested in measurement and estimation of surface water and to a certain extent groundwater. Consumptive use or evapotranspiration (ET) losses in the water budgets however are estimated mainly by meteorological methods (i.e. thermal measurements by remote sensing and/or ground measurements of microclimate). The meteorological data are often measured by the climate stations, which are spread in agriculture and riparian regions of New Mexico. During the last few years, the climate stations in the Middle and Lower Rio Grande have deteriorated due to lack of proper maintenance. Improper maintenance of instrumentation at the climate stations can result in meteorological data measurements that are prone to large errors, which then affects the consumptive use estimates in the water budget. In this project, a total of seven climate stations from south Albuquerque to Sunland, NM were visited, inspected and maintained since October of 2016.

Project Objective

The objective of this research was to:

- Assess the condition of climate stations
- Conduct maintenance and replace sensors that were malfunctioning,
- Analyze the historical data collected by these weather stations stored on the station data logger
- Collect data for FY 16 – 17, and
- Calculate reference ET using historical data and data collected in 2017 from the climate stations. The calculated ET can be used to estimate the water budget of the Middle and Lower Rio Grande or for other applications.

Methodology

Seven weather stations were visited, inspected and maintained. The station towers for mounting the sensors were inspected to make sure they are secure and not wobbling. Sensor models and their accuracies were compiled, and their respective siting heights measured. All the sensors were inspected for any damage and then cleaned using distilled water and fine cotton cloth during the field visits. The sensors that were malfunctioning were removed and replaced. The data output from cleaned sensors were also checked to make sure that they were reading reasonable values. All sensor wires were inspected for any damages and old electric tapes and zip ties removed. Sensor wires were secured properly on the tower using new electric tape and zip ties. Solar panels were cleaned of bird droppings and dust. The batteries were inspected and voltages checked. The power regulators were checked to make sure they functioned properly.

Data collected include solar radiation, air and soil temperature, wind speed and direction, relative humidity, and precipitation. This data was processed and analyzed. Data revealed to be erroneous was removed during data processing. Collected data was used as parameters for the calculation of ET referenced to grass for years 2016 and 2017 using *ASCE* Standardized ET method (or ETsz; Allen et al., 2005).

Results

The following weather stations were visited and assessed as part of quality control:

1. Sunland Park weather station, Sunland Park, NM.
2. Saltgrass weather station, Las Palomas, NM
3. Slake weather station, Elephant Butte dam
4. Nlake weather station, Elephant Butte by Monticello
5. South Bosque weather station, Bosque del Apache National Wildlife Refuge
6. Gherardi weather station, Albuquerque (South Albuquerque)
7. James' farm weather station, Albuquerque (South Albuquerque)

The sensor specifications, their siting heights and pictures are included in the following pages. Summary of analyzed climate data for each station are listed in the appendix.

Sunland Park Weather Station
Name of Station: Sunland Park
Location: Sunland Park
County: Dona Ana
State: New Mexico
Lat/Long: 31°50'24.71"N and 106°36'40.36"W
Elevation: 1144 m (3754 ft)

Station Installation Date: July-2015
Source of Funding: NSF-EPSCoR
Contact: Salim Bawazir, Ph.D. (e-mail: abawazir@nmsu.edu); 575-646-6044 (NMSU)

Measurement	Sensor Type/Model	Sensor Accuracy	Height from Ground Surface
Wind speed and direction	Wind Monitor AQ (Model 05103)[a]	Speed: ±0.3 m/s or 1% of reading Direction: ±3°	3.45 m (136 in)
Solar radiation	LI200X Pyranometer[a]	±5% max ±3% typical	3.12 m (123 in)
Air temperature and relative humidity	HMP45C[a] Relative Humidity: Vaisala' SHUMICAP® H-chip Temp Sensor: 100 ohm PRT	Accuracy at 20°C ±2% (0 to 90% Relative Humidity) ±3% (0 to 100% Relative Humidity)	2.44 m (96 in)
Rain Gage	Rain gage model TB4[a] (0.01-in per tip)	<±2% at high precipitation rates of 500 mm/hr.	2.34 m (92 in)
Soil Moisture, Temperature and Salinity @ 4in & 20in	Hydra Probes (SDI-12 Hydra Probe II)[b]	Temp.: ±0.3 °C (-10 to +55 °C) Conductivity: ±2.0% (0.01 to 1.5 S/m)	-0.10 m (-4 in) -0.51 m (-20in)
Soil Moisture, Temperature @ 10 cm	T107	Temp.: ±0.2 °C (-35 to 50 °C)	0.10m (-3.9 in)
Barometric Pressure	CS106 Vaisala PTB110[a]	±1.5 mb@ -40 to 60 °C	1.67 m (66 in)
Data logger	CR1000[a]		~ 1.7 m (70 in)
Inside Enclosure Relative Humidity	CS210 (10162)[a]	Accuracy at 25 °C: ±3% RH (10 to 90% Relative Humidity	~1.7 m (70 in)

[a]Campbell Scientific Inc., Logan Utah, 84321; [b] Stevens Water Monitoring Systems, Inc., Portland, OR 97220

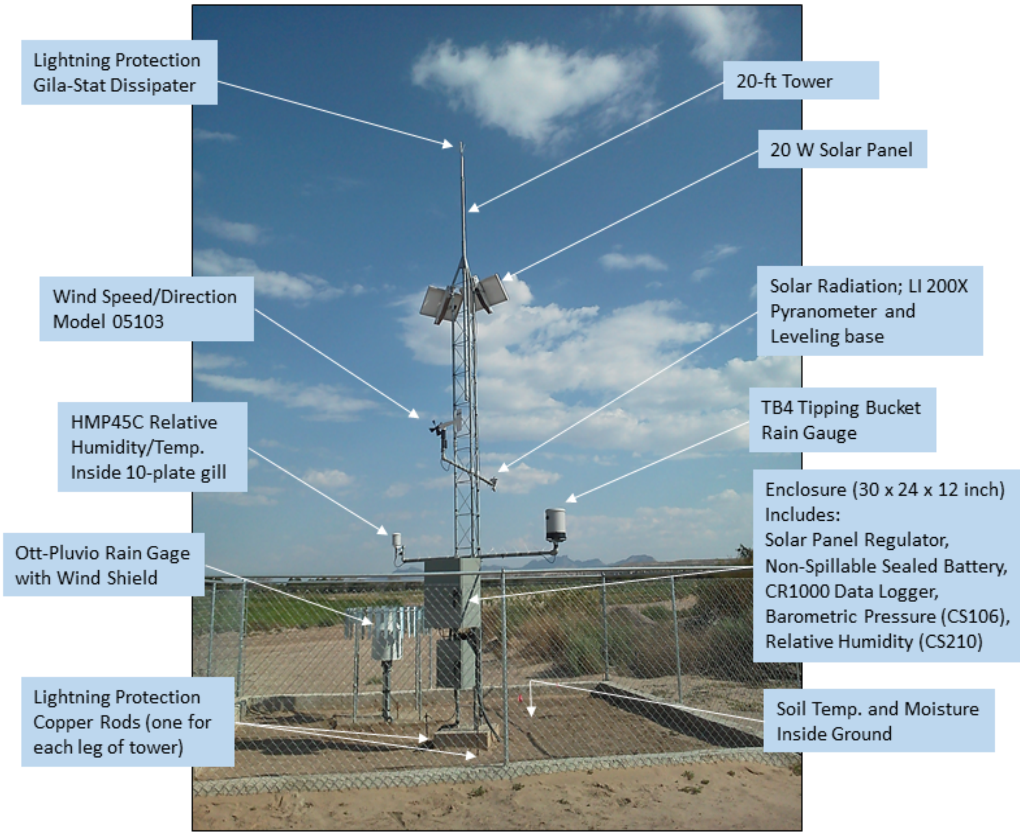

Figure 1. Sunland Park weather station.

Caballo Weather Station

Name of Station: Saltgrass
Location: Las Palomas, NM (North of Caballo Lake)
County: Sierra
State: New Mexico
Lat/Long: 33° 4' 1.53"N and 107°16'58.58"W
Elevation: 1284 m (4213 ft)

Station Installation Date: No available information
Source of Funding: Bureau of Reclamation
Contact: Salim Bawazir, Ph.D. (e-mail: abawazir@nmsu.edu); 575-646-6044 (NMSU)

Measurement	Sensor Type/Model	Sensor Accuracy	Height from Ground Surface
Wind speed and direction	Wind Monitor AQ (Model 05103)[a]	Speed: ±0.3 m/s or 1% of reading Direction: ±3°	3.4 m (134 in)
Solar radiation	LI200X Pyranometer[a]	±5% max ±3% typical	2.6 m (101 in)
Air temperature and relative humidity	HMP50 Temperature and Relative Humidity Probe INTERCAP Temp Sensor: 1000 ohm PRT	Temp: ±0.8°C (-15 TO 60°C) RH at 20°C ±3% (0 to 90% RH)	2.3 m (89 in)
Rain Gage	TR-525USW Rainfall Sensor	1.0% up to 50 mm/hr (2 in/hr)	0.1 m (6 in)
Barometric Pressure	CS105 Vaisala PTB110[a]	±1.5 mb @ -40 to 60 °C	1.1 m (42 in)
Data logger	CR1000[a]		~ 1.7 m

[a]Campbell Scientific Inc., Logan Utah, 84321;
[b] Stevens Water Monitoring Systems, Inc., Portland, OR 97220

Figure 2. Saltgrass Weather Station

South Lake (Slake) Weather Station

Name of Station: Slake [NRCS Scan type weather station]
Location: South Lake **(**Elephant Butte, NM)
County: Socorro
State: New Mexico
Lat/Long: 33° 08′ 45.52"N and 107° 11′ 03.44" W (Elephant Butte Dam)
Elevation: 1378 m (4512 ft; NAD27); 1395 m (4576 ft) (WGS 84 handheld GPS)

Station Installation Date: 7-29-2013. This station replaced the old station at the site.
Source of Funding: New Mexico EPSCoR-NSF
Contact: Salim Bawazir, Ph.D. (e-mail: abawazir@nmsu.edu); 575-646-6044 (NMSU)

Measurement	Sensor Type/Model	Sensor Accuracy	Height from Ground Surface
Wind speed and direction	Wind Monitor AQ (Model 05103)[a]	Speed: ±0.3 m/s or 1% of reading Direction: ±3°	3.18 m (125 in)
Solar radiation	LI200X Pyranometer[a]	±5% max ±3% typical	2.87 m (113 in)
Air temperature and relative humidity	HMP45C[a] Relative Humidity: Vaisala' SHUMICAP® H-chip Temp Sensor: 100 ohm PRT	Accuracy at 20°C ±2% (0 to 90% Relative Humidity) ±3% (0 to 100% Relative Humidity)	2.54 m (100 in)
Rain Gage	Rain gage model TB4[a] (0.01-in per tip)	<±2% at high precipitation rates of 500 mm/hr.	2.54 m (100 in)
Soil Moisture, Temperature and Salinity @ 2, 4, 8 & 20 in	Hydra Probes (SDI-12 Hydra Probe II)[b]	Temp.: ±0.3 °C (-10 to +55 °C) Conductivity: ±2.0% (0.01 to 1.5 S/m)	-5.08 cm (-2 in), -10.16 cm (-4 in), -20.32 cm (-8 in) and -50.8 cm (-20 in)
Barometric Pressure	CS106 Vaisala PTB110[a]	±1.5 mb@ -40 to 60 °C	~1.7 m
Data logger	CR1000[a]		~ 1.7 m
Inside Enclosure Relative Humidity	CS210 (10162)[a]	Accuracy at 25 °C: ±3% RH (10 to 90% Relative Humidity	~1.7 m

[a]Campbell Scientific Inc., Logan Utah, 84321;
[b] Stevens Water Monitoring Systems, Inc., Portland, OR 97220

Figure 3. Slake Weather Station at Elephant Butte Dam

North Lake (Nlake) Weather Station

Name of Station: Nlake [NRCS SCAN type weather station]
Location: Western side of North end of Elephant Butte Reservoir
County: Socorro
State: New Mexico
Lat/Long: 33° 17' 50.14"N and 107°11'37.88"W
Elevation: 1373 m (4504 ft)

Station Installation Date: No available information
Source of Funding: Bureau of Reclamation
Contact: Salim Bawazir, Ph.D. (e-mail: abawazir@nmsu.edu); 575-646-6044 (NMSU)

Measurement	Sensor Type/Model	Sensor Accuracy	Height from Ground Surface
Wind speed and direction	Wind Monitor AQ (Model 05103)[a]	Speed: ±0.3 m/s or 1% of reading Direction: ±3^o	3.38 m (133 in)
Solar radiation	LI200X Pyranometer[a]	±5% max ±3% typical	3.12 m (123 in)
Air temperature and relative humidity	HMP45C[a] Relative Humidity: Vaisala' SHUMICAP® H-chip Temp Sensor: 100 ohm PRT	Accuracy at 20^{o}C ±2% (0 to 90% Relative Humidity) ±3% (0 to 100% Relative Humidity)	2.41 m (95 in)
Rain Gage	Rain gage model TB4[a] (0.01-in per tip)	<±2% at high precipitation rates of 500 mm/hr.	2.44 m (96 in)
Soil Moisture, Temperature and Salinity @ 4	Hydra Probes (SDI-12 Hydra Probe II)[b]	Temp.: ±0.3 ^{o}C (-10 to +55 ^{o}C) Conductivity: ±2.0% (0.01 to 1.5 S/m)	-0.10 m (-4 in)
Soil Moisture, Temperature @ 10 cm	T107	Temp.: ±0.2 ^{o}C (-35 to 50 ^{o}C)	0.10m (-3.9 in)
Barometric Pressure	CS106 Vaisala PTB110[a]	±1.5 mb@ -40 to 60 ^{o}C	1.67 m (66 in)
Data logger	CR1000[a]		~ 1.7 m (70 in)
Inside Enclosure Relative Humidity	CS210 (10162)[a]	Accuracy at 25 ^{o}C: ±3% RH (10 to 90% Relative Humidity	~1.7 m (70 in)

[a]Campbell Scientific Inc., Logan Utah, 84321;
[b] Stevens Water Monitoring Systems, Inc., Portland, OR 97220

Figure 4. North Lake Weather Station

South Bosque Weather Station
Name of Station: South Bosque
Location: Bosque National Wildlife Refuge
County: Socorro
State: New Mexico
Lat/Long: 33° 46' 35.35"N and 106° 52' 49.43"W
Elevation: 1374 m (4508 ft)

Station Installation Date: No available information
Source of Funding: Bureau of Reclamation
Contact: Salim Bawazir, Ph.D. (e-mail: abawazir@nmsu.edu); 575-646-6044 (NMSU)

Measurement	Sensor Type/Model	Sensor Accuracy	Height from Ground Surface
Wind speed and direction	Wind Monitor AQ (Model 05103)[a]	Speed: ±0.3 m/s or 1% of reading Direction: ±3°	3.76 m (148 in)
Solar radiation	LI200X Pyranometer[a]	±5% max ±3% typical	3.38 m (133 in)
Air temperature and relative humidity	S1650009 Humitter	Accuracy at 20°C ±2% (0 to 90% Relative Humidity) ±3% (0 to 100% Relative Humidity)	1.35 m (53 in)
Rain Gage	TR-525I	<±2% at high precipitation rates of 500 mm/hr.	0.48 m (19 in)
Soil Moisture, Temperature @ 10 cm	T107	Temp.: ±0.2 °C (-35 to 50 °C)	0.10m (-3.9 in)
Soil Moisture, Temperature and Salinity @ 2, 4, 8 & 20 in	Hydra Probes (SDI-12 Hydra Probe II)[b]	Temp.: ±0.3 °C (-10 to +55 °C) Conductivity: ±2.0% (0.01 to 1.5 S/m)	-5.08 cm (-2 in), -10.16 cm (-4 in), -20.32 cm (-8 in) and -50.8 cm (-20 in)
Barometric Pressure	CS105 Vaisala PTB101B	±1.5 mb@ -40 to 60 °C	1.63 m (64 in)
Data logger	CR1000[a]		~ 1.7 m (70 in)
Inside Enclosure Relative Humidity	CS210 (10162)[a]	Accuracy at 25 °C: ±3% RH (10 to 90% Relative Humidity	~1.7 m (70 in)

[a]Campbell Scientific Inc., Logan Utah, 84321;
[b] Stevens Water Monitoring Systems, Inc., Portland, OR 97220

Figure 5. South Bosque Weather Station

Gherardi Weather Station
Name of Station: Gherardi
Location: Albuquerque
County: Bernalillo
State: New Mexico
Lat/Long: 34° 58' 4.25"N and 106° 41' 57.85"W
Elevation: 1497 m (4912 ft)

Station Installation Date: No Available information
Source of Funding: EPSCORE/ Office of State Engineer
Contact: Salim Bawazir, Ph.D. (e-mail: abawazir@nmsu.edu); 575-646-6044 (NMSU)

Measurement	Sensor Type/Model	Sensor Accuracy	Height from Ground Surface
Wind speed and direction	Wind Monitor AQ (Model 05103)[a]	Speed: ±0.3 m/s or 1% of reading Direction: ±3^{o}	3.18 m (125 in)
Solar radiation	LI200X Pyranometer[a]	±5% max ±3% typical	2.56 m (101 in)
Air temperature and relative humidity	CS215	Accuracy at 20^{o}C ±2% (0 to 90% Relative Humidity) ±3% (0 to 100% Relative Humidity)	2.01 m (79 in)
Rain Gage	Rain gage model TB4[a] (0.01-in per tip)	<±2% at high precipitation rates of 500 mm/hr.	0.78 m (31 in)
Soil Moisture, Temperature @ 10 cm	T107	Temp.: ±0.2 ^{o}C (-35 to 50 ^{o}C)	0.10m (-3.9 in)
Barometric Pressure	CS105 Vaisala PTB110[a]	±1.5 mb@ -40 to 60 ^{o}C	1.27 m (50 in)
Data logger	CR1000[a]		~1.7 m (70 in)
Inside Enclosure Relative Humidity	CS210 (10162)[a]	Accuracy at 25 ^{o}C: ±3% RH (10 to 90% Relative Humidity	~1.7 m (70 in)

[a]Campbell Scientific Inc., Logan Utah, 84321;
[b] Stevens Water Monitoring Systems, Inc., Portland, OR 97220

Figure 6. Gherardi Weather Station

James Weather Station

Name of Station: James
Location: South Albuquerque
County: Bernalillo
State: New Mexico
Lat/Long: 34° 59' 28.86"N and 106° 42' 30.49"W
Elevation: 1500 m (4921 ft)

Station Installation Date: No available information
Source of Funding: EPSCORE/Office of State Engineer
Contact: Salim Bawazir, Ph.D. (e-mail: abawazir@nmsu.edu); 575-646-6044 (NMSU)

Measurement	Sensor Type/Model	Sensor Accuracy	Height from Ground Surface
Wind speed and direction	Wind Monitor AQ (Model 05103)[a]	Speed: ±0.3 m/s or 1% of reading Direction: ±3°	116 in (2.95 m)
Solar radiation	LI200X Pyranometer[a]	±5% max ±3% typical	97 in
Air temperature and relative humidity	CS215	Accuracy at 20°C ±2% (0 to 90% Relative Humidity) ±3% (0 to 100% Relative Humidity)	79 in
Rain Gage	Rain gage model TB4[a] (0.01-in per tip)	<±2% at high precipitation rates of 500 mm/hr.	34 in
Soil Moisture, Temperature @ 10 cm	T107	Temp.: ±0.2 °C (-35 to 50 °C)	-3.9 in
Barometric Pressure	CS105 Vaisala PTB110[a]	±1.5 mb@ -40 to 60 °C	46in
Data logger	CR1000[a]		~ 70 in
Inside Enclosure Relative Humidity	CS210 (10162)[a]	Accuracy at 25 °C: ±3% RH (10 to 90% Relative Humidity	~ 70 in

[a]Campbell Scientific Inc., Logan Utah, 84321;
[b] Stevens Water Monitoring Systems, Inc., Portland, OR 97220

Figure 7. James Weather Station

Who Could Benefit From These Results

The work conducted in this project will benefit water management agencies including the Middle Rio Grande Conservancy and Elephant Butte Irrigation districts, US Geological Survey, US Bureau of Reclamation, Natural Resources Conservation Service, and Fish and Wildlife. Other beneficiaries include farmers, researchers, climatologists, and others.

Presentations made on this project

The following poster was presented at the NM WRRI's 61st Annual NM Water Conference at Silver City, NM:

> Gibson, Garrett, Bawazir, A. Salim, and Solis, Juan. (2016). Improved Meteorological Infrastructure for Water Management in the Middle and Lower Rio Grande, New Mexico. The NM WRRI's 61st Annual NM Water Conference, *Where Does All the Water Go? History, Hydrology and Management of New Mexico's Scarce Waters.* Silver City October 6-7, 2016.

Contributors

- Aldo Pinon-Villarreal (PhD. G, CE)
- Cantekin Kivrak (MS. G, CE)
- Ian Hewitt (Research Assist. WRRI)
- Juan Olivares (UG, CE)
- Juan Solis (PhD. G, CE)
- Pablo Soto (UG, ME)

My future career goals

I anticipate on graduating with a bachelor's degree in civil engineering in December 2018 at New Mexico State University. My goal is to pursue a career in Civil Engineering specializing in water resources. I plan to take the fundamentals of engineering exam and begin the process of achieving my professional engineering license.

Other - photos

Figure 8. Garrett Gibson installing Pluvio rain gauge at Leyendecker

Before **After**

Figure 9. Gherardi weather station before and after maintenance

Figure 10. A Relative Humidity/Temperature sensor clogged with soil (left) and cleaned (right)

Figure 11. Left: Chew marks on sensor cable. Right: Spider webs on humidity and temperature sensor.

Figure 12. Nlake Weather Station (left) and Bosque Weather Station (right)

Figure 13. Mixing concrete for installing weather station components. From Left to Right: Pablo Soto, Aldo Pinon-Villarreal, Dr. A. Salim Bawazir, and Ian Hewitt.

Figure 14. Left: Juan Solis adjusting solar radiation sensor. Right: From left to right Ian Hewitt, Garrett Gibson, Pablo Soto, Juan Solis, and Dr. A. Salim Bawazir after installation of Leyendecker climate station.

References

Allen RG, Walter IA, Elliot RL, Howell TA, Itenfisu D, Jensen ME, Snyder RL (Eds.). 2005. The ASCE Standardized Reference Evapotranspiration Equation. American Society of Civil Engineers: Reston: Virginia.

Appendix. Climate Data

Monthly means data from Sunland Park weather station

Year	Month	Tmx	Tmn	RHmx	RHmn	Rs	Uavg	ET_sz	Days
		deg. C	deg. C	%	%	MJ/m²	m/s	mm	N
2016	1	16.03	-2.95	83.90	19.76	14.60	1.44	1.89	25
2016	2	20.98	-1.42	73.76	11.56	18.03	1.46	2.69	29
2016	3	24.86	3.80	60.46	10.44	22.00	2.04	4.11	31
2016	4	26.47	6.58	69.73	11.12	25.96	1.90	5.15	30
2016	5	30.42	11.35	63.94	11.45	28.02	2.23	6.06	31
2016	6	36.33	18.81	65.93	13.64	27.85	2.03	6.51	30
2016	7	38.23	20.90	70.14	14.49	27.20	1.69	6.35	31
2016	8	33.49	18.91	83.78	23.81	22.78	1.76	5.32	31
2016	9	31.58	16.60	83.56	23.14	20.18	1.79	4.40	30
2016	10	29.88	10.15	81.09	17.54	18.68	1.34	3.20	31
2016	11	21.02	4.68	77.49	23.99	13.49	1.90	2.14	30
2016	12	16.41	0.26	85.40	31.42	10.82	1.55	1.49	31
2017	1	16.00	-0.23	87.35	27.30	13.01	1.64	1.86	31
2017	2	21.06	1.76	79.75	17.87	16.54	1.59	2.90	28
2017	3	26.89	5.52	65.31	10.79	21.96	1.82	4.51	31
2017	4	27.42	7.23	66.96	9.08	25.17	2.04	5.46	15
2017	5								
2017	6								
2017	7								
2017	8								
2017	9								
2017	10								
2017	11								
2017	12								

Tmx = Maximum Air Temperature
Tmn = Minimum Air Temperature
RHmx = Maximum Relative Humidity
RHmn = Minimum Relative Humidity
Rs = Solar Radiation
ET_sz = ET referenced to grass
Uavg = Windspeed

Monthly means from saltgrass weather station

Year	Month	Tmx	Tmn	RHmx	RHmn	Rs	Uavg	ET_sz	Days
		deg. C	deg. C	%	%	MJ/m²	m/s	mm	N
2016	1	14.29	-5.61	84.25	21.49	13.06	2.00	2.27	31
2016	2	20.75	-3.55	67.08	10.68	18.32	2.13	3.55	29
2016	3	23.91	1.37	55.34	9.55	21.93	2.95	5.24	31
2016	4	24.98	4.50	75.52	11.53	25.19	2.90	5.80	30
2016	5	28.68	7.16	75.35	11.52	27.41	3.00	6.88	31
2016	6	36.08	14.00	72.44	11.64	27.30	2.34	7.54	29
2016	7	37.38	17.02	76.14	13.96	25.75	1.95	7.00	31
2016	8	32.38	16.52	88.05	23.61	22.49	1.83	5.54	31
2016	9	30.58	13.24	88.66	22.99	19.52	1.76	4.67	30
2016	10	29.07	6.97	88.27	16.68	17.96	1.44	3.75	31
2016	11	19.26	2.02	88.18	25.69	12.88	1.85	2.44	30
2016	12	15.79	-2.11	84.42	26.04	11.03	1.88	2.05	31
2017	1	14.48	-2.46	88.46	28.07	12.21	2.08	2.11	31
2017	2	19.86	-1.23	87.40	18.34	16.29	2.21	3.24	28
2017	3	25.13	2.24	71.94	11.29	21.75	2.37	4.85	31
2017	4	26.81	3.62	75.02	10.03	26.02	2.57	5.94	30
2017	5	29.53	7.20	69.06	10.49	28.59	2.44	6.73	31
2017	6	35.64	11.02	77.29	9.95	27.99	1.86	7.00	20
2017	7								
2017	8								
2017	9								
2017	10								
2017	11								
2017	12								

Tmx = Maximum Air Temperature
Tmn = Minimum Air Temperature
RHmx = Maximum Relative Humidity
RHmn = Minimum Relative Humidity
Rs = Solar Radiation
ET_sz = ET referenced to grass
Uavg = Windspeed

Monthly means from Slake weather station

Year	Month	Tmx	Tmn	RHmx	RHmn	Rs	Uavg	ET_sz	Days
		deg. C	deg. C	%	%	MJ/m²	m/s	mm	N
2016	1	23.22	4.07	50.13	9.13	--	2.30	--	20
2016	2	24.06	7.13	39.40	8.37	--	3.32	--	29
2016	3	24.66	9.25	54.47	10.30	--	3.16	--	31
2016	4	28.33	13.55	48.04	10.04	--	3.61	--	30
2016	5	35.47	20.13	47.76	10.03	--	2.93	--	31
2016	6	37.31	22.96	46.95	11.41	--	2.75	--	30
2016	7	33.60	20.72	74.41	21.54	--	2.70	--	11
2016	8	30.49	18.06	73.21	22.48	22.14	2.34	5.30	21
2016	9	29.77	16.55	73.27	22.05	19.77	2.48	4.58	30
2016	10	27.97	12.57	61.93	16.29	17.89	2.25	3.55	31
2016	11	17.80	5.92	74.14	26.70	12.13	2.34	2.12	30
2016	12	14.49	1.75	72.98	27.02	10.55	2.35	1.73	31
2017	1	13.42	1.21	75.12	28.75	11.68	2.83	2.27	31
2017	2	18.57	3.53	69.49	18.90	15.72	2.78	3.43	28
2017	3	23.77	7.34	51.47	11.56	21.66	2.99	5.15	31
2017	4	25.55	9.50	47.71	10.08	25.92	3.34	6.49	30
2017	5	28.34	13.78	41.77	10.47	28.30	3.31	7.53	31
2017	6	35.08	18.95	47.14	9.54	28.45	2.69	8.11	20
2017	7								
2017	8								
2017	9								
2017	10								
2017	11								
2017	12								

Tmx = Maximum Air Temperature
Tmn = Minimum Air Temperature
RHmx = Maximum Relative Humidity
RHmn = Minimum Relative Humidity
Rs = Solar Radiation
ET_sz = ET referenced to grass
Uavg = Windspeed

Monthly means from Nlake weather station

Year	Month	Tmx	Tmn	RHmx	RHmn	Rs	Uavg	ET_sz	Days
		deg. C	deg. C	%	%	MJ/m²	m/s	mm	N
2016	1								
2016	2								
2016	3								
2016	4								
2016	5								
2016	6	36.69	19.97	47.54	11.76	26.14	2.44	6.53	15
2016	7	37.50	21.19	52.07	12.48	26.45	2.43	6.56	31
2016	8	32.09	17.56	78.98	21.60	22.49	2.13	5.40	31
2016	9	30.20	15.05	78.76	21.88	19.96	2.10	4.47	30
2016	10	28.31	10.97	62.60	15.79	17.90	1.95	3.40	31
2016	11	18.18	4.23	77.00	25.69	12.52	2.11	2.03	30
2016	12	14.33	-0.15	76.75	27.04	10.84	2.02	1.60	31
2017	1	13.53	0.14	77.97	28.24	11.50	2.36	2.04	31
2017	2	18.70	2.00	72.86	18.75	15.75	2.39	3.13	28
2017	3	24.24	5.50	50.78	11.48	21.58	2.51	4.84	31
2017	4	26.04	7.61	50.35	10.12	25.63	2.86	6.13	30
2017	5	29.05	11.65	43.97	10.18	27.98	2.88	7.17	31
2017	6	35.85	17.05	46.79	9.33	28.11	2.45	7.87	20
2017	7								
2017	8								
2017	9								
2017	10								
2017	11								
2017	12								

Tmx = Maximum Air Temperature
Tmn = Minimum Air Temperature
RHmx = Maximum Relative Humidity
RHmn = Minimum Relative Humidity
Rs = Solar Radiation
ET_sz = ET referenced to grass
Uavg = Windspeed

Monthly means from South Bosque weather station

Year	Month	Tmx	Tmn	RHmx	RHmn	Rs	Uavg	ET_sz	Days
		deg. C	deg. C	%	%	MJ/m²	m/s	mm	N
2016	1	13.12	-6.80	88.50	24.61	12.68	1.39	1.66	31
2016	2	19.84	-6.48	83.44	12.53	17.92	1.33	2.64	29
2016	3	24.24	-1.75	67.45	8.65	21.89	2.00	4.40	31
2016	4	24.64	2.29	77.10	12.83	25.70	2.11	5.19	29
2016	5	28.44	5.28	75.79	12.54	30.23	2.67	6.87	30
2016	6	36.58	12.38	73.80	10.63	30.34	1.71	7.24	30
2016	7	37.95	14.99	73.94	12.10	28.66	1.64	7.06	31
2016	8	32.89	14.22	87.50	19.85	24.04	1.72	5.69	30
2016	9	31.10	10.88	87.26	19.48	20.99	1.78	4.78	30
2016	10	28.79	3.96	85.35	15.79	11.41	1.43	3.17	31
2016	11	18.37	0.10	84.71	24.45	10.40	1.94	2.21	30
2016	12	13.99	-4.66	85.09	26.93	9.80	1.93	1.73	31
2017	1	13.36	-3.88	87.11	27.59	12.55	2.04	1.90	31
2017	2	18.81	-2.57	86.47	18.53	15.64	2.02	2.87	28
2017	3	24.54	-0.26	76.63	10.99	21.03	2.40	4.59	31
2017	4	25.72	2.61	80.38	11.45	24.74	2.44	5.40	30
2017	5	29.39	6.00	75.86	10.12	28.90	2.54	6.73	31
2017	6	35.04	9.56	81.42	10.11	30.04	1.77	7.08	15
2017	7								
2017	8								
2017	9								
2017	10								
2017	11								
2017	12								

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ET_sz = ET referenced to grass
Uavg = Windspeed

Monthly means from Gherardi weather station

Year	Month	Tmx	Tmn	RHmx	RHmn	Rs	Uavg	ET_sz	Days
		deg. C	deg. C	%	%	MJ/m²	m/s	mm	N
2016	1	8.76	-6.15	93.63	36.18	9.82	1.27	1.16	21
2016	2								
2016	3								
2016	4								
2016	5								
2016	6	34.64	13.33	80.95	14.17	27.46	1.45	6.22	29
2016	7	35.41	15.27	82.45	16.46	26.93	1.48	6.17	31
2016	8	31.00	13.89	94.18	26.89	22.19	1.28	4.98	31
2016	9	30.05	10.09	94.97	22.84	19.34	1.23	3.98	30
2016	10	26.21	4.34	92.96	20.48	17.22	1.02	2.81	31
2016	11	17.09	-0.57	93.79	30.22	11.76	1.40	1.65	30
2016	12	12.07	-5.59	92.29	33.91	9.77	1.35	1.19	31
2017	1	11.67	-3.88	90.97	33.33	10.26	1.64	1.47	31
2017	2	16.59	-2.62	89.33	24.27	14.27	1.67	2.26	28
2017	3	22.60	0.04	75.57	14.04	20.30	1.79	3.78	31
2017	4	22.53	2.84	81.13	16.61	22.60	1.96	4.48	30
2017	5	26.28	6.24	81.28	15.14	26.27	1.76	5.39	31
2017	6	32.58	10.58	79.08	12.36	28.12	1.54	6.29	15
2017	7								
2017	8								
2017	9								
2017	10								
2017	11								
2017	12								

Tmx = Maximum Air Temperature
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RHmn = Minimum Relative Humidity
Rs = Solar Radiation
ET_sz = ET referenced to grass
Uavg = Windspeed

Monthly means from James weather station

Year	Month	Tmx	Tmn	RHmx	RHmn	Rs	Uavg	ET_sz	Days
		deg. C	deg. C	%	%	MJ/m²	m/s	mm	N
2016	1	9.09	-5.03	93.68	37.28	10.06	0.94	1.06	21
2016	2								
2016	3								
2016	4								
2016	5								
2016	6	34.42	14.50	78.84	14.77	27.63	0.95	6.03	28
2016	7	35.59	16.44	80.49	17.19	27.09	0.85	5.94	31
2016	8	30.64	14.97	92.61	27.97	23.36	0.85	5.05	31
2016	9	28.94	11.04	94.36	25.31	20.32	0.78	3.95	30
2016	10	26.12	5.61	90.75	21.27	17.57	0.63	2.69	31
2016	11	17.02	0.42	94.01	31.91	11.88	0.97	1.55	30
2016	12	12.46	-4.58	92.42	34.85	9.81	0.90	1.09	31
2017	1	12.09	-3.07	91.50	34.41	10.45	1.13	1.29	31
2017	2	17.06	-1.92	89.70	25.02	14.31	1.18	2.06	28
2017	3	22.95	0.91	74.37	15.05	20.61	1.37	3.52	31
2017	4	23.07	3.49	80.21	17.64	23.53	1.28	4.14	30
2017	5	27.10	7.06	79.82	15.55	26.41	1.16	5.02	31
2017	6	32.28	11.42	77.48	13.68	27.46	0.95	5.58	15
2017	7								
2017	8								
2017	9								
2017	10								
2017	11								
2017	12								

Tmx = Maximum Air Temperature
Tmn = Minimum Air Temperature
RHmx = Maximum Relative Humidity
RHmn = Minimum Relative Humidity
Rs = Solar Radiation
ET_sz = ET referenced to grass
Uavg = Windspeed

Annual precipitation measured at each weather station

Station Name	Year	Precipitation mm	No. of Days Data Collected
Sunland Park	2016 2017	119.37 38.09	360 105
Saltgrass	2016 2017	238.76 72.91	366 171
Slake	2016 2017	273.30 95.75	325 171
Nlake	2016 2017	178.57 75.18	199 171
South Bosque	2016 2017	206.50 87.12	366 166
Gherardi	2016 2017	192.80 94.49	234 166
James	2016 2017	166.12 98.56	233 166