Appendix H – Climate Assessment

Maumelle River

Maumelle, Arkansas

General Investigations Feasibility Study
Integrated Draft Feasibility Report and Environmental Impact Assessment

July 2020

US Army Corps of Engineers®
Little Rock District

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Climate Assessment

1 Introduction

The US Army Corps of Engineers (USACE) Civil Works Program and its water resources infrastructure represent a tremendous Federal investment that supports public health and safety, regional and national economic development, and national ecosystem restoration goals.

The hydrologic processes underlying this water resources management infrastructure are very sensitive to changes in climate and weather. Therefore, USACE has a compelling need to understand and adapt to climate change and variability to continue providing authorized performance despite changing conditions. The objective is to mainstream climate change adaptation in all activities to help enhance the resilience of our built and natural water-resource infrastructure and reduce its potential vulnerabilities to the effects of climate change and variability.

1.1 Climate

The Maumelle River is located in central Arkansas. It originates in the Ouachita National Forest and empties into the Arkansas River just north of Little Rock, Arkansas. Arkansas experiences a humid subtropical climate with hot humid summers that reach an average temperature of 93ºF. Winters are mild but occasionally drop to freezing.

1.2 Technical Hydrology and Hydraulic Analysis

A sediment transport analysis was performed by the Little Rock District Hydraulics and Hydrology Branch, Appendix A. Most of the technical data in this appendix was developed using the tools available in the US Army Corps of Engineers Climate Preparedness and Resilience CoP Applications Portal.

2 Qualitative Climate Assessment

Engineering and Construction Bulletin No. 2018-14 “Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects” provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate preparedness and resilience policy and ER 1105-2-101. The objective of ECB-2018-14 is to enhance USACE climate preparedness and resilience by incorporating relevant information about observed and expected climate change impacts in hydrologic analyses for planned, new, and existing USACE projects. This includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant climatic and hydrologic variables. The ECB helps support a qualitative assessment of potential climate change threats and impacts, focusing on those aspects of climate and hydrology relevant to the project's problems, opportunities, and alternatives, and include consideration of both past (observed) changes as well as projected, future (modeled) changes.

2.1 Project Location and Gaging Information

The Maumelle River Central Arkansas Water project area is located within the Hydrologic Unit Code (HUC) 1111 - Lower Arkansas Subregion. Figure 2-1 shows the HUC location map for Texas and the location of the study area. The Maumelle River runs into Lake Maumelle, the primary drinking water source for over 450,000 people in central Arkansas.

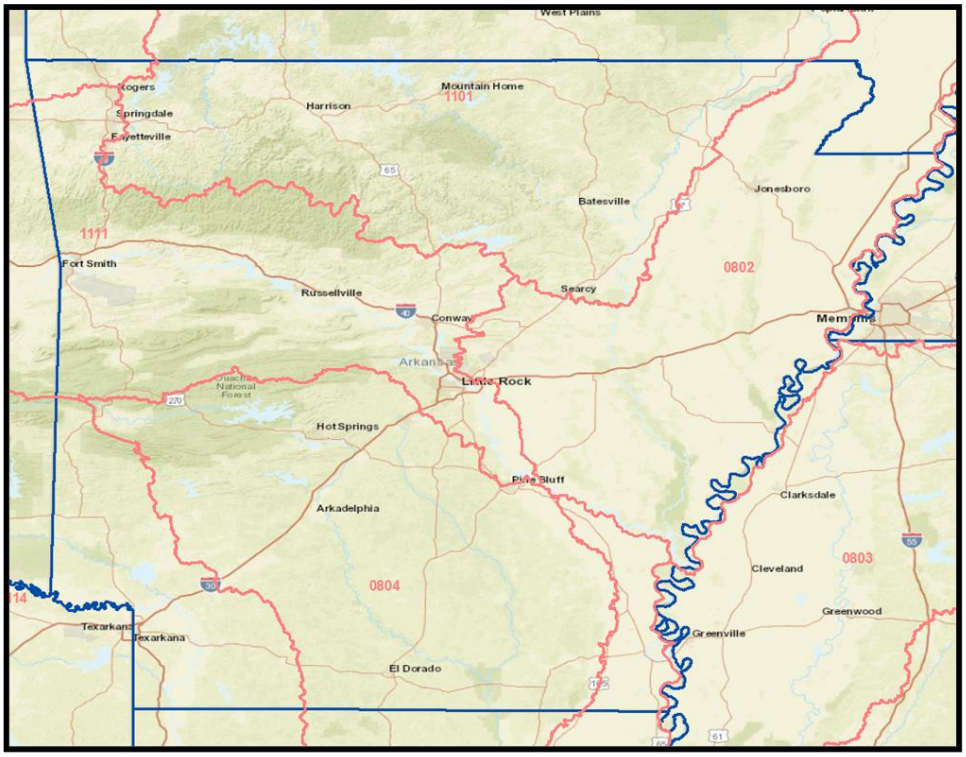


Figure 2-1 HUC Locations in Arkansas

There are several gages in the project area: USGS 07263295 Maumelle River at Williams Junction, USGS 072632962 Bringle Creek at Martindale, USGS 07263296 Maumelle River near Wye, USGS 072643966 state Hwy 10 Bridge over Lake Maumelle and 07263300 Maumelle River at Maumelle Dam at Natural Steps, AR. The drainage area for the most downstream gage, USGS 07263300, is 137 mi^2. Figure 2-2 shows gage locations.

Maumelle River is not affected by regulation. There are currently two low head concrete dams still in place.

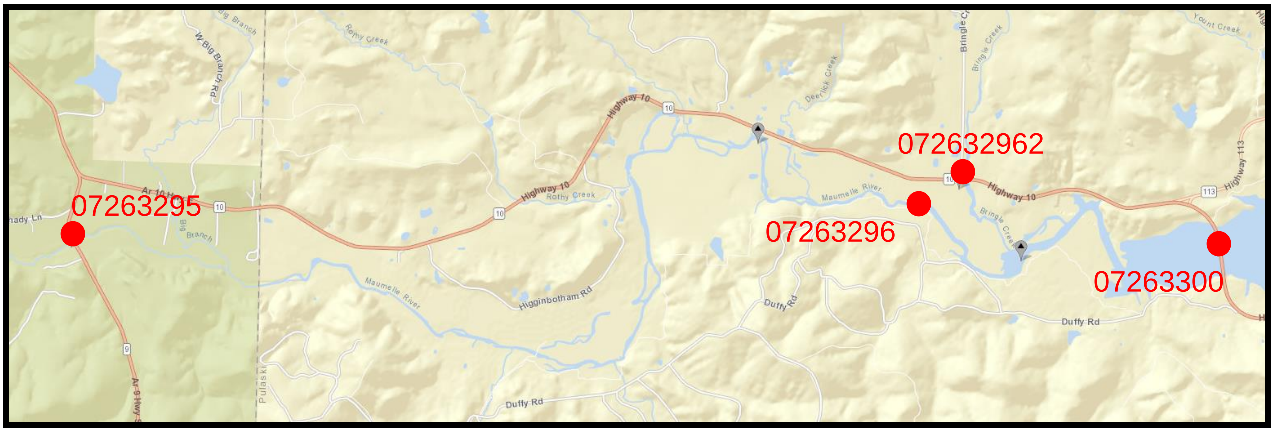


Figure 2-2 Gage Locations on Maumelle River

2.2 Literature Review

A literature search was conducted to locate information related to observed and projected climate trends.

Natural ecosystems in the southeast region will be transformed by climate change. In the southeast, reductions in the frequency and intensity of cold winter temperatures can allow tropical and subtropical species to move northward and replace more temperate species. Drought and extreme heat can result in tree mortality and can also affect aquatic and wetland ecosystems. Increases in extreme rainfall can affect wetland plant mortality because of the prolonged inundation and lack of oxygen. Natural systems in the region will have to become resilient to both too little water and too much water. (Reidmiller, 2018)

According to “Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Arkansas, White and Red Rivers Region 11” the general consensus for the for this region is a mild upward trending for average precipitation and extreme precipitation events as well as an upward trending for average streamflow, Figure 2-3.

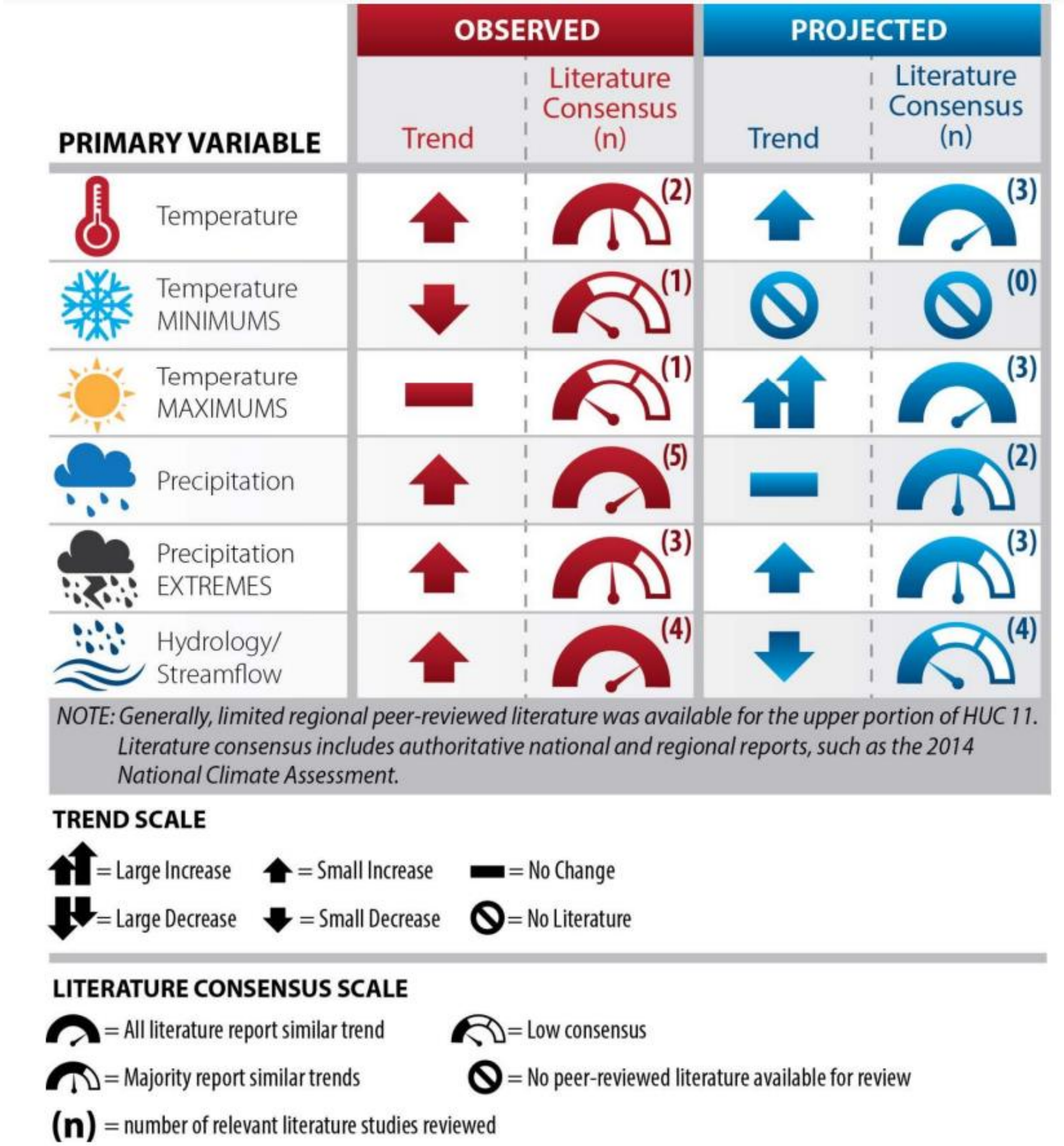


Figure 2-3 Observed and Projected Climate Trends in HUC 11 and Literary Consensus.

2.2.1 Temperature

On a larger scale, there has been an increase in the average temperature of the contiguous United States over the past several decades. Figure 2-4 show the change in annual average temperature across the United States. Table 2-1 shows an increase in the average annual temperatures in the Southeast region, though it is a comparatively smaller increase than what has occurred in the rest of the U.S.

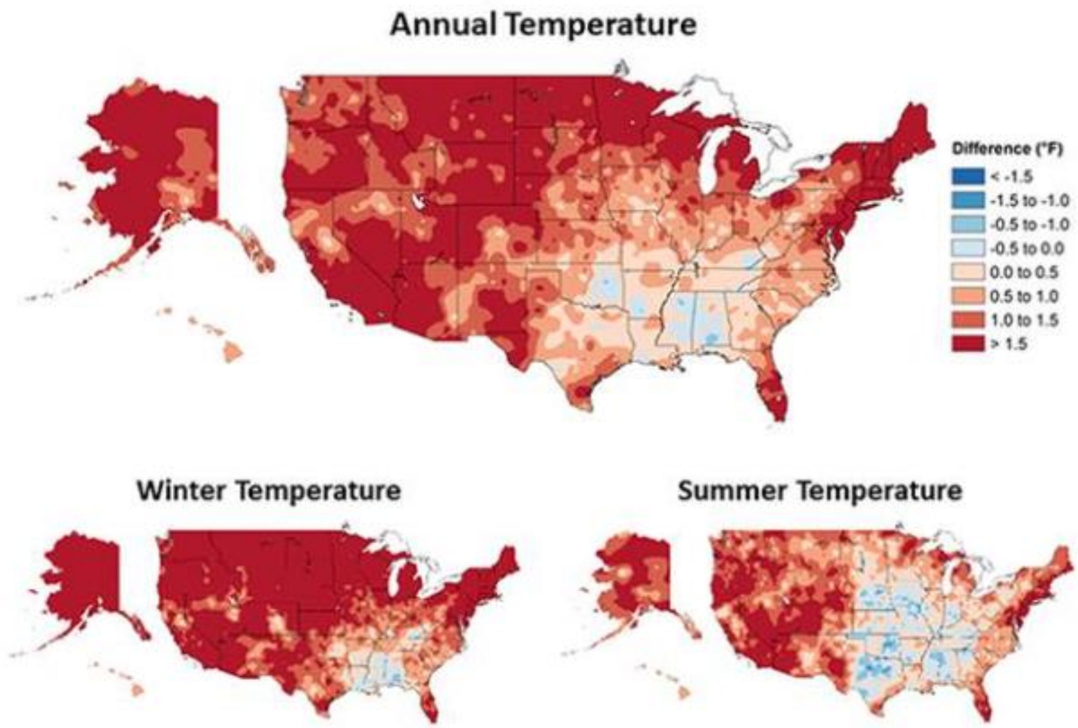


Figure 7. Observed changes in annual, winter, and summer temperature (°F). Changes are the difference between the average for present-day (1986–2016) and the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska and Hawai'i). Estimates are derived from the nClimDiv dataset.(Vose et al., 2014 ; Bose et al., 2017,), (Figure source: NOAA/NCEI). (NCA4 Vol.1, Chapter 6: Temperature Changes in the United States, Fig 6.1)

Figure 2-4 Observed changes in Annual Temperature

Table 2-1 Observed Changes in Annual Average Temperatures by Region

NCA Region	Change in Annual Average Temperature	Change in Annual Average Maximum Temperature	Change in Annual Average Minimum Temperature
Contiguous U.S.	**1.23°F**	**1.06°F**	**1.41°F**
Northeast	1.43°F	1.16°F	1.70°F
Southeast	**0.46°F**	**0.16°F**	**0.76°F**
Midwest	1.26°F	0.77°F	1.75°F
Great Plains North	1.69°F	1.66°F	1.72°F
Great Plains South	0.76°F	0.56°F	0.96°F
Southwest	1.61°F	1.61°F	1.61°F
Northwest	1.54°F	1.52°F	1.56°F
Alaska	1.67°F	1.43°F	1.91°F
Hawaii	1.26°F	1.01°F	1.49°F
Caribbean	**1.35°F**	**1.08°F**	**1.60°F**

Table 1. Observed changes in annual average temperature (°F) for each National Climate Assessment region. Changes are the difference between the average for present-day (1986–2016) and the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska, Hawai'i, and the Caribbean). Estimates are derived from the nClimDiv dataset. (Vose et al., 2014 ; Vose et al., 2017) (NCA4 Vol.1 Table 6.1)

Temperature data wasn't available at Lake Maumelle, but analysis of observed daily temperature at the Little Rock weather station shows trends that are consistent with those observed for the United States. Table 2-2 and Figure 2-5 shows the monthly and yearly average temperatures from 1879 – 2021 for the Little Rock area. The data trend to the increase of average temperature for the Little Rock area in the future.

Table 2-2 Yearly and Average Temperatures for Little Rock, AR

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
1879	M	M	M	M	M	M	83.8	76.2	71.5	66.8	57.0	48.2	67.3
1880	56.0	49.9	54.1	66.1	75.0	77.4	79.4	79.0	69.9	62.0	42.1	41.4	62.7
1881	35.8	44.4	52.3	62.7	73.5	81.1	83.5	85.0	77.3	68.5	51.2	49.5	63.7
1882	44.8	54.1	59.0	64.8	66.8	79.7	77.8	77.2	71.4	67.1	53.3	44.8	63.4
1883	40.4	45.1	53.0	63.8	69.1	79.0	81.0	78.4	71.1	67.3	56.3	49.1	62.8
1884	35.7	47.7	54.5	60.6	69.9	77.1	82.9	78.7	77.0	66.5	52.4	41.6	62.0
1885	37.6	41.9	51.6	63.8	68.9	80.4	84.7	81.7	75.0	61.2	52.6	43.5	61.9
1886	29.8	41.1	49.5	61.3	73.5	75.6	80.2	80.5	75.1	63.1	49.2	38.2	59.8
1887	41.0	48.5	55.2	63.0	72.2	76.6	81.7	80.0	75.4	62.0	52.3	40.7	62.4
1888	38.8	46.1	50.0	65.9	68.6	75.8	81.9	79.9	71.3	58.7	50.2	44.7	61.0
1889	44.0	43.8	54.3	64.6	67.7	73.8	80.6	76.8	70.8	60.7	47.4	59.2	62.0
1890	50.7	52.6	50.6	62.3	69.1	78.1	81.3	78.1	70.7	61.6	55.3	46.2	63.1
1891	42.4	48.2	47.8	63.8	67.6	78.8	76.8	76.3	74.5	61.3	49.2	47.7	61.2
1892	36.2	50.8	48.9	61.8	67.5	77.0	79.0	78.4	71.6	64.2	50.2	41.0	60.6
1893	39.9	42.8	50.8	65.5	68.3	76.5	81.0	77.9	74.4	61.0	50.1	46.4	61.2
1894	45.4	42.3	55.6	63.3	70.4	77.6	78.6	78.1	73.8	63.8	50.7	45.6	62.1

1895	38.1	35.3	52.5	63.5	68.6	77.3	79.3	79.6	78.3	58.8	50.8	44.6	60.6
1896	41.9	46.1	49.4	68.5	75.6	77.9	84.2	82.7	73.8	61.8	53.2	46.7	63.5
1897	39.9	46.8	56.5	61.8	68.9	78.9	83.9	80.3	77.9	69.3	52.5	40.3	63.1
1898	46.0	46.1	55.5	59.5	73.0	79.4	80.1	80.2	75.7	60.7	48.3	40.4	62.1
1899	39.9	32.9	51.0	60.9	73.1	77.5	79.5	82.4	72.4	66.6	55.5	41.1	61.1
1900	44.3	40.6	52.4	63.4	70.3	76.6	79.9	81.0	78.2	66.6	53.0	46.3	62.7
1901	47.0	41.4	51.8	59.3	68.8	79.5	83.8	81.1	72.9	64.8	52.4	39.8	61.9
1902	39.2	36.1	54.2	62.7	74.6	78.6	80.4	81.5	69.7	63.9	57.8	41.7	61.7
1903	42.5	42.6	56.5	62.0	68.6	71.6	80.0	79.1	71.4	62.4	49.0	41.6	60.6
1904	41.3	45.6	56.1	58.0	68.5	76.4	78.6	78.8	76.1	64.0	53.3	44.1	61.7
1905	34.3	33.5	58.8	62.4	71.8	78.5	77.3	80.0	75.0	62.5	54.8	40.0	60.7
1906	45.1	42.5	46.0	65.1	69.5	77.6	77.5	78.8	76.5	59.3	51.5	48.0	61.4
1907	50.5	46.0	63.1	55.7	64.4	76.3	82.5	82.3	74.9	63.3	50.7	46.2	63.0
1908	43.9	46.0	60.9	63.8	70.4	77.1	80.1	80.0	74.5	60.6	55.1	47.5	63.3
1909	43.9	49.4	54.2	61.7	67.6	77.8	82.5	83.0	74.8	64.1	60.3	37.1	63.0
1910	44.1	40.4	62.3	60.4	66.8	74.5	79.1	79.0	76.9	64.0	52.6	42.3	61.9
1911	48.3	50.6	57.0	60.7	72.2	81.7	78.5	78.5	79.5	63.2	47.0	44.3	63.5
1912	35.1	38.9	46.6	62.7	70.5	73.9	82.0	79.0	74.8	64.7	51.9	43.2	60.3
1913	45.1	42.3	51.4	61.8	70.0	78.2	81.5	82.1	71.7	60.7	58.2	44.8	62.3
1914	47.0	41.7	51.0	61.8	70.6	83.9	82.7	78.3	74.6	63.3	54.2	36.9	62.2
1915	40.2	46.3	43.3	65.5	70.3	76.2	80.0	75.3	76.0	65.4	55.5	46.0	61.7
1916	45.2	43.9	54.8	60.7	72.3	76.5	83.6	81.3	72.9	63.3	53.5	43.5	62.6
1917	45.0	44.8	54.1	61.2	64.0	76.2	80.1	77.7	72.5	57.9	52.9	35.4	60.1
1918	28.6	48.0	58.8	60.7	74.1	80.6	80.3	82.8	69.0	66.5	51.0	49.5	62.5
1919	43.2	45.0	53.8	61.7	67.1	77.3	82.2	81.0	75.3	66.6	52.7	40.6	62.2
1920	40.8	46.3	53.0	60.3	70.9	75.4	80.4	77.3	75.3	65.4	48.4	44.6	61.5
1921	47.2	49.0	61.3	60.4	70.9	79.0	82.2	81.4	79.6	62.9	55.9	48.0	64.8
1922	39.7	48.1	52.3	64.1	71.5	79.4	80.5	81.5	77.7	65.2	54.2	48.4	63.6
1923	49.7	42.4	49.6	62.4	67.4	77.5	80.0	81.5	73.2	60.8	52.6	51.1	62.4
1924	36.9	44.1	47.3	62.6	65.6	79.3	79.9	82.7	69.9	67.2	54.3	41.8	61.0
1925	41.8	50.0	56.8	68.2	69.0	82.9	81.5	81.1	81.9	59.3	51.3	40.9	63.7
1926	41.5	49.2	48.7	59.2	70.7	77.9	81.2	81.3	77.4	65.8	47.8	43.6	62.0
1927	42.9	52.2	54.0	66.2	71.8	76.2	80.5	76.7	76.6	67.2	56.3	42.3	63.6
1928	43.9	45.8	53.9	57.7	70.3	74.8	81.0	81.7	71.6	67.1	51.3	44.3	62.0
1929	38.9	36.6	56.8	64.7	67.7	77.0	82.3	81.7	74.5	64.1	47.5	46.1	61.5
1930	35.0	54.0	52.1	66.4	69.9	78.8	86.4	82.8	76.5	61.1	51.6	42.3	63.1
1931	44.1	49.6	48.2	60.6	66.0	80.1	81.7	77.8	79.9	68.2	58.8	49.8	63.7
1932	48.0	53.3	49.4	65.4	70.6	79.8	83.6	82.8	74.5	61.7	47.4	40.2	63.1
1933	50.1	42.0	52.7	61.4	72.2	79.4	80.9	79.3	79.3	63.3	53.7	48.9	63.6
1934	44.7	41.6	49.7	62.4	71.3	81.2	85.0	84.6	72.1	68.2	54.4	42.2	63.1
1935	43.5	46.4	59.7	60.2	67.0	75.5	82.3	82.2	73.8	64.3	49.9	38.4	61.9
1936	38.2	36.8	58.0	59.9	72.2	80.7	82.6	84.9	79.4	62.2	49.6	46.1	62.6
1937	41.8	44.2	48.8	62.0	72.3	79.7	80.7	83.1	73.5	61.0	48.7	43.0	61.6

1938	43.0	50.9	60.5	62.8	70.9	76.6	82.9	84.0	76.6	68.0	51.5	44.6	64.4
1939	46.3	44.0	56.6	59.5	69.9	78.8	82.4	80.8	80.8	66.0	50.1	47.0	63.5
1940	29.1	42.5	52.4	60.4	66.6	76.0	78.8	78.6	72.6	66.6	51.0	48.2	60.2
1941	44.3	41.0	47.8	64.7	72.5	77.0	81.4	81.3	76.1	68.7	51.2	45.8	62.7
1942	39.7	42.0	54.1	63.2	68.8	78.2	82.5	79.4	72.4	63.8	54.3	43.1	61.8
1943	41.9	48.6	47.3	63.2	72.6	81.7	84.3	85.4	72.2	62.1	49.8	40.5	62.5
1944	42.6	48.9	51.6	60.9	71.4	81.0	82.7	81.0	75.7	65.4	52.9	38.1	62.7
1945	40.8	43.5	59.6	63.9	67.1	76.7	79.3	79.9	74.4	61.4	53.8	38.0	61.5
1946	41.7	48.5	59.4	65.6	67.4	76.8	81.5	79.8	72.5	64.1	54.3	49.2	63.4
1947	43.9	38.1	45.7	62.4	68.5	77.7	79.3	85.0	75.8	69.8	48.2	45.5	61.7
1948	34.9	42.3	51.8	67.5	69.9	79.8	82.1	79.2	73.8	61.1	52.5	45.9	61.7
1949	43.5	48.2	52.0	62.0	73.1	79.5	82.1	79.0	70.1	64.4	54.1	45.9	62.8
1950	49.7	47.6	49.9	60.6	71.1	77.7	78.8	77.0	71.2	67.1	48.4	38.7	61.5
1951	43.2	45.9	52.4	59.2	71.0	77.6	81.9	82.8	72.6	63.6	45.9	45.0	61.8
1952	47.9	49.9	51.1	59.3	70.5	84.1	83.6	82.0	73.2	57.0	50.2	44.0	62.7
1953	46.9	46.6	57.0	59.0	71.8	85.0	81.8	81.5	77.1	66.3	51.0	42.1	63.8
1954	41.8	51.6	52.7	67.8	66.6	82.3	86.7	87.2	78.7	65.0	52.7	44.2	64.8
1955	42.5	44.6	54.0	67.0	73.2	74.7	83.4	81.4	77.4	63.6	50.9	42.5	62.9
1956	40.0	47.5	53.0	60.8	74.0	78.1	82.6	83.5	74.1	67.4	50.6	49.4	63.4
1957	39.8	50.4	51.0	62.9	72.4	78.8	82.7	80.1	72.6	60.8	52.2	49.1	62.7
1958	40.4	38.8	46.6	61.5	71.5	77.5	81.9	81.1	74.8	63.2	54.7	40.3	61.0
1959	39.7	45.0	53.1	62.2	74.7	77.4	79.6	81.9	75.2	64.1	47.0	46.6	62.2
1960	41.1	39.8	41.3	64.9	68.3	78.4	80.7	81.4	76.3	63.5	50.6	37.6	60.3
1961	35.8	47.6	55.9	60.4	67.8	75.8	80.6	78.7	74.3	63.4	51.0	41.6	61.1
1962	37.1	49.2	49.5	59.5	75.3	77.6	81.8	82.8	73.2	66.3	50.7	41.8	62.1
1963	34.0	39.4	57.7	64.3	71.3	80.4	81.5	81.1	74.7	70.0	53.3	33.3	61.8
1964	40.8	41.6	52.7	64.7	72.3	80.6	83.2	79.2	73.6	60.1	53.9	43.9	62.2
1965	44.2	43.2	44.4	65.8	72.7	78.1	82.9	81.7	74.3	61.6	56.5	46.6	62.7
1966	35.4	42.9	54.5	62.4	68.4	78.0	84.2	77.8	72.0	59.2	54.7	43.2	61.1
1967	41.6	40.4	58.8	66.6	68.6	79.4	77.9	75.5	69.0	60.9	49.1	42.7	60.9
1968	37.7	37.9	50.8	60.9	67.5	77.8	77.8	81.4	70.7	62.9	51.1	42.2	59.9
1969	43.5	42.9	45.5	61.8	69.9	77.6	84.8	79.0	72.9	62.4	49.4	40.7	60.9
1970	35.7	42.1	48.1	63.1	71.9	78.7	79.9	81.2	78.1	61.4	50.3	47.2	61.5
1971	40.9	44.4	49.9	59.3	65.6	79.3	80.0	78.0	76.4	69.3	50.5	49.9	62.0
1972	43.6	46.7	53.3	62.5	69.7	79.4	80.4	81.1	75.8	62.6	47.2	41.0	61.9
1973	39.6	42.0	58.2	59.9	68.2	78.6	81.1	80.4	75.7	67.5	56.6	42.7	62.5
1974	42.4	45.7	58.0	60.7	71.3	74.3	83.2	79.0	69.0	62.3	51.9	44.3	61.8
1975	44.6	44.5	48.7	60.7	72.5	78.6	80.1	79.5	69.1	62.9	51.4	42.9	61.3
1976	39.7	52.5	56.4	61.1	64.6	74.4	80.2	78.7	72.1	57.8	45.9	41.8	60.4
1977	31.3	46.8	56.4	64.7	73.7	80.0	82.0	80.4	77.3	62.6	52.9	42.0	62.5
1978	31.7	34.0	51.0	65.9	71.4	78.9	84.1	83.0	76.6	62.0	54.6	43.3	61.4
1979	29.8	38.6	55.5	62.7	70.1	77.9	80.9	79.0	72.7	65.2	50.3	45.8	60.7
1980	43.9	40.8	50.3	61.5	70.6	79.4	88.1	86.9	78.6	60.4	50.4	43.0	62.8

1981	39.7	44.6	52.5	67.4	67.4	80.1	83.5	79.9	75.3	61.3	55.5	43.2	62.5
1982	37.4	41.3	57.1	58.0	72.7	76.6	83.1	82.1	74.2	64.6	53.2	48.3	62.4
1983	39.2	43.8	51.1	54.4	67.6	77.4	82.5	86.0	76.0	64.0	50.8	30.9	60.3
1984	36.6	46.5	50.1	59.6	68.0	79.7	79.7	78.1	71.0	65.0	48.9	52.0	61.3
1985	33.7	39.3	57.6	63.0	69.9	78.1	81.2	80.8	72.5	66.1	56.1	38.1	61.4
1986	42.4	48.2	55.4	63.6	71.3	79.7	86.2	78.1	77.6	63.1	49.6	42.4	63.1
1987	40.1	47.1	53.4	62.4	76.3	79.9	82.2	84.4	74.8	59.1	53.0	45.2	63.2
1988	35.6	42.8	52.2	61.5	70.3	78.8	81.7	82.4	75.8	60.3	53.3	44.4	61.6
1989	46.2	38.4	52.4	62.6	69.6	76.2	79.3	80.2	71.1	63.3	55.3	35.7	60.9
1990	48.1	51.3	55.4	62.0	68.0	80.6	83.1	82.2	77.5	61.4	56.3	43.1	64.1
1991	39.0	49.1	56.2	64.3	74.1	79.5	82.7	80.0	73.7	64.3	49.2	46.7	63.2
1992	42.7	50.5	54.4	62.6	68.9	76.5	81.0	76.5	72.7	64.4	50.1	43.8	62.0
1993	40.4	43.1	51.2	58.3	68.8	78.7	86.0	83.7	73.5	61.4	48.3	44.9	61.5
1994	38.2	45.2	53.9	64.4	68.3	81.7	80.0	78.8	72.6	64.3	56.1	46.3	62.5
1995	43.0	46.4	55.5	62.4	70.6	77.6	83.0	86.7	72.5	64.1	50.1	42.1	62.8
1996	40.0	46.2	48.2	60.4	74.3	79.3	81.9	80.8	73.4	63.6	48.4	46.4	61.9
1997	41.0	47.2	56.7	58.2	68.3	77.0	84.0	80.4	76.4	63.9	49.8	42.6	62.1
1998	46.6	48.8	51.6	62.0	75.9	83.1	87.2	83.9	80.5	65.7	54.8	44.9	65.4
1999	43.8	50.9	50.0	65.1	70.1	78.3	83.5	83.2	74.0	64.0	56.8	46.1	63.8
2000	43.0	50.7	55.8	61.1	72.2	76.5	82.7	86.5	75.4	65.7	47.9	32.0	62.5
2001	38.6	46.3	49.4	67.2	71.3	76.9	83.2	82.0	72.7	60.6	55.7	45.8	62.5
2002	44.4	42.9	49.3	64.6	67.9	77.9	81.5	81.2	76.8	61.2	49.6	43.3	61.7
2003	38.0	40.5	52.2	63.7	71.8	74.7	81.7	83.1	72.5	65.3	55.6	44.1	61.9
2004	42.9	42.1	58.1	62.5	72.1	77.4	80.0	77.5	75.3	67.3	54.7	43.3	62.8
2005	45.8	49.3	53.0	62.6	70.1	80.1	82.1	84.8	78.5	64.3	55.4	43.1	64.1
2006	49.8	42.6	55.5	68.2	72.4	79.0	84.0	84.4	73.0	62.1	53.3	47.1	64.3
2007	41.5	43.5	61.7	59.6	73.5	80.2	80.1	87.2	76.8	65.7	54.4	45.3	64.1
2008	40.6	45.5	53.8	60.6	70.6	79.8	83.4	80.4	73.7	62.7	50.7	42.9	62.1
2009	40.5	49.0	54.7	61.9	69.7	81.2	79.0	79.1	73.8	59.4	55.4	40.2	62.0
2010	38.8	38.3	53.9	66.1	74.4	84.9	86.0	86.5	77.4	65.6	53.1	41.0	63.8
2011	39.3	46.1	54.0	66.0	69.6	84.2	86.9	84.7	72.0	63.0	55.8	45.7	63.9
2012	46.5	49.3	64.3	66.6	75.6	80.4	87.3	82.6	75.0	61.5	51.7	48.2	65.8
2013	43.7	44.8	49.0	60.1	69.4	79.6	80.7	81.2	78.1	63.7	49.3	42.9	61.9
2014	37.9	40.8	48.8	61.7	70.0	79.1	77.5	81.5	75.6	66.1	47.9	45.2	61.0
2015	41.4	38.1	52.5	64.7	72.2	81.1	84.6	81.9	78.3	66.4	55.9	52.0	64.1
2016	42.1	49.3	58.2	64.6	70.3	82.7	85.8	83.7	79.7	67.8	55.1	43.3	65.2
2017	46.2	53.2	56.4	64.8	69.1	76.5	81.8	78.3	74.9	64.0	55.2	43.0	63.6
2018	37.2	46.2	55.9	56.3	76.4	80.8	82.8	79.7	75.7	63.8	47.3	44.8	62.2
2019	41.8	46.9	50.2	62.0	71.7	77.0	80.1	81.9	81.2	62.0	47.3	46.2	62.4
2020	44.4	45.5	57.2	59.6	68.4	77.5	82.4	80.3	73.4	60.7	54.7	43.8	62.3
2021	42.9	36.0	56.1	59.7	68.5	78.7	81.4	82.5	M	M	M	M	63.2

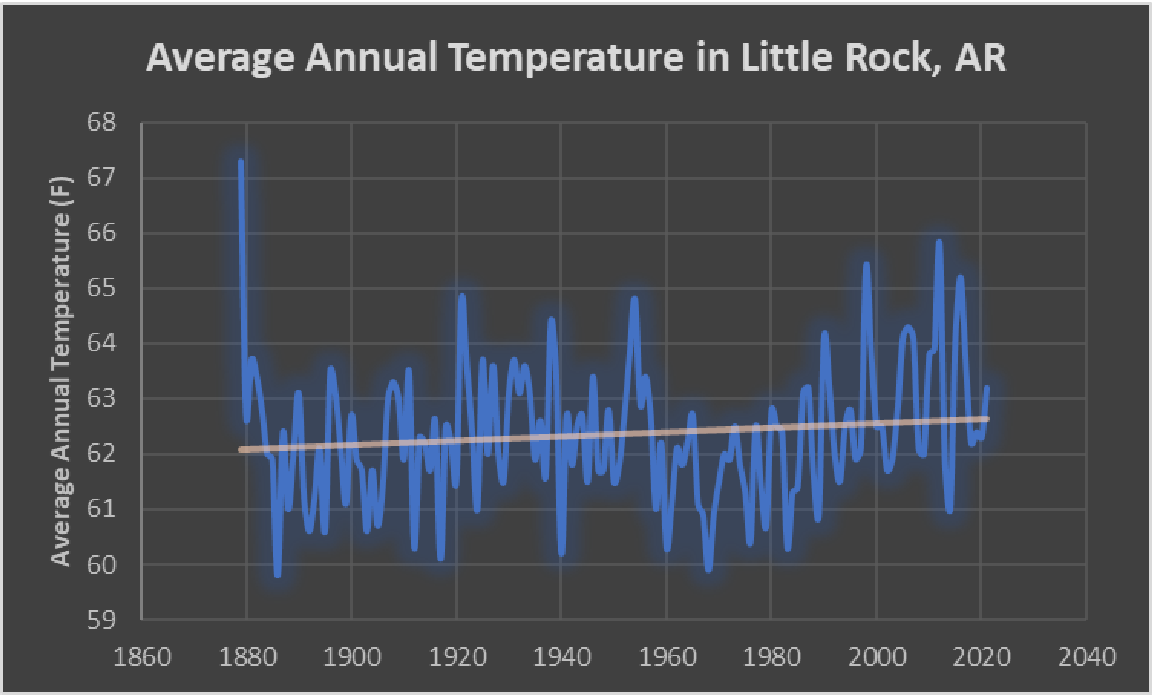


Figure 2-5 Trend in Average Annual Temperatures in Little Rock, AR

Figure 2-6 and Table 2-3 show the projected increase in average temperatures across the U.S. The temperature of the southeast region is expected to increase to between 3.40ºF and 4.30ºF in the middle part of the century and between 4.43ºF and 7.72ºF in the late part of the century. The number of nights above 75ºF is expected to increase between 50 and 100 nights/year by the later part of the century.

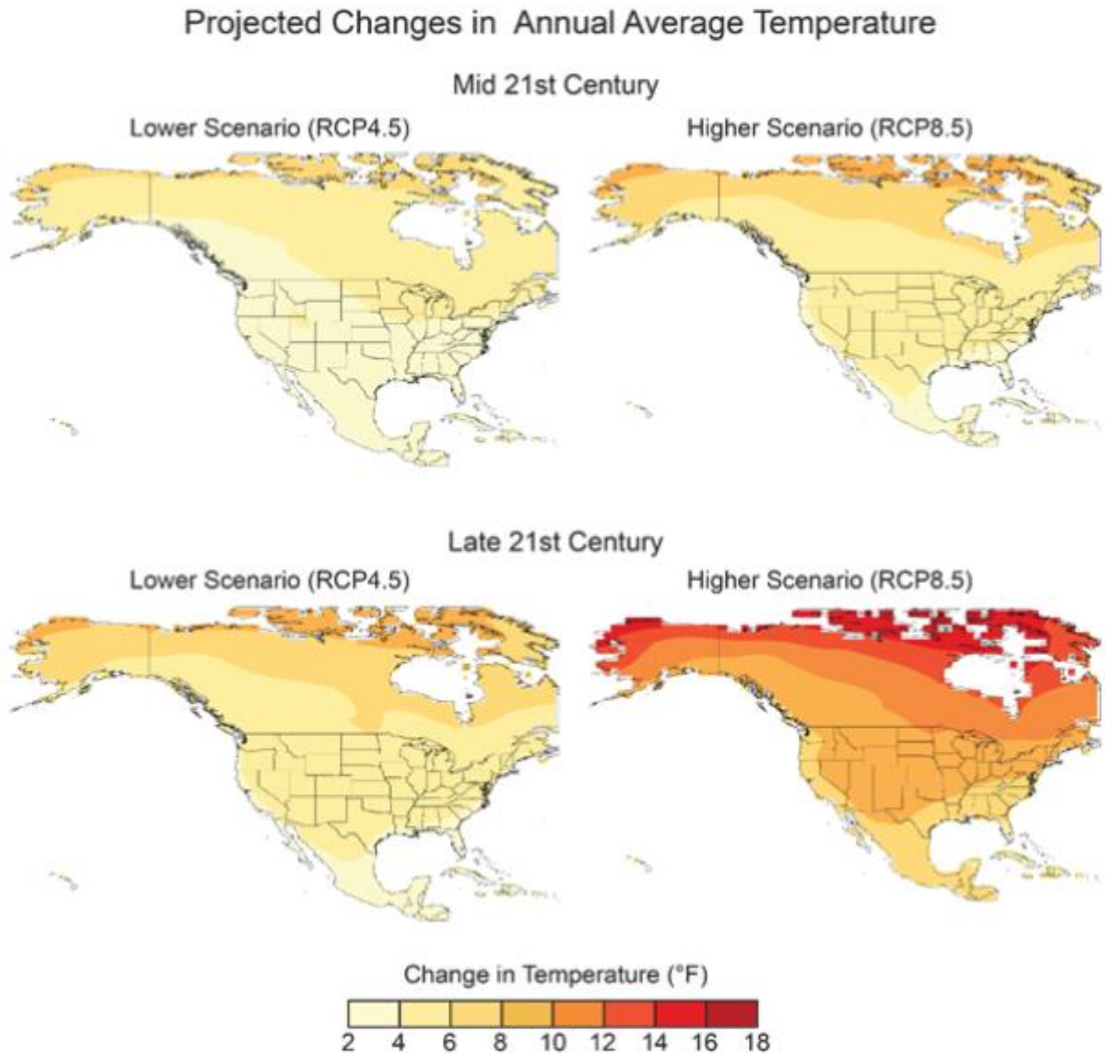


Figure 2-6 Projected Changes in Annual Average Temperature for two RCPs

Table 2-3 Projected temperature changes in mid-century and late-century for two RCPs

NCA Region	RCP4.5 Mid-Century (2036–2065)	RCP8.5 Mid-Century (2036–2065)	RCP4.5 Late-Century (2071–2100)	RCP8.5 Late-Century (2071–2100)
Northeast	3.98°F	5.09°F	5.27°F	9.11°F
Southeast	3.40°F	4.30°F	4.43°F	7.72°F
Midwest	4.21°F	5.29°F	5.57°F	9.49°F
Great Plains North	4.05°F	5.10°F	5.44°F	9.37°F
Great Plains South	3.62°F	4.61°F	4.78°F	8.44°F
Southwest	3.72°F	4.80°F	4.93°F	8.65°F
Northwest	3.66°F	4.67°F	4.99°F	8.51°F

Table 2. Projected changes in annual average temperature (°F) for each National Climate Assessment region in the contiguous United States. Changes are the difference between the average for mid-century (2036–2065) or late-century (2071–2100) and the average for near-present (1976–2005) under the higher scenario (RCP8.5) and a lower scenario (RCP4.5). Estimates are derived from 32 climate models that were statistically downscaled using the Localized Constructed Analogs technique (Pierce et al., 2014). Increases are statistically significant in all areas (that is, more than 50% of the models show a statistically significant change, and more than 67% agree on the sign of the change; Sun et al., 2015). (NCA4 Vol.1 Table 6.4)

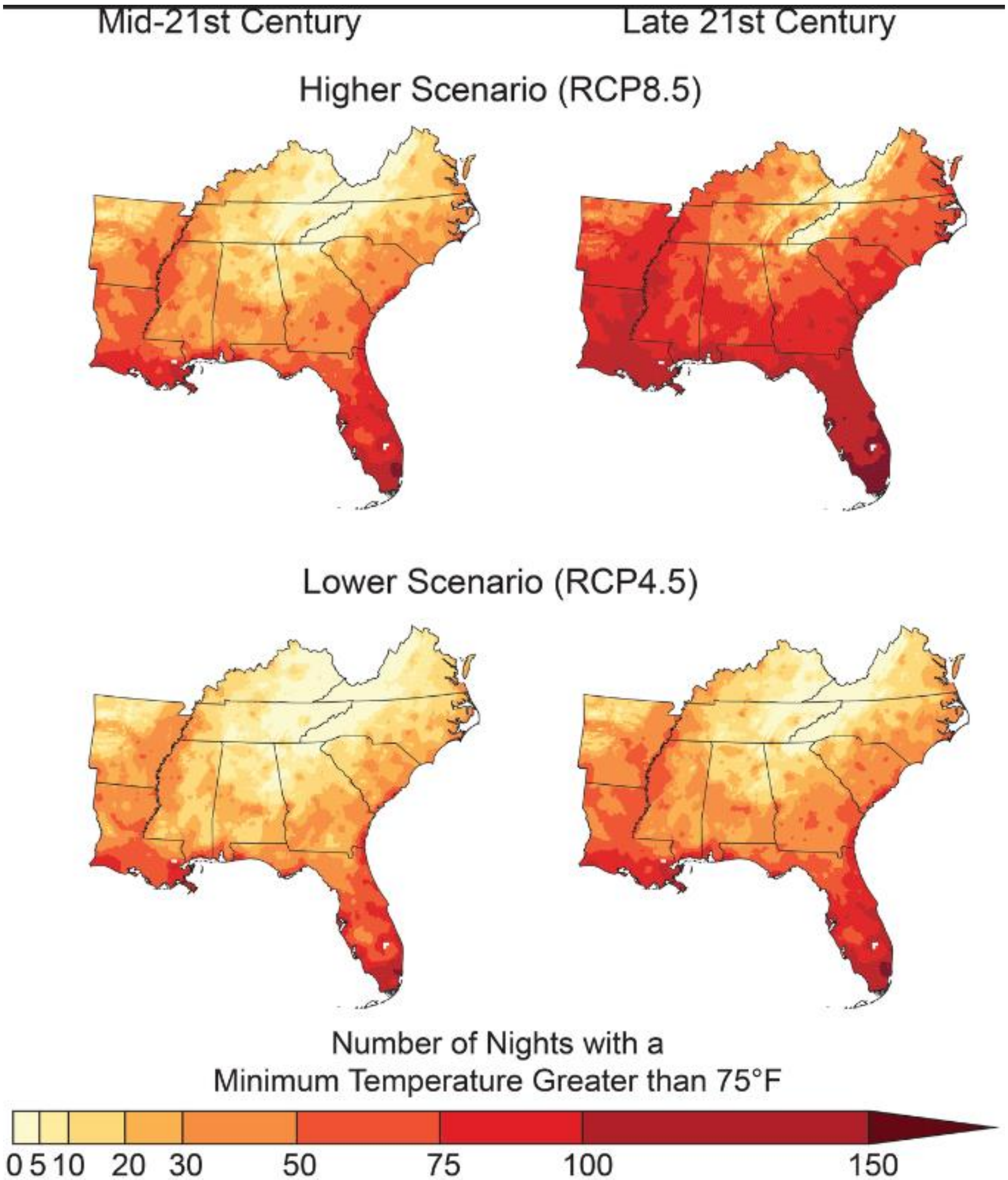


Figure 2-7 Projected number of warm nights per year in the Southeast for the mid- and late-21st century under 2 different climate change variable conditions.

2.2.2 **Precipitation**

The Maumelle River is situated right at the junction of the Ouachitas with the Arkansas River Valley and just near the Mississippi Alluvial Plain and Coastal Plain. The average annual precipitation for the Maumelle River area is around 51 inches   Precipitation extremes vary from 10.11 inches in 1917 to 52.28 inches in 1973. Most precipitation occurs in May, June, September, and October. During some of these events, rain has exceeded 5 inches in several hours and caused flash flooding. Monthly and yearly precipitation totals from 2000 to 2019 are shown in Table 2-4. Yearly precipitation totals from 1934 – 2018 are shown in Figure 2-8.

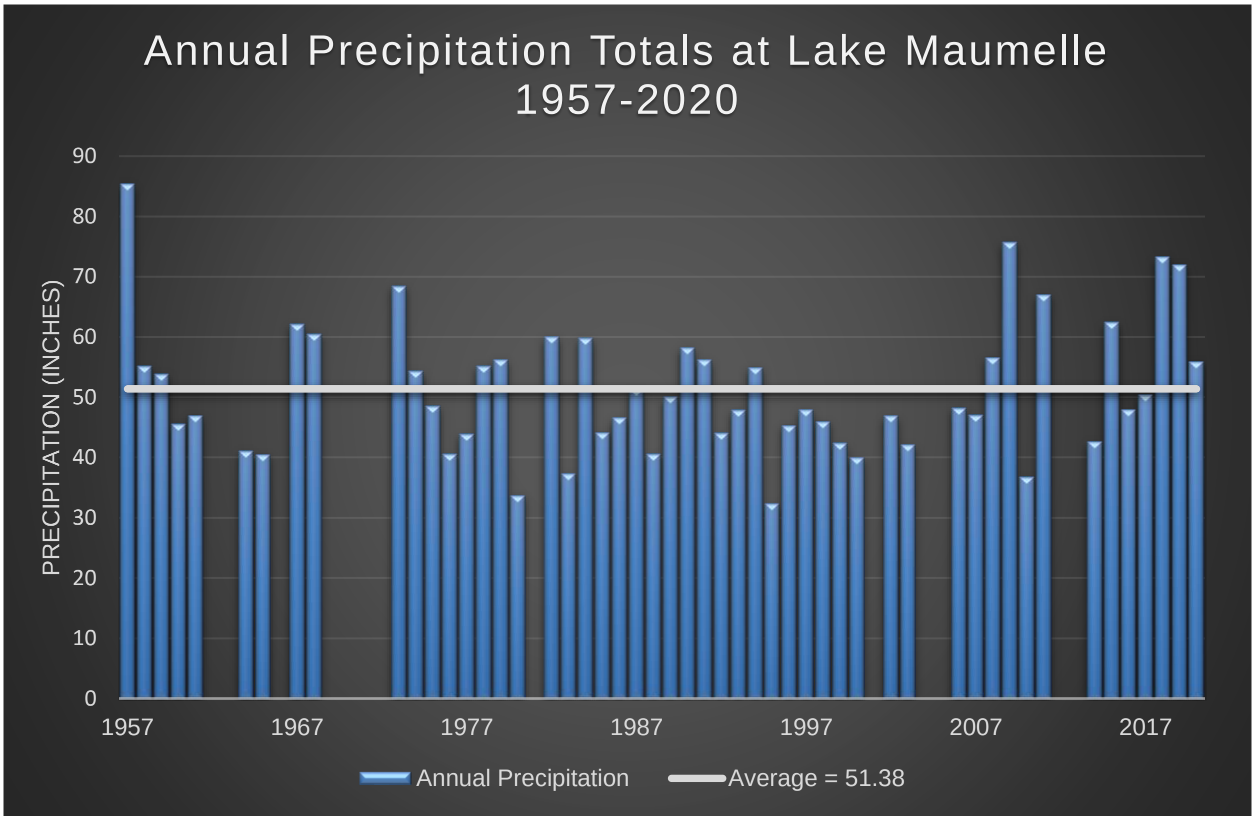


Figure 2-8 Annual Precipitation at Lake Maumelle Arkansas

Table 2-4 Monthly and Yearly Precipitation 1957-2021

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1957	9.72	3.00	4.22	15.04	15.34	6.52	3.28	10.21	3.23	3.77	7.74	3.29	85.36
1958	3.66	1.28	6.04	7.14	5.77	7.92	4.25	3.49	8.08	1.04	5.49	0.93	55.09
1959	2.22	7.32	3.54	2.30	2.69	6.87	6.15	1.56	6.90	3.08	2.90	8.32	53.85
1960	4.83	3.52	3.66	1.41	7.12	7.76	3.76	1.73	2.37	2.28	2.43	4.64	45.51
1961	0.41	3.61	8.40	2.77	4.39	1.25	6.97	4.37	1.56	0.55	6.39	6.29	46.96
1962	M	7.69	5.54	2.90	0.26	5.07	3.23	6.39	7.76	3.80	2.26	1.36	M
1963	0.58	2.66	M	3.33	2.06	1.66	4.37	1.55	1.34	0.13	5.84	2.36	M
1964	0.83	3.25	8.68	8.10	0.75	0.42	2.75	3.40	6.74	0.12	3.55	2.45	41.04
1965	5.12	4.86	4.58	1.38	3.00	1.79	5.46	3.08	8.23	0.02	1.29	1.67	40.48
1966	6.49	3.84	0.96	10.4	2.43	1.60	3.64	8.71	1.18	M	2.36	4.31	M
1967	1.98	1.73	3.41	6.89	10.26	3.95	7.67	5.04	7.37	4.20	2.91	6.63	62.04
1968	4.11	0.94	6.34	4.96	12.82	3.51	4.50	1.92	7.89	2.99	4.82	5.68	60.48
1969	9.39	2.23	3.14	1.73	4.66	3.40	M	M	M	M	M	M	M
1970	M	M	M	M	M	M	M	M	M	M	M	M	M
1971	M	M	M	M	M	M	M	M	M	M	M	M	M
1972	M	M	M	M	M	M	M	M	M	M	5.86	5.66	M
1973	4.87	2.81	13.14	12.88	2.26	2.85	3.64	0.64	8.11	5.56	6.99	4.64	68.39
1974	4.08	2.41	2.10	7.08	7.78	9.03	2.88	2.70	4.00	3.07	7.21	1.96	54.3
1975	4.54	5.18	10.41	4.00	5.08	3.72	3.94	1.05	3.05	1.40	2.44	3.69	48.5
1976	2.45	3.07	4.62	1.81	7.21	6.03	0.66	2.58	2.04	6.65	1.19	2.23	40.54
1977	3.08	2.04	7.96	5.15	2.44	3.26	1.82	1.63	5.69	0.61	7.90	2.25	43.83
1978	5.43	1.93	3.48	2.90	4.18	5.42	3.91	5.46	6.53	0.96	7.80	7.18	55.18
1979	3.43	5.72	5.27	9.05	9.92	3.25	3.74	4.14	4.10	2.36	2.85	2.36	56.19
1980	2.92	1.11	3.89	5.06	5.26	0.80	0.42	0.60	3.99	3.85	3.71	2.07	33.68
1981	0.91	4.64	M	2.19	12.16	M	3.75	0.86	0.52	5.39	2.54	0.79	M
1982	5.76	2.79	2.91	7.68	4.10	6.23	5.13	1.73	0.65	2.13	9.00	11.91	60.02
1983	1.65	2.81	2.73	5.22	7.51	2.51	0.61	1.04	0.61	2.26	3.49	6.82	37.26
1984	1.5	3.89	4.82	3.27	6.19	0.17	3.89	4.46	3.59	16.79	6.73	4.43	59.73

1985	3.23	3.58	4.81	6.06	3.11	2.25	0.94	2.11	5.59	3.72	4.92	3.83	44.15
1986	0.31	2.32	3.49	6.65	8.30	5.77	1.43	4.95	0.75	4.77	5.01	2.82	46.57
1987	2.47	8.47	2.31	0.52	3.30	4.73	1.01	0.59	4.77	1.41	9.48	12.25	51.31
1988	3.65	3.15	3.48	3.66	1.20	2.26	4.24	2.09	1.44	2.41	10.84	2.12	40.54
1989	2.61	9.19	7.22	4.25	7.46	4.16	5.94	1.04	4.16	1.59	1.52	0.93	50.07
1990	4.83	4.52	10.68	4.26	8.32	2.17	0.82	0.86	2.80	6.39	3.27	9.29	58.21
1991	5.83	3.47	2.43	11.15	2.41	3.44	1.35	4.89	2.79	6.30	6.25	5.85	56.16
1992	1.51	3.47	6.19	1.30	2.77	5.41	5.37	5.74	1.18	0.48	4.62	5.96	44.00
1993	3.56	3.32	2.94	7.32	4.08	1.65	5.12	3.21	1.45	4.42	5.54	5.18	47.79
1994	5.26	3.37	4.07	4.06	5.81	4.00	6.83	2.49	4.73	1.97	7.78	4.52	54.89
1995	3.52	1.80	2.44	3.74	3.66	1.88	2.49	0.15	2.00	3.88	3.34	3.39	32.29
1996	1.32	1.19	3.65	3.37	5.00	3.14	4.97	1.21	4.96	6.15	7.75	2.61	45.32
1997	2.44	3.96	6.40	7.06	3.23	4.53	1.66	2.06	4.58	4.78	3.50	3.72	47.92
1998	4.23	6.87	4.16	1.75	3.89	1.87	3.44	5.11	3.91	6.58	1.43	2.70	45.94
1999	7.43	0.77	5.22	5.24	3.18	2.26	1.28	1.24	2.16	6.04	3.26	4.23	42.31
2000	0.91	1.89	4.01	2.87	4.85	6.42	0.45	0.28	1.73	1.89	11.47	3.20	39.97
2001	2.55	6.39	3.19	1.42	3.88	1.37	5.88	2.16	2.14	3.30	M	8.06	M
2002	3.25	2.65	8.09	1.61	4.06	1.38	2.47	3.58	4.92	4.56	2.13	8.17	46.87
2003	0.74	6.12	1.71	2.07	6.00	4.47	4.58	2.56	4.62	2.04	4.38	2.81	42.1
2004	2.84	3.98	4.69	7.23	3.52	M	5.43	2.36	0.16	8.66	7.58	3.23	M
2005	4.47	2.40	4.65	M	0.97	2.38	4.12	1.48	3.94	0.00	4.88	1.33	M
2006	3.15	1.94	5.27	5.69	3.62	2.45	3.51	2.82	3.68	4.81	4.75	6.49	48.18
2007	7.32	2.54	1.45	7.85	1.48	2.93	3.09	T	4.75	5.12	3.22	7.23	46.98
2008	0.75	5.88	8.28	6.67	3.75	4.80	3.23	5.55	8.92	3.52	1.92	3.29	56.56
2009	1.82	2.40	5.93	6.49	12.19	0.82	9.29	3.42	7.45	13.99	1.03	10.84	75.67
2010	2.88	4.57	2.98	2.38	6.01	3.56	2.80	0.82	1.98	1.04	5.60	2.10	36.72
2011	1.12	4.42	3.19	9.17	17.79	1.89	0.43	5.79	1.51	2.33	12.45	6.90	66.99
2012	3.93	M	M	2.31	0.48	0.93	1.55	3.96	7.48	2.77	1.46	4.13	M
2013	5.25	M	4.28	5.04	4.85	M	3.33	3.30	1.44	3.18	3.86	5.69	M
2014	2.22	2.77	5.49	4.09	5.82	6.33	3.06	1.82	1.08	4.92	1.80	3.17	42.57
2015	2.96	3.16	7.39	7.02	11.10	2.62	3.89	2.04	1.03	4.51	10.25	6.40	62.37
2016	2.23	1.71	9.13	6.94	2.86	3.67	4.34	8.90	1.00	0.56	2.90	3.66	47.9
2017	2.91	5.3	3.73	8.25	7.82	3.53	3.77	5.04	0.13	1.35	0.86	7.72	50.41

2018	2.47	15.5	4.03	5.91	1.34	1.79	3.58	11.07	6.46	8.77	3.36	8.96	73.24
2019	3.78	9.16	4.6	11.71	16.19	5.37	3.13	4.88	2.30	4.75	5.17	0.91	71.95
2020	4.58	5.86	6.36	6.51	7.86	5.71	1.75	5.72	4.37	2.26	1.74	3.19	55.91
2021	2.97	3.99	3.45	2.27	6.23	M	M	M	M	M	M	M	M

Observed precipitation information from the Fourth National Climate Assessment for the Southeast region is shown in Figure 2-9. By every metric, there has been an increase in heavy precipitation in Arkansas; the five year maximum daily precipitation has increased by 10-19%, the $99^{\%}$ precipitation has increased between 20-29%, and the number of 5-year, 2-day events has increased 40+%

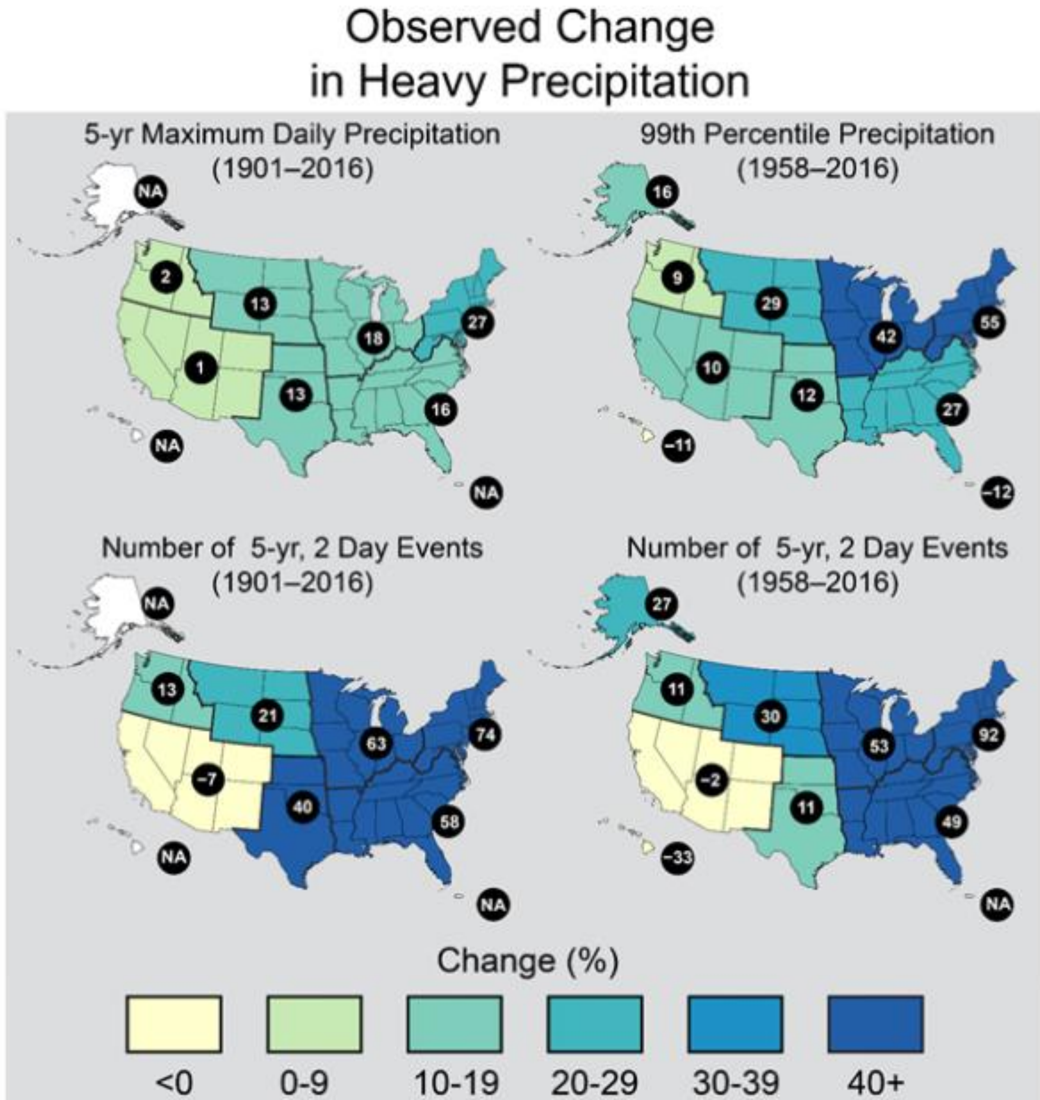


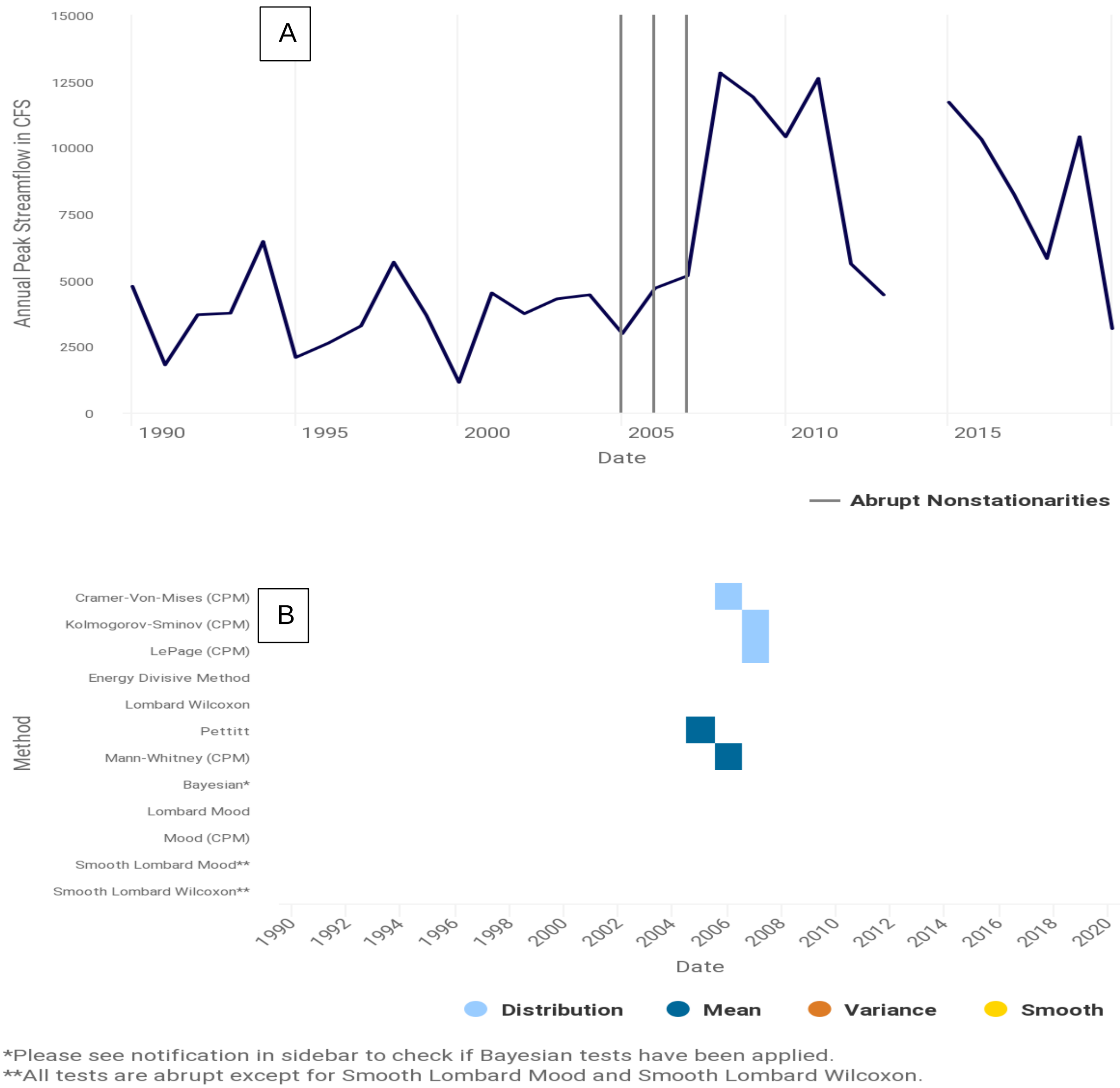
Figure 5. These maps show the change in several metrics of extreme precipitation by NCA4 region, including (upper left) the maximum daily precipitation in consecutive 5-year blocks, (upper right) the amount of precipitation falling in daily events that exceed the 99th percentile of all non-zero precipitation days, (lower left) the number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average, only once every 5 years, as calculated over 1901–2016, and (lower right) the number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average, only once every 5 years, as calculated over 1958–2016. The numerical value is the percent change over the entire period, either 1901–2016 or 1958–2016. The percentages are first calculated for individual stations, then averaged over 2° latitude by 2° longitude grid boxes, and finally averaged over each NCA4 region. Note that Alaska and Hawai'i are not included in the 1901–2016 maps owing to a lack of observations in the earlier part of the 20th century. (Figure source: CICS-NC and NOAA NCEI). (NCA4 Vol.1, Chapter 7: Precipitation Change in the United States, Fig 7.4)

Figure 2-9 Observed and Changes of Several Metrics of Extreme Precipitation

2.3 **Nonstationarity Detection**

The USACE Nonstationarity Detection Tool was developed in conjunction with USACE Engineering Technical Letter (ETL) 1100-2-3, Guidance for Detection of Nonstationarities in Annual Maximum Discharges, to detect nonstationarities in maximum annual flow time series.

This tool was also used to assess abrupt or slowly varying changes in observed peak flow data collected by the USGS gage located along the Maumelle River for the period of record spanning 1990 – 2020. Figure 2-10 shows the abrupt nonstationarities detected using maximum annual flow analysis for the USGS 07263295 Maumelle River at Williams Junction, AR. Nonstationarities were detected in the mean and the distribution. The yearly annual maximum mean jumped from 3700 to 8700.



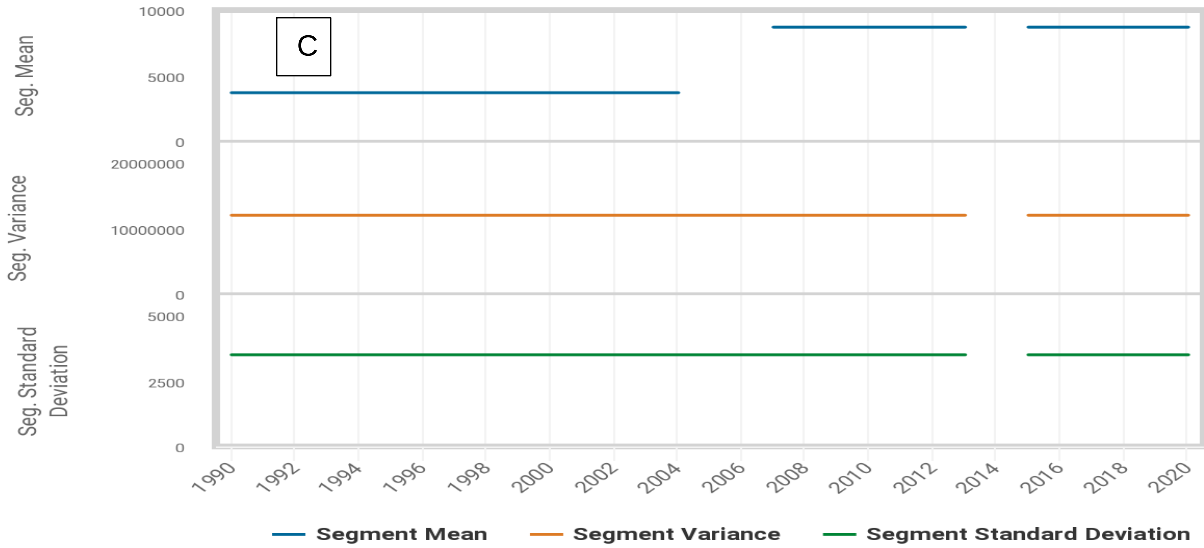
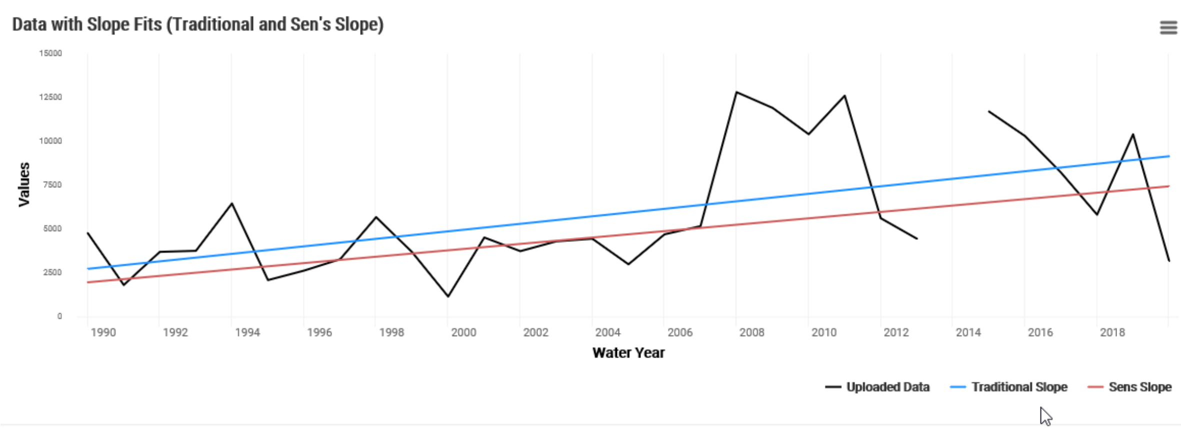


Figure 2-10 Non-Stationarity Detected at Maumelle River at Williams Junction, AR in the three graphs. A) Non-stationarities shown by gray lines B) Non-stationarities detected in the mean and distribution C) shows the mean, variance, and deviation between the non-stationarities. 2014 is missing. Note increase in the mean before and after the non-stationarity.

A plot of the increasing observed annual peak streamflow at the Maumelle River at Williams Junction with a linear regression fit is shown in Figure 2-11. The t-test, Mann-Kendall test, and Spearman Rank-Order test all indicate a statistically significant increasing trend in the annual peak stream flow



Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	214	-423292
Sen's Slope	Positive	182	-361221

Trend Hypothesis Test

Test	P-Value
t-Test	0.0012063
Mann-Kendall	0.003424
Spearman Rank-Order	0.0020147

- **A statistically significant trend (at the alpha = .05 level) was detected by the t-Test.**
- **A statistically significant trend (at the alpha = .05 level) was detected by the Mann-Kendall Test.**
- **A statistically significant trend (at the alpha = .05 level) was detected by the Spearman Rank-Order Test.**

Figure 2-11 Observed Annual Peak Streamflow Maumelle River at Williams Junction, AR

2.4 **Climate Hydrology Assessment Tool**

The USACE Climate Hydrology Assessment Tool (CHAT) was used to enhance USACE climate preparedness and resilience. This tool aids in preparing a qualitative analysis regarding climate change impacts for projects with hydrologic based aspects. The CHAT allows users to access data representing past (observed) changes, as well as potential future (projected) changes to relevant hydrologic inputs. This provides qualitative information about future climate conditions and provides a tool to develop repeatable analytical results using consistent information. The tool reduces potential error, while increasing the speed of information development so that data can be used earlier in the decision-making process.

The USACE CHAT was also used to investigate potential future trends in streamflow for the Maumelle River watershed. Figure 2-12 displays the range of projected annual maximum monthly streamflow computed from 93 different climate changed hydrologic model runs for the period of 1950-2099. The projected streamflow computations are computed at the HUC8 watershed scale. As expected for this type of qualitative analysis, there is considerable, but consistent spread in the projected annual maximum monthly flows. The spread in the projected annual maximum monthly flows is indicative of the high degree of uncertainty associated with projected, climate changed hydrology.

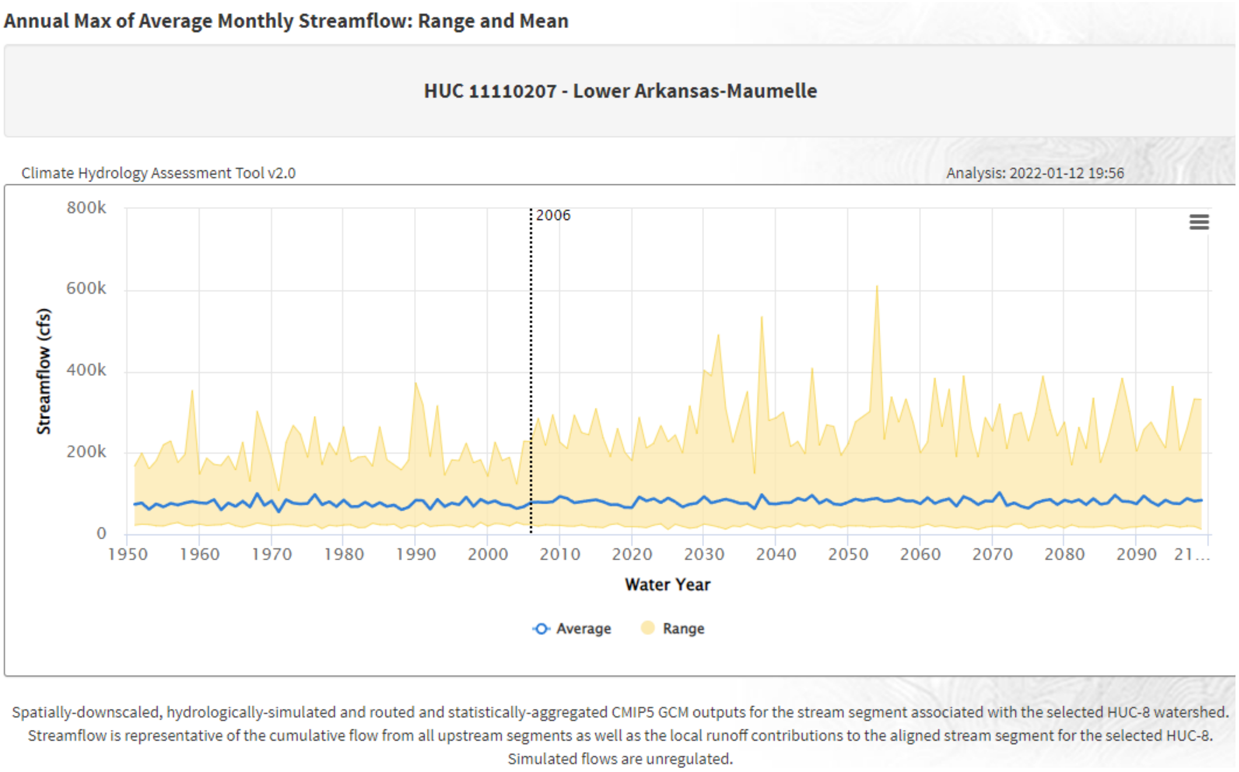
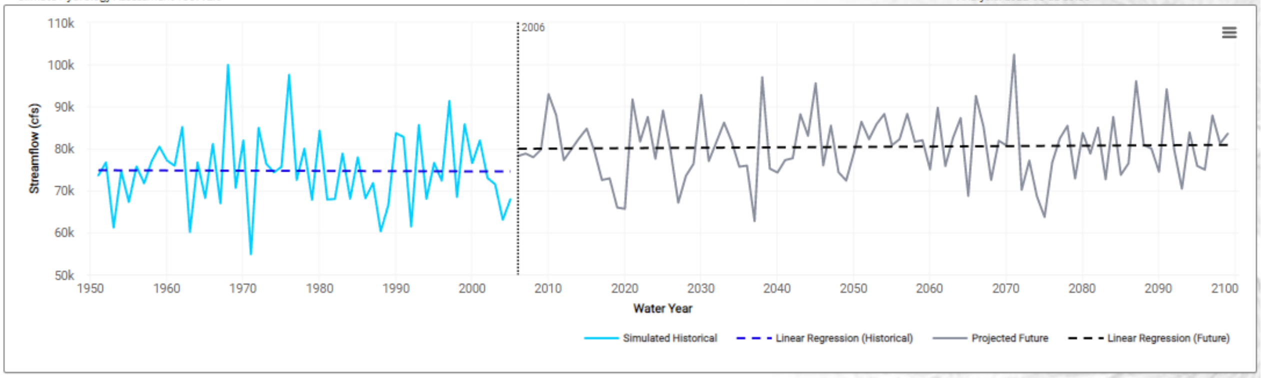


Figure 2-12 Range of Projected Annual Maximum Monthly Streamflow

Trends in Mean Annual Max of Average Monthly Streamflow from 64 Climate-Changed Hydrology Models

HUC 11110207 - Lower Arkansas-Maumelle

Climate Hydrology Assessment Tool v2.0 Analysis: 2022-01-12 19:56



Spatially-downscaled, hydrologically-simulated and routed and statistically-aggregated CMIP5 GCM outputs for the stream segment associated with the selected HUC-8 watershed. Streamflow is representative of the cumulative flow from all upstream segments as well as the local runoff contributions to the aligned stream segment for the selected HUC-8. Simulated flows are unregulated.

Trend Lines

Simulated Historical (1951 to 2005)

REGRESSION LINE
Flow = 85238 + -5*water year

ADJUSTED R-SQUARED
-0.02

Projected Future (2006 to 2099)

REGRESSION LINE
Flow = 60050 + 10*water year

ADJUSTED R-SQUARED
-0.01

Statistical Significance Tests (Historical)

The p-value is for the linear regression fit drawn; a smaller p-value indicates greater statistical significance. There is no recommended threshold for statistical significance, but typically 0.05 is associated with a 5% risk of a Type I error or false positive.

Test	p-value
t-Test	0.94488
Mann-Kendall	0.96526
Spearman Rank-Order	0.89146

- **A statistically significant trend (at the alpha = .05 level) was NOT detected by the Mann-Kendall Test.**

Statistical Signficance Tests (Future)

The p-value is for the linear regression fit drawn; a smaller p-value indicates greater statistical significance. There is no recommended threshold for statistical significance, but typically 0.05 is associated with a 5% risk of a Type I error or false positive.

Test	p-value
t-Test	0.73497
Mann-Kendall	0.86
Spearman Rank-Order	0.84498

- **A statistically significant trend (at the alpha = .05 level) was NOT detected by the Mann-Kendall Test.**

Figure 2-13 Mean Projected annual Maximum Monthly Streamflow

The overall trend in the mean projected annual maximum monthly streamflow over time is shown in blue in Figure 2-13.

2.5 **Vulnerability Assessment to Climate Change Impacts**

The USACE Watershed Climate Vulnerability Assessment Tool was used to compare the relative vulnerability of the HUC 121003, Texas Gulf Region, to climate change to the other watersheds across the continental United States. The tool facilitates a screening level, comparative assessment of how vulnerable a given watershed is to the impacts of climate change. The Climate Vulnerability Assessment Tool is used to assess the vulnerability of the Texas Gulf Region for the USACE Ecosystem Restoration business line to projected climate change impacts relative to the effects that climate change might have on the USACE ecosystem restoration business line in the other watersheds in the continental United States. The tool uses the Weighted Order Weighted Average (WOWA) method to represent a composite index of how vulnerable a given HUC-4 watershed (Vulnerability Score) is to climate change specific to a given business line. The USACE Climate Vulnerability Assessment Tool makes an assessment for two 30-year epochs of time centered at 2050 and 2085. These two periods were selected to be consistent with many of the other national and international analyses. The tool assesses how vulnerable a given watershed is to the impacts of climate change for a given business line. The top 50% of the traces is called the "wet" subset of traces and the bottom 50% of the traces is called the "dry" subset of traces. There is a combination of four epoch subset combinations, which provide for an indication of the variability/uncertainty in the outputs.

For a given scenario and a given business line, only the top 20% of the HUCs are marked as vulnerable. In Figure 2-14 the WOWA score for ecosystem restoration business line for HUC-1111 does not change appreciably across the 4 scenarios, but the ranking of HUC-1111 against all other HUC-4 watersheds does change. HUC-1111 is considered vulnerable in the Dry 2050 Forecast.

The indicators that drive vulnerability for HUC-1111 and their relative contributions to the WOWA score for Dry 2050 forecast are shown in Figure 2-15. The indicators for ecosystem restoration vulnerability for HUC-1111 in order of decreasing contribution to the WOWA score are percent of freshwater plant communities at risk, percent change in runoff divided by percent change in precipitation, monthly runoff variation relative to mean runoff, macroinvertebrate index of biotic condition, mean annual runoff, low flow reduction factor (increased in HUC-1111), flood magnification factor (increased in HUC-1111), and change in sediment load due to change in future precipitation.

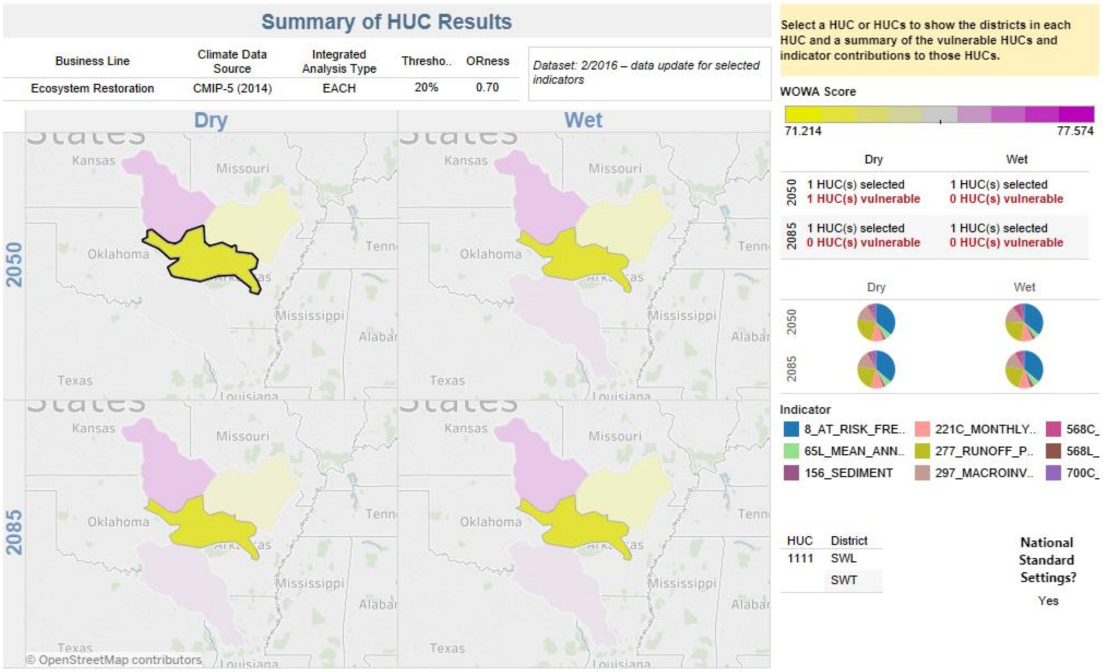


Figure 2-14 Summary of HUC-1111 Results

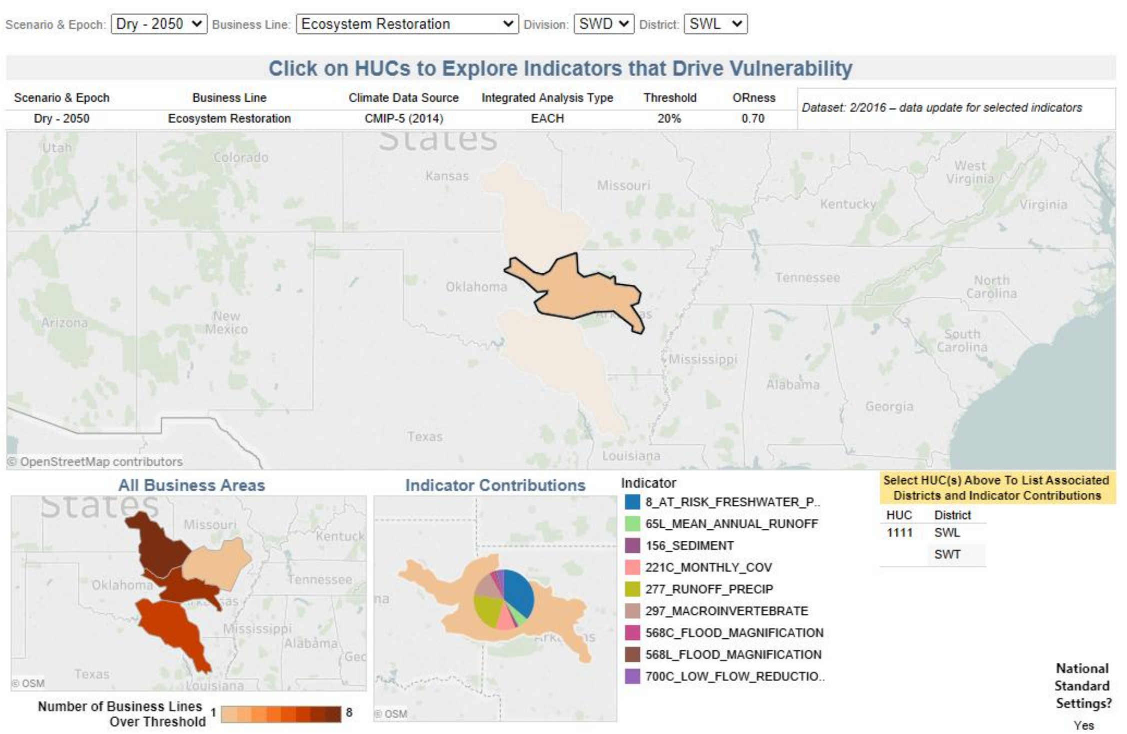


Figure 2-15 Indicators that Drive Vulnerability in a Dry Forecast 2050

The results of the USACE Watershed Climate Vulnerability Assessment Tool are presented in Table 2-5.

Table 2-5 Projected Vulnerability with Respect to Ecosystem Restoration

HUC4 Watershed	Projected Vulnerability with Respect to Ecosystem Restoration			
	Ecosystem Reduction Vulnerability Score			
Lower Arkansas 1111	2050 Dry	2050 Wet	2085 Dry	2085 Wet
	72.465	72.363	72.120	72.245

Terrestrial and aquatic ecosystems are being directly and indirectly altered by climate change. Some species can adapt to extreme droughts, unprecedented floods, and wildfires from a changing climate, while others cannot, resulting in significant impacts to both services and people living in these ecosystems. Any ecosystem restoration projects in this region are going to be vulnerable due largely to the number of freshwater plant communities at risk and the change in runoff to precipitation ratio, and ongoing considerations should reflect these vulnerabilities.

3 Conclusion

While there are concerns related to climate change with the Maumelle Ecosystem Restoration, overall the project will increase resiliency of the Maumelle River Ecosystem. This project cannot prevent a shift in average temperature in the area. But by restoring the sod farm and removing the low head dams, the area will become better fish habitat. Restoring the riparian zones will provide shade to reduce stream water temperatures. It will filter sediment and pollution which can also cause an increase in water temperature. The reforestation of the overbanks will provide storing of flood water and will help in decreasing erosion and increase bank stabilization. Increased vegetation will work to support the animals most threatened by climate change.

The ecosystem restoration project is itself potentially vulnerable to climate change, and considerations should be made for increasing temperatures and increased extreme precipitation. However, the project will increase the resilience of the Maumelle River's ecosystem to climate change.

4 References

CWTS. (2015). *Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions - Arkansas, White, and Red River Regions. Civil Works Technical Report.* Washington DC: USACE.

ECB 2018-14. (2020, September 10). *Engineering and Construction Bulletin*. U.S. Army Corps of Engineers.

NOAA. (n.d.). *NOAA*. Retrieved from NOAA Climate Data Online: https://www.ncdc.noaa.gov/cdo-web/datatools/findstation

Reidmiller, D. C. (2018). *Impacts, Risks and Adaptation in the United States: Fourth National Climate Assessment, Volume II.* Washington, DC, USA: U.S. Global Change Research Program.