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Technical Memorandum No. ENV-2019-087

Supplemental Agricultural Irrigation Demand Estimates for the Upper Red River Basin Study

Prepared for:

Oklahoma-Texas Area Office

Great Plains Region

September 2019

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

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Technical Service Center, Denver, Colorado
Sedimentation and River Hydraulics Group, 86-68240
Technical Memorandum ENV-2019-087

Supplemental Agricultural Irrigation Demand Estimates for the Upper Red River Basin

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Acronyms and Abbreviations

Basin Study	Upper Red River Basin Study
CDL	cropland data layer
CT	central tendency
ET	evapotranspiration
ETo	reference evapotranspiration
ETc	crop evapotranspiration
GCM	global climate or general circulation model
GIS	geographic information system
HUC8	eight-digit Hydrologic Unit Code
LWW	less warm-wetter
NIWR	net irrigation water requirement
OTAO	Oklahoma-Texas Area Office
P	precipitation
Reclamation	Bureau of Reclamation
T	temperature
TSC	Technical Service Center
USDA	U.S. Department of Agriculture
WD	Warm-dryer

Table of Contents

List of Figures

List of Tables

1 Introduction

This technical memorandum presents estimates of historical and future agricultural irrigation demands in the Upper Red River Basin. The Bureau of Reclamation's (Reclamation) Oklahoma-Texas Area Office (OTAO) recently requested Reclamation's Technical Service Center (TSC) to develop irrigation demand estimates for two specific areas within the basin as part of the ongoing Upper Red River Basin Study. As these estimates were being developed, errors were discovered in the basin-wide estimates previously developed and reported by the TSC (Reclamation, 2017). The previously reported basin-wide estimates have been corrected and are presented in addition to the recently requested estimates.

It is noted that OTAO requested that this document reference Reclamation (2017) as much as possible and not duplicate its contents including discussions, figures, tables, etc.

2 Background

The Upper Red River Basin Study (Basin Study) is being conducted under Reclamation's West-Wide Risk Assessment Program. It is intended to consider future water supply and demand conditions and develop adaptation strategies to address gaps in supply/demand. Figure 1 of Reclamation (2017) is a location map that shows the Upper Red River Basin, surface water and groundwater sources, and the Lugert-Altus Irrigation District.

One component of the Basin Study is to estimate future agricultural irrigation demands under changing climate. Reclamation (2017) provides a description of the methods used to develop historical and future estimates for all currently irrigated agricultural lands in the basin. This includes how cropping patterns were identified, descriptions of meteorological data and global climate model (GCM, also general circulation model) projections used, and a brief description of the computer modeling program used to estimate evapotranspiration (ET) irrigation demands (ET Demands Model). A detailed description of the model is provided in Reclamation (2015).

In summary, the basin-wide estimates were developed for the historical baseline period 1950 to 1999 and future demands were estimated for 2060. The future demands were developed for three climate change scenarios: (1) warmer-dryer (WD); (2) central tendency (CT), and (3) less warm-wetter (LWW). Average annual values were estimated for each of the basin's seven eight-digit Hydrologic Unit Code (HUC8) drainage areas (see Figure 1 on page 3). The values were calculated as the area-weighted average for all crop types within each sub-basin. The process includes developing estimates of daily reference ET (ETo) for each sub-basin and crop ET (ETc) for all crops within each sub-basin. Estimates of net

irrigation water requirement (NIWR) are calculated by the model based on ETc and effective precipitation.

Since the basin-wide results were developed and reported in 2017, OTAO requested estimates of irrigation demands during the 2013 growing season for the areas overlying the North Fork Red River and Elk City Aquifers that are located within the Oklahoma portion of the basin (see Reclamation, 2017, Figure 1). As these estimates were being developed, errors were discovered in the crop areas used for the basin-wide estimates. The basin-wide crop area estimates have been recalculated and revised historical and future irrigation demands are included in this document along with the 2013 irrigation demand estimates for the areas overlying the aquifers discussed above.

3 Irrigation Demands

This section discusses the revised basin-wide estimates of historical and future irrigation demands and the estimates of irrigation demand during 2013 for the areas overlying the North Fork Red River Aquifer and the Elk Creek Aquifer.

3.1 Recalculation of Basin-wide Irrigation Demands

Reclamation (2017) discusses that estimates of irrigated croplands are based on the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service data as reported for 2013.[1] This data source includes what is known as the Cropland Data Layer (CDL) which is well suited for the purposes of this analysis since the croplands are mapped. However, these data do not differentiate between cropped areas that are irrigated versus those not irrigated, so other information was used to estimate the portion of the CDL croplands that are irrigated.

Since geographic information system (GIS) shape files are readily available for water rights permitted lands in Oklahoma, all permitted crop lands were assumed to be irrigated. This was accomplished by overlaying the CDL and water rights GIS shape files. For Texas, the USDA county-based 2012 Census of Agriculture data (USDA, 2014) were used by first calculating the ratio of census-reported irrigated crop lands to CDL total crop lands for each county. The county ratios were then applied uniformly to sub-basin CDL croplands in the respective county.

Reclamation (2017) describes the historical meteorological data input to the ET Demands Model and the source of the soils information that is also input.

[1] https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php

The errors discovered in Reclamation (2017) are associated with the ratios calculated for the Texas counties and poor accounting of two crops on the same area ("double-cropped" areas) throughout the basin. The corrected irrigated cropland estimates are summarized in Table 1.

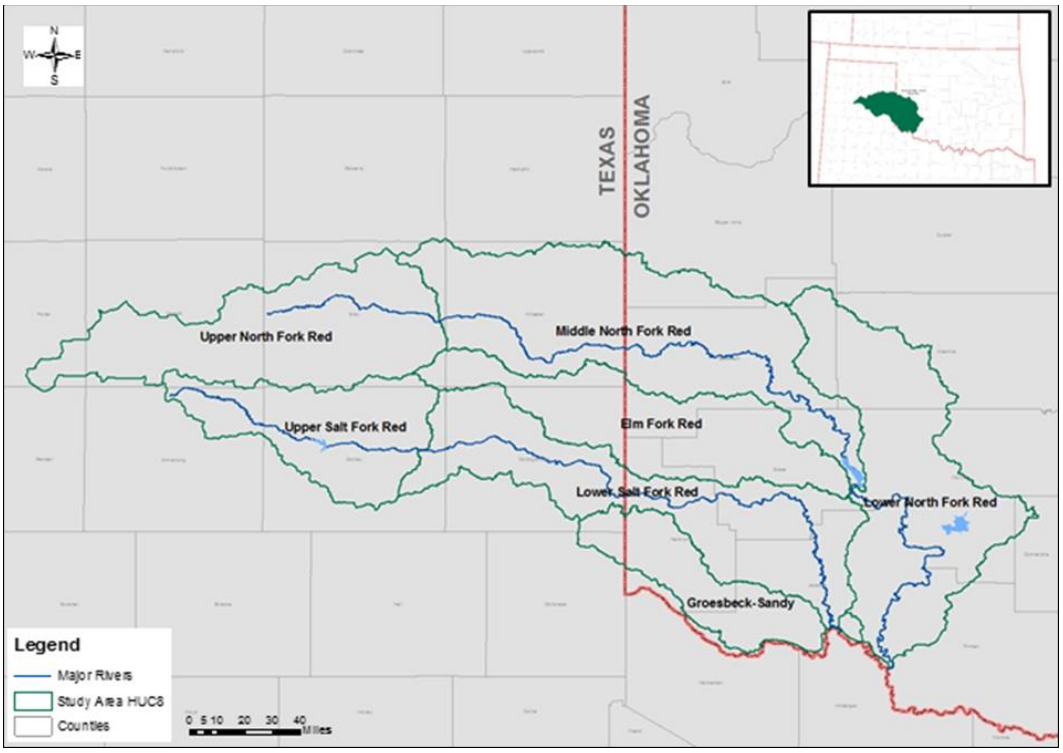

Figure 1 - Eight-digit Hydrologic Unit Code (HUC8) sub-basins

Table 1 – Eight-digit Hydrologic Unit Code (HUC8) Sub-basin number designation, names, total areas and estimated irrigated crop areas

HUC Number	HUC Name	Total Surface Area (acres)	Irrigated Crop Area (acres)
11120201	Upper Salt Fork Red	473,922	28,700
11120202	Lower Salt Fork Red	798,339	87,727
11120301	Upper North Fork Red	754,992	63,308
11120302	Middle North Fork Red	1,058,834	86,162
11120303	Lower North Fork Red	885,942	65,137
11120304	Elm Fork Red	594,190	34,050
11130101	Groesbeck-Sandy	840,695	67,571
	TOTALS	5,406,914	432,655

The revised crop data were input to the ET Demands Model along with the required meteorological and soils data to calculate estimated historical and future ETo, ETc and NIWR.

3.1.1 Historical Baseline Demands

The ET Demands model results for baseline conditions include ETo, ETc, NIWR depth, and NIWR volume for each HUC8 sub-basin. Again, for the purposes of this study, the historical baseline results presented consist of the mean annual values for 1950-1999. The results are presented graphically along with the mean annual values of the bias corrected temperature (T) and precipitation (P) values that were input to the model. Average T, P, ETo, ETc, NIWR depth, and NIWR volume are shown respectively in Figures 2 through 7. Tabulated baseline values are included along with future estimates in Section 2.1.2.

Reclamation (2017) discusses favorable comparisons that were made between the historical average ETc values from the ET Demands Model to similar estimates by others. Comparisons were also made with the revised estimates and they also matched those by others favorably. Specifically, the annual average ETc values for several crops in the Lower Salt Fork Red sub-basin were compared to 2015 ETc values reported for the Altus Mesonet Site.[2] Values were compared for 5 crops (corn, cotton, peanuts, sorghum and soybeans) and the differences in ETc estimates range from 0.9% to 8.0% with a median difference of 5.3%.

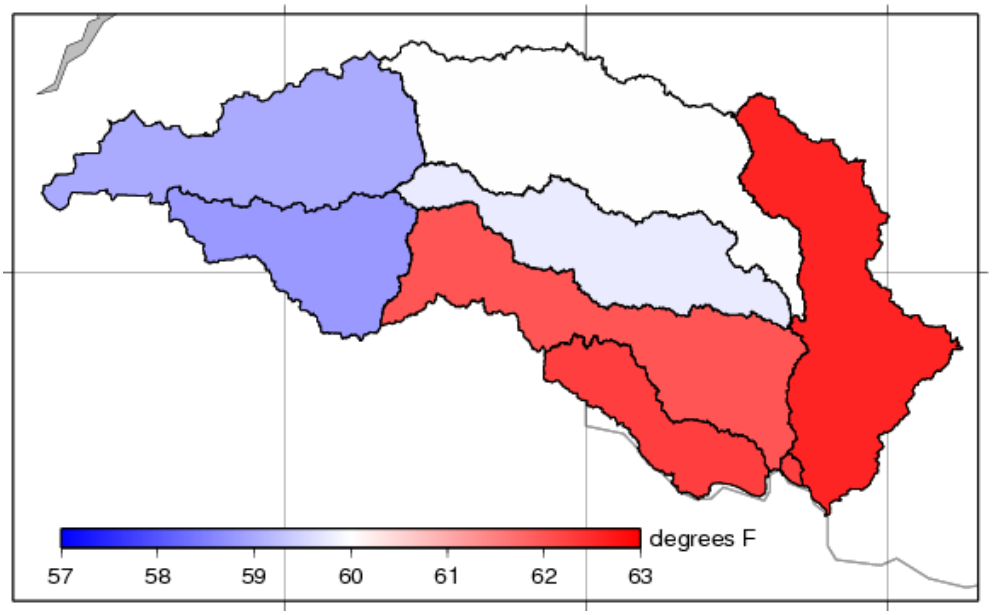

Figure 2 - Spatial distribution of historical baseline (1950-1999) mean annual temperature

[2] http://www.mesonet.org/index.php/weather/local/altu

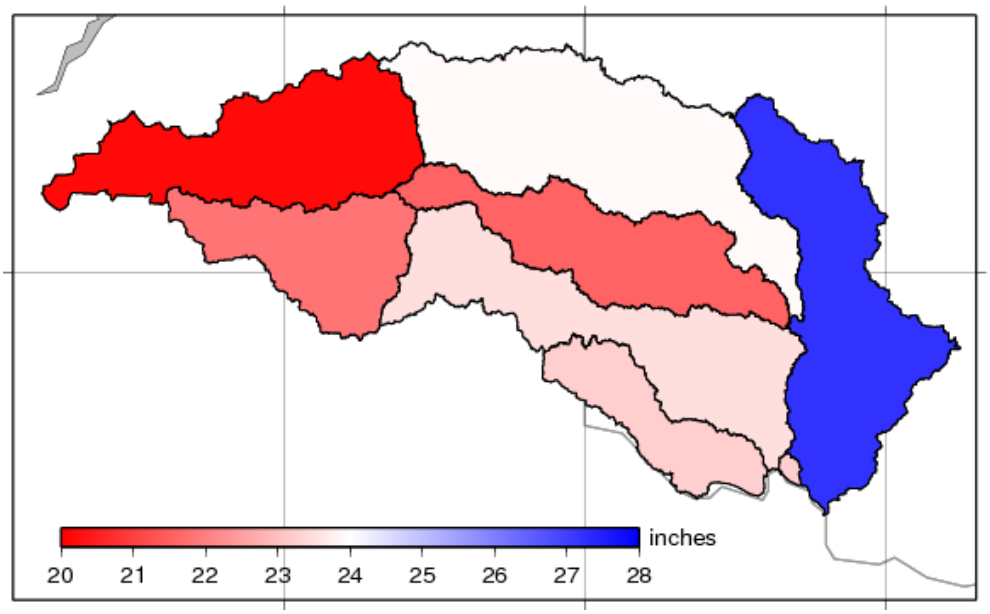

Figure 3 - Spatial distribution of historical baseline (1950-1999) mean annual precipitation

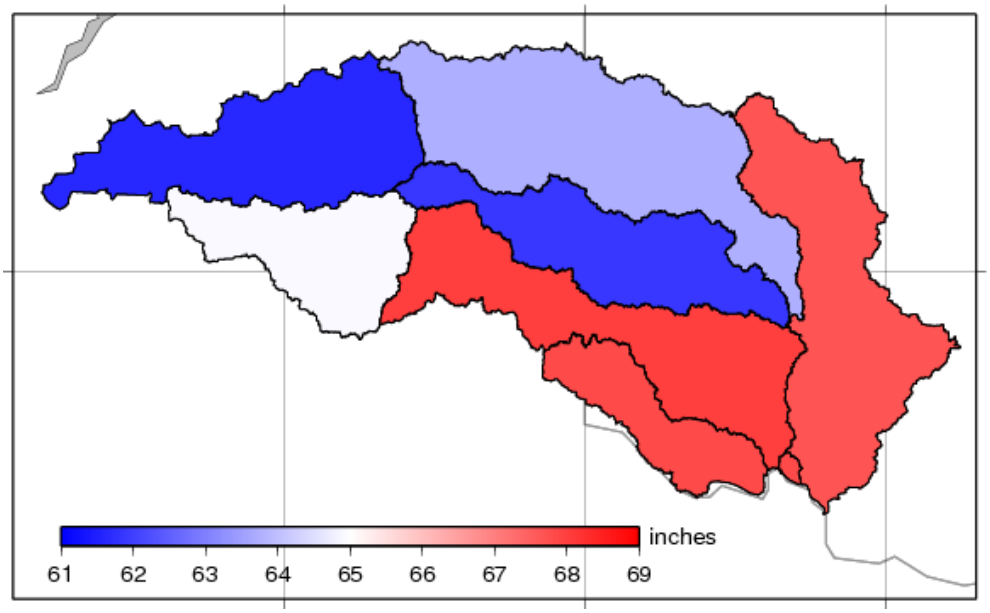

Figure 4 -Spatial distribution of historical baseline (1950-1999) reference ET

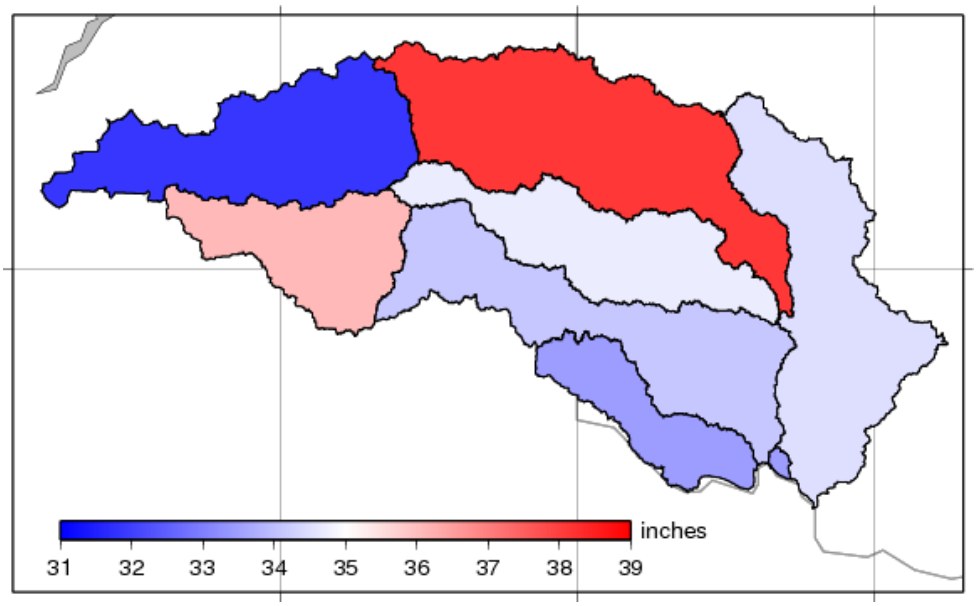

Figure 5 - Spatial distribution of historical baseline (1950-1999) crop ET

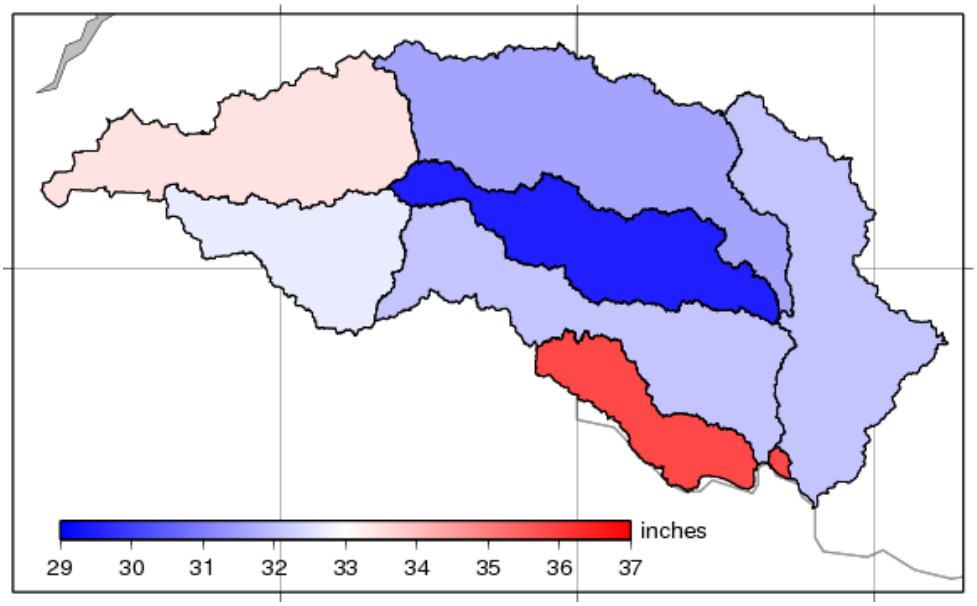

Figure 6 - Spatial distribution of historical baseline (1950-1999) mean annual NIWR depth

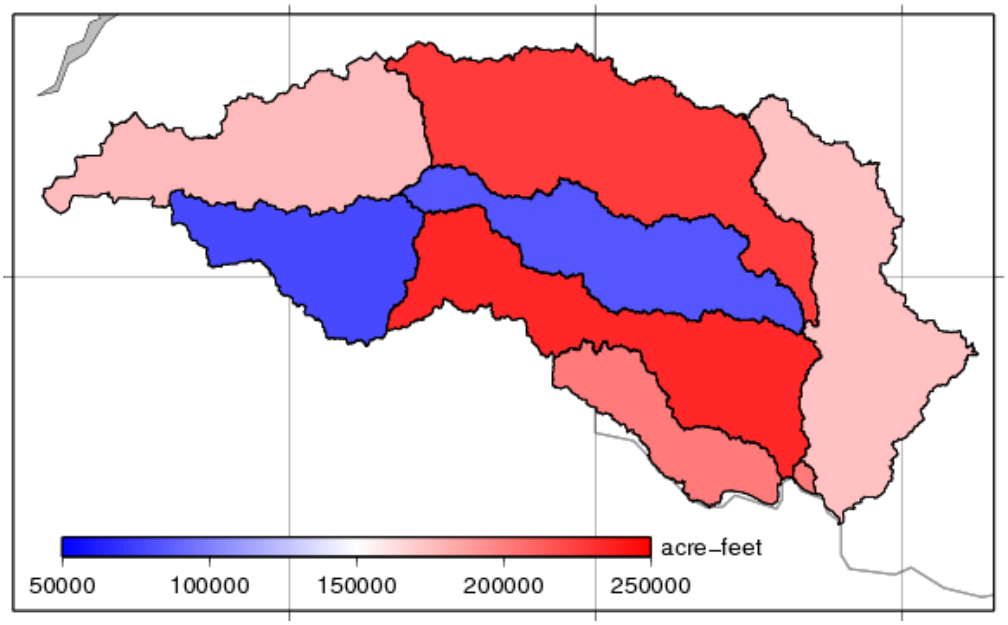

Figure 7 - Spatial distribution of historical baseline (1950-1999) mean annual NIWR volume

3.1.2 Future Demands

The future demands results are summarized on the following pages in a series of figures showing predicted changes from historical baseline values, with accompanying tables that include the historical baseline and future values and change values for each sub-basin. Predicted GCM-based changes are presented as the difference from historical baseline mean values for temperature, and percent change from baseline mean values for all other results. Again, the three future scenarios are: Less warm-wetter (LWW), Central Tendency (CT) and Warmer-drier (WD), and the future period is 2060.

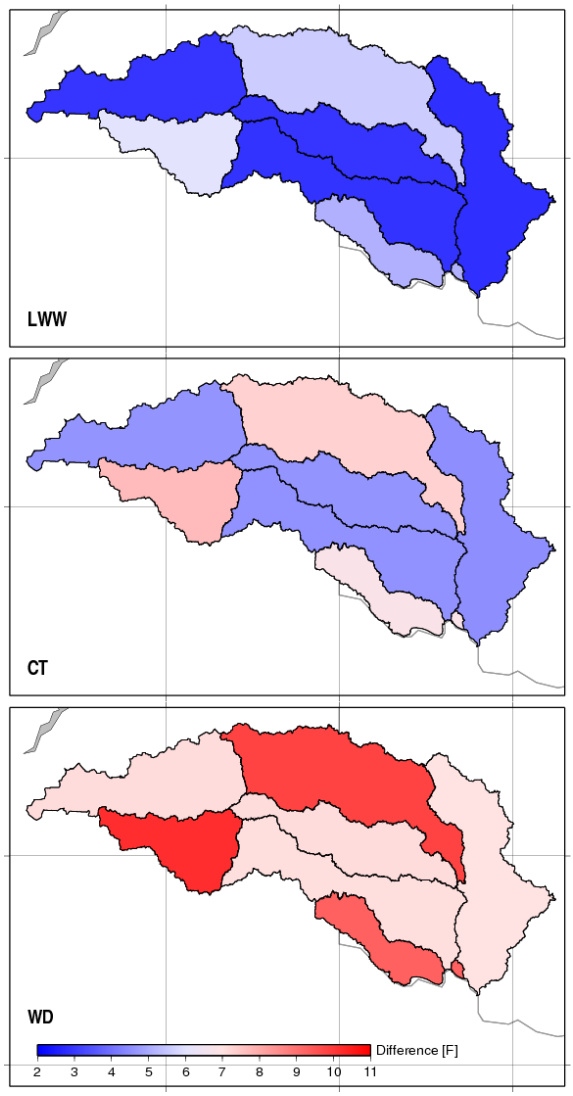

Figure 8 - Spatial distribution of projected 2060s temperature change from historical baseline

Table 2 - Summary of sub-basin average annual historical baseline and projected future temperatures and future average annual change in temperature

HUC8 Sub-basin	Average Annual Temperature (°F)				Change in Temperature (°F)		
	Baseline	LWW	CT	WD	LWW	CT	WD
11120201	58.8	64.8	66.5	69.0	6.0	7.7	10.2
11120202	62.0	64.9	66.6	69.1	2.9	4.6	7.1
11120301	59.0	61.9	63.6	66.1	2.9	4.6	7.1
11120302	60.0	65.6	67.3	69.8	5.6	7.3	9.8
11120303	62.6	65.4	67.1	69.6	2.8	4.5	7.0
11120304	59.8	62.7	64.4	66.9	2.9	4.6	7.1
11130101	62.3	67.4	69.0	71.6	5.1	6.8	9.3
Total Basin	61.0	64.8	66.5	69.0	3.9	5.5	8.0
Maximum	62.6	67.4	69.0	71.6	6.0	7.7	10.2
Minimum	58.8	61.9	63.6	66.1	2.8	4.5	7.0

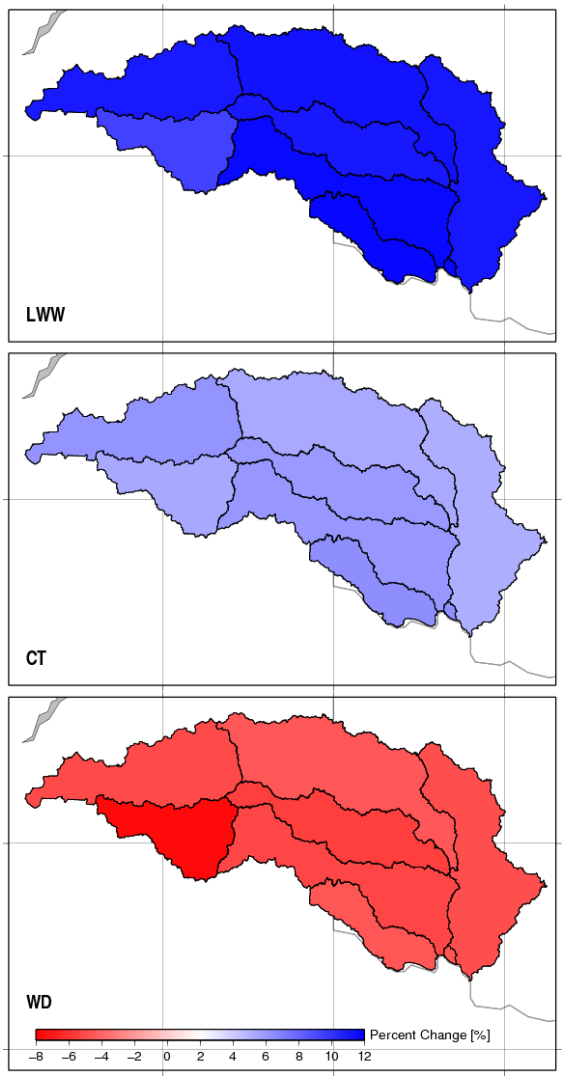

Figure 9 – Spatial distribution of projected 2060s precipitation change from historical baseline

Table 3 - Summary of sub-basin average annual historical baseline and projected future precipitation, average annual change and percent change in precipitation

HUC8 Sub-basin	Average Annual Precipitation (inches)				Change in Precipitation (inches)			Percent Change in Precipitation (%)		
	Baseline	LWW	CT	WD	LWW	CT	WD	LWW	CT	WD
11120201	21.8	23.9	23.0	20.2	2.1	1.2	-1.7	9.5%	5.4%	-7.6%
11120202	23.5	26.2	24.9	22.3	2.7	1.4	-1.2	11.6%	6.1%	-5.2%
11120301	20.1	22.4	21.4	19.1	2.2	1.3	-1.0	11.0%	6.2%	-5.1%
11120302	23.9	26.6	25.2	22.8	2.7	1.3	-1.1	11.3%	5.4%	-4.6%
11120303	27.2	30.2	28.6	25.9	3.0	1.4	-1.3	11.1%	5.2%	-4.9%
11120304	21.5	23.9	22.8	20.3	2.4	1.3	-1.2	11.0%	6.0%	-5.6%
11130101	23.2	26.0	24.7	22.2	2.7	1.5	-1.1	11.7%	6.4%	-4.6%
Total Basin	23.8	26.4	25.2	22.5	2.6	1.4	-1.3	11.1%	5.7%	-5.4%
Maximum	27.2	30.2	28.6	25.9	3.0	1.5	-1.0	11.7%	6.4%	-4.6%
Minimum	20.1	22.4	21.4	19.1	2.1	1.2	-1.7	9.5%	5.2%	-7.6%

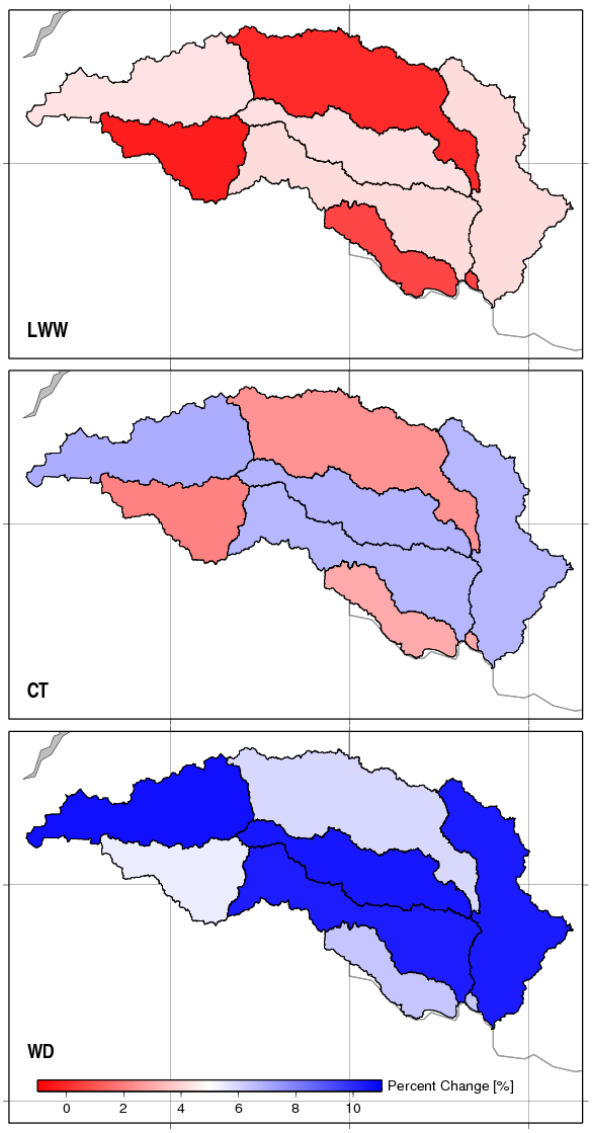

Figure 10 - Spatial distribution of projected 2060s reference ET percent change from historical baseline

Table 4 - Summary of sub-basin average annual reference ET, projected average annual change and percent change in reference ET

HUC8 Sub-basin	Average Annual Reference ET (inches)				Change in Reference ET (inches)			Percent Change in Reference ET (%)		
	Baseline	LWW	CT	WD	LWW	CT	WD	LWW	CT	WD
11120201	64.9	64.7	66.2	68.4	-0.2	1.3	3.5	-0.3%	2.1%	5.5%
11120202	68.0	70.9	72.6	75.0	2.8	4.6	7.0	4.2%	6.7%	10.3%
11120301	61.6	64.3	65.9	68.2	2.7	4.3	6.5	4.3%	6.9%	10.6%
11120302	63.7	63.7	65.3	67.5	0.0	1.6	3.8	0.0%	2.5%	5.9%
11120303	67.7	70.5	72.2	74.7	2.8	4.5	7.0	4.2%	6.7%	10.4%
11120304	61.9	64.5	66.1	68.3	2.6	4.2	6.5	4.3%	6.8%	10.5%
11130101	67.8	68.3	69.9	72.2	0.4	2.0	4.3	0.7%	3.0%	6.4%
Total Basin	65.1	66.9	68.5	70.8	1.8	3.4	5.7	2.7%	5.2%	8.8%
Maximum	68.0	70.9	72.6	75.0	2.8	4.6	7.0	4.3%	6.9%	10.6%
Minimum	61.6	63.7	65.3	67.5	-0.2	1.3	3.5	-0.3%	2.1%	5.5%

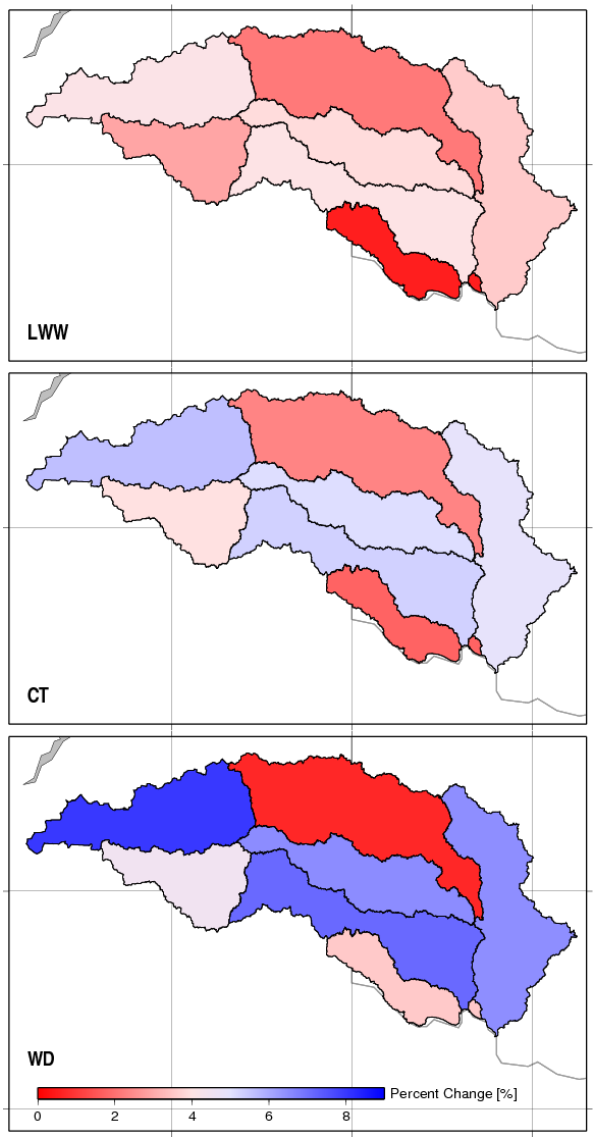

Figure 11 - Spatial distribution of projected 2060s crop ET percent change from historical baseline

Table 5 - Summary of sub-basin average historical growing season crop ET and projected future average change and percent change in crop ET

HUC8 Sub-basin	Average Growing Season Crop ET (inches)				Change in Crop ET (inches)			Percent Change in Crop ET (%)		
	Baseline	LWW	CT	WD	LWW	CT	WD	LWW	CT	WD
11120201	36.1	37.1	37.5	37.7	1.0	1.4	1.6	2.9%	4.0%	4.5%
11120202	34.1	35.5	35.9	36.6	1.4	1.8	2.4	4.1%	5.3%	7.1%
11120301	31.8	33.2	33.6	34.4	1.3	1.8	2.6	4.1%	5.6%	8.0%
11120302	38.1	39.0	39.0	38.4	0.8	0.9	0.3	2.1%	2.3%	0.7%
11120303	34.5	35.7	36.2	36.7	1.2	1.7	2.2	3.6%	4.9%	6.5%
11120304	34.7	36.0	36.4	37.0	1.3	1.8	2.3	3.9%	5.1%	6.5%
11130101	33.5	33.6	34.0	34.6	0.2	0.6	1.2	0.5%	1.8%	3.5%
Total Basin	34.5	35.6	36.0	36.4	1.1	1.5	1.9	3.2%	4.3%	5.4%
Maximum	38.1	39.0	39.0	38.4	1.4	1.8	2.6	4.1%	5.6%	8.0%
Minimum	31.8	33.2	33.6	34.4	0.2	0.6	0.3	0.5%	1.8%	0.7%

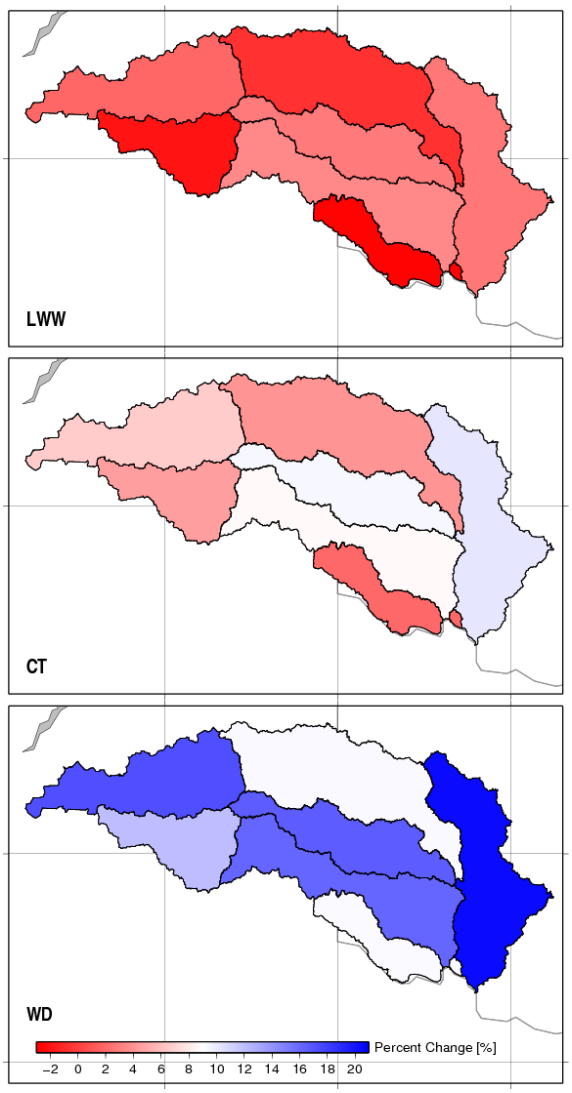

Figure 12 - Spatial distribution of projected 2060s NIWR depth (Table 6) and volume (Table 7) percent change from historical baseline

Table 6 - Summary of sub-basin historical average annual NIWR depth and projected future average annual change and percent change in NIWR depth

HUC8 Sub-basin	Average Annual NIWR Depth (inches)				Change in NIWR Depth (inches)			Percent Change in NIWR Depth (%)		
	Baseline	LWW	CT	WD	LWW	CT	WD	LWW	CT	WD
11120201	32.7	32.0	34.1	36.6	-0.7	1.4	3.9	-2.1%	4.4%	12.1%
11120202	32.1	33.2	34.9	37.3	1.1	2.8	5.2	3.5%	8.7%	16.2%
11120301	33.5	34.1	35.6	39.2	0.6	2.2	5.8	1.8%	6.6%	17.3%
11120302	31.6	31.3	32.8	34.5	-0.2	1.2	2.9	-0.7%	3.9%	9.3%
11120303	32.1	32.9	35.3	38.7	0.8	3.3	6.6	2.6%	10.2%	20.5%
11120304	29.5	30.3	32.2	34.4	0.8	2.8	4.9	2.7%	9.4%	16.7%
11130101	35.9	34.8	36.5	39.2	-1.0	0.7	3.3	-2.9%	1.9%	9.2%
Total Basin	32.9	33.3	35.3	37.9	0.4	2.4	5.0	1.3%	7.4%	15.2%
Maximum	35.9	34.8	36.5	39.2	1.1	3.3	6.6	3.5%	10.2%	20.5%
Minimum	29.5	30.3	32.2	34.4	-1.0	0.7	2.9	-2.9%	1.9%	9.2%

Table 7 - Summary of sub-basin historical average annual NIWR volume and projected future average annual change and percent chance in NIWR volume

HUC8 Sub-basin	Average Annual NIWR Volume (acre-feet)				Change in NIWR Volume (acre-feet)			Percent Change in NIWR Volume (%)		
	Baseline	LWW	CT	WD	LWW	CT	WD	LWW	CT	WD
11120201	78,139	76,517	81,599	87,582	-1,622	5,081	5,984	-2.1%	4.4%	12.1%
11120202	234,508	242,601	254,936	272,583	8,093	12,334	17,647	3.5%	8.7%	16.2%
11120301	176,498	179,729	188,063	206,988	3,231	8,334	18,925	1.8%	6.6%	17.3%
11120302	226,677	225,038	235,600	247,680	-1,639	10,562	12,080	-0.7%	3.9%	9.3%
11120303	174,078	178,559	191,796	209,831	4,481	13,237	18,034	2.6%	10.2%	20.5%
11120304	83,600	85,866	91,482	97,552	2,266	5,616	6,070	2.7%	9.4%	16.7%
11130101	201,934	196,164	205,739	220,594	-5,770	9,575	14,855	-2.9%	1.9%	9.2%
Total Basin	114,470	115,664	122,384	131,702	1,194	6,720	9,318	1.0%	6.9%	15.1%
Maximum	234,508	242,601	254,936	272,583	8,093	13,237	18,925	3.5%	10.2%	20.5%
Minimum	78,139	76,517	81,599	87,582	-5,770	5,081	5,984	-2.9%	1.9%	9.2%

3.2 Estimated Irrigation Demands for Areas Overlying Aquifers Within the Basin

The ET Demands Model was used to develop estimates of irrigation demands during 2013 for the areas overlying the North Fork Red River Aquifer and the Elk City Aquifer. The same method was used to estimate irrigated croplands as was used for the basin-wide estimates in Oklahoma (intersection of CDL and water right permitted areas). And the same method for identifying soils conditions was also used. Meteorological data used for the North Fork Red River Aquifer were from the Altus Mesonet Site[3] and data from the Bessie Mesonet Site[4] were used for the Elk City Aquifer.

3.2.1 Estimated Irrigation Demands for Area Overlying North Fork Red River Aquifer

The estimates of NIWR for each crop and associated crop areas are summarized in Table 8. The resulting crop area-weighted average for the area overlying the aquifer's estimated 33,319 acres of irrigated crops is 2.6-feet.

3.2.2 Estimated Irrigation Demands for Area Overlying Elk City Aquifer

The estimates of NIWR for each crop and associated crop areas are summarized in Table 9. The resulting crop area-weighted average for the area overlying the aquifer's estimated 17,700 acres of irrigated crops is 2.4-feet.

[3] http://www.mesonet.org/index.php/weather/local/altu
[4] http://www.mesonet.org/index.php/weather/local/bess

Table 8 - Summary of irrigation demand estimates and crop areas overlying the North Fork Red River Aquifer

Crop	Area* (acres)	NIWR Depth (feet)	NIWR Volume (acre-feet)
Alfalfa	1,630.1	4.81	7,841.8
Pasture	8,270.8	3.25	26,855.4
Corn	1.5	2.13	3.2
Sp. Grain	4,917.5	1.68	8,243.4
W. Wheat	9,545.0	2.62	25,052.6
Potatoes	403.0	1.84	742.8
Herbs	2.0	3.67	7.3
Canola	214.1	2.99	640.4
Cotton	6,519.4	2.08	13,549.9
Sorghum	562.5	0.84	474.9
Soybeans	13.1	1.88	24.6
Peanuts	1,233.7	2.29	2,827.5
Millet	6.4	1.47	9.4
Totals	33,319.1	NA	86,273.3

*The total area of irrigated land is less than the Table 8 total since some areas are double-cropped (i.e., two crops on the same area).

Table 9 - Summary irrigation demand estimates and crop areas overlying Elk City Aquifer

Crop	Area (acres)	NIWR Depth (feet)	NIWR Volume (acre-feet)
Alfalfa	231.7	4.34	1,004.6
Corn	3.1	2.10	6.5
Spring Grain	2,123.4	1.55	3,286.5
W. Wheat	13,754.3	2.54	34,888.2
Peas	1.8	0.89	1.6
Canola	43.6	2.70	117.8
Cotton	1,169.8	2.14	2,498.9
Sorghum	237.3	0.93	221.3
Peanuts	10.2	2.32	23.7
Pecans	125.2	3.08	385.7
Total	17,700.4	NA	42,434.9

*The total area of irrigated land is less than the Table 9 total since some areas are double-cropped (i.e., two crops on the same area).

4 References

Reclamation (Bureau of Reclamation), 2014. Technical Memorandum No. 86-68210-2014-01, West-Wide Climate Risk Assessments: Irrigation Demand and Reservoir Evaporation Projections, Technical Service Center, December 2014.

Reclamation (Bureau of Reclamation), 2017. Technical Memorandum No. 86-68210-17-04, Upper Red River Basin Study Estimation of Future Agricultural Irrigation and Municipal and Industrial Water Demands, Technical Service Center, October 2017.