Mississippi Valley Division,
Regional Planning and Environment Division South

Memphis Metropolitan Stormwater – North DeSoto County Feasibility Study, DeSoto County, Mississippi

Appendix H – Climate Change Assessment for DeSoto County, Mississippi

May 2021

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Section 1

Climate Change Assessment for DeSoto County, Mississippi

1.1 INTRODUCTION

Engineering and Construction Bulletin (ECB) 2018-14, rev. 1 (September 10, 2020) 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 ECB guides a qualitative analysis of potential climate change threats and impacts that may be relevant to USACE hydrologic analyses taking into consideration shifting natural climate variability. The formal analyses outlined in the guidance result in better-informed planning and engineering decisions. Further implementation guidance may arise following the issuance of EO 14008, Tackling the Climate Crisis at Home and Abroad was issued on January 27, 2021, which emphasizes climate change considerations be incorporated in planning and programmatic documents.

1.2 LITERATURE REVIEW

A literature review was performed to summarize climate change literature relevant to the study area and highlight both observed and projected assessments of relevant climate change variables. As this is a flood risk management study, the primary relevant variable is streamflow. This variable is also affected by precipitation and air temperature. Therefore, this review focuses on observed and projected changes in air temperature, precipitation and hydrology.

1.2.1 Temperature

1.2.1.1 Observed Temperature

The Fourth National Climate Assessment (USGCRP, 2017) states that observed temperatures in the United States have increased as much as 1.9 degrees Fahrenheit since 1895, with the increase in temperatures accelerating since the 1970s. The National Climate Assessment goes on to say that warming is projected for all parts of the United States. The 2015 review conducted by the USACE Institute for Water Resources (IWR) summarizes the available literature on climate change for the Lower Mississippi River Region, which includes the Horn Lake Creek Basin. In general, studies have found varying trends in observed air temperature. A study by Westby et al. (2013) identified a cooling trend in the region. Another study by Liu et al (2012), noted that the cooling trend ends in the 1970s and transitions to a warming trend from 1976 onwards. Overall, this region differs from the national results observed in the Fourth National Climate Assessment, as there is not a consistent overall warming trend since the early 1900s in the Lower Mississippi (USGCRP, 2017).

In addition, the IWR's Climate Change Literature Review notes that there is a statistically significant increasing trend in the number of one day extreme minimum temperatures in the Lower Mississippi Region. Note there is not a statistically significant trend for the number of one day extreme maximum temperatures. The consensus from the Climate Change Literature Review indicates only mild increases in annual temperature in the region over the past century with significant variability. However, there is consensus that the extreme minimum daily air temperatures are increasing.

Similar warming trends have been noted in the project area. The longest running gage in the area, located at the Memphis International Airport (MEM) has continuous records going back to the 1940s and is located seven miles north of the headwaters of the study area, as shown in Figure H:1-1. From 1930 to the 1970, the average annual temperature at the gage followed no noticeable trend but transitioned to a consistent increase starting in the 1970s.

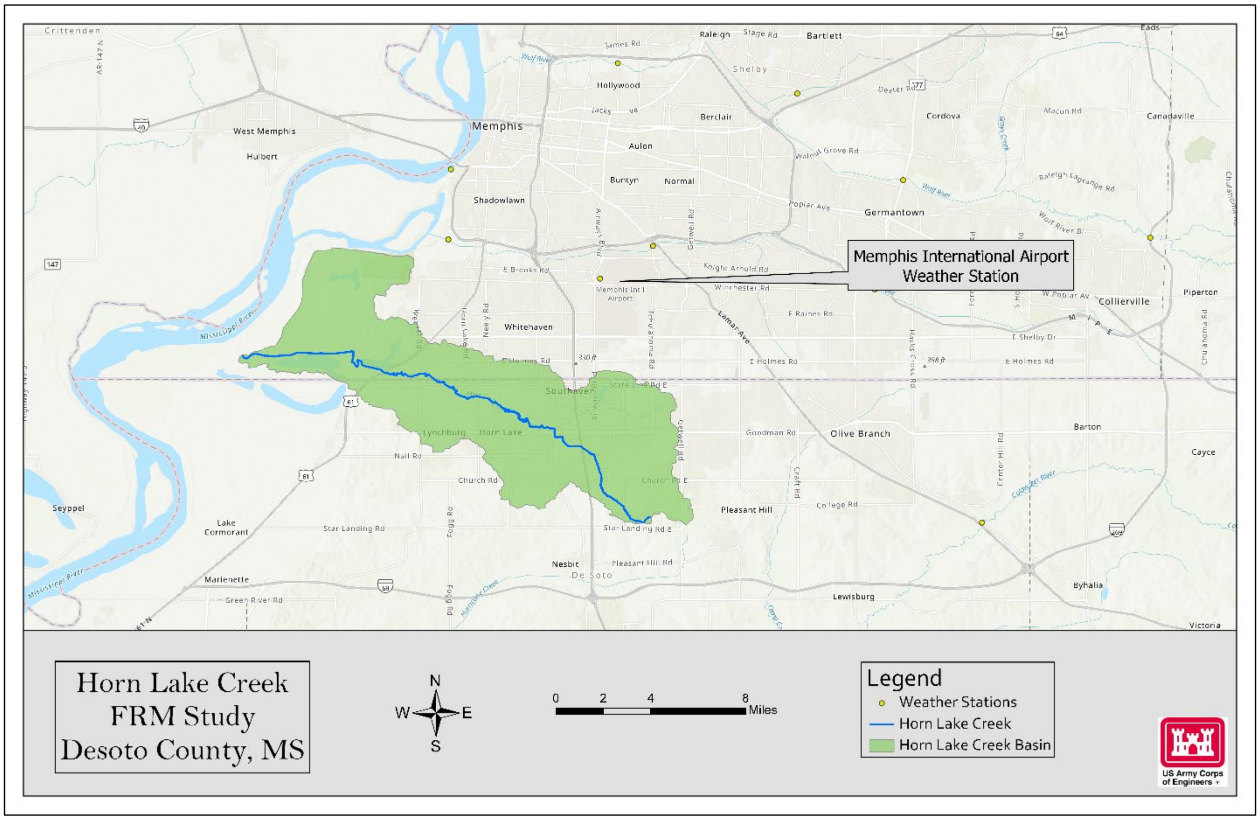


Figure H:1-1. Study Area and Location of the Memphis International Airport (MEM) WeatherStation used in the Statistical Temperature Analysis for the Horn Lake Creek Basin

Statistical hypothesis testing was performed on the annual average temperature from the MEM airport gage. The alternative hypothesis of an apparent trend is accepted to be true at the 0.05 significance level – meaning that p-values less than 0.05 are indicative of statistical significance and p-values less than 0.001 as statistically highly significant. These thresholds are commonly adopted within statistical references. In this case, the entire period of record data produces a p-value of 0.0000007465, as seen in Figure H:1-2, which is very indicative of a statistically upward trend in temperatures.

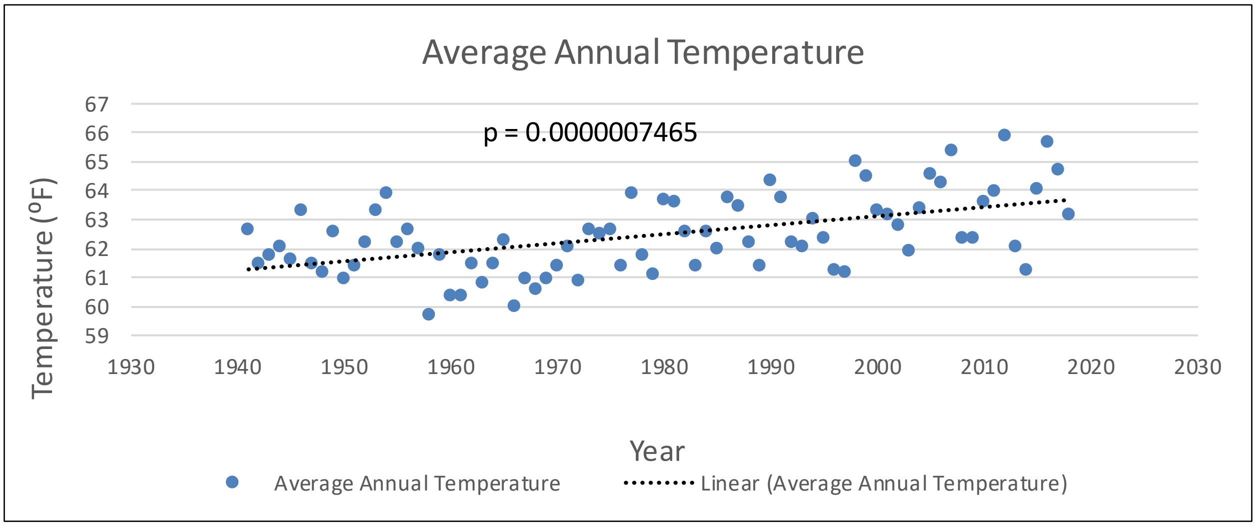


Figure H:1-2. Annual Average Temperature and P-Value from 1940 – 2018 (MEM)

Performing the same test of average annual temperatures from 1940 – 1970 produces a p-value of 0.01519, which is above the reference threshold (Figure H:1-3). Visually there appears to be a decreasing trend in temperature from 1940 to 1970, much like the cooling period that the literature review in the Observed Temperature Section (Section 1.2.1.1). However, the statistical test on the dataset does show a statistically significant downward trend.

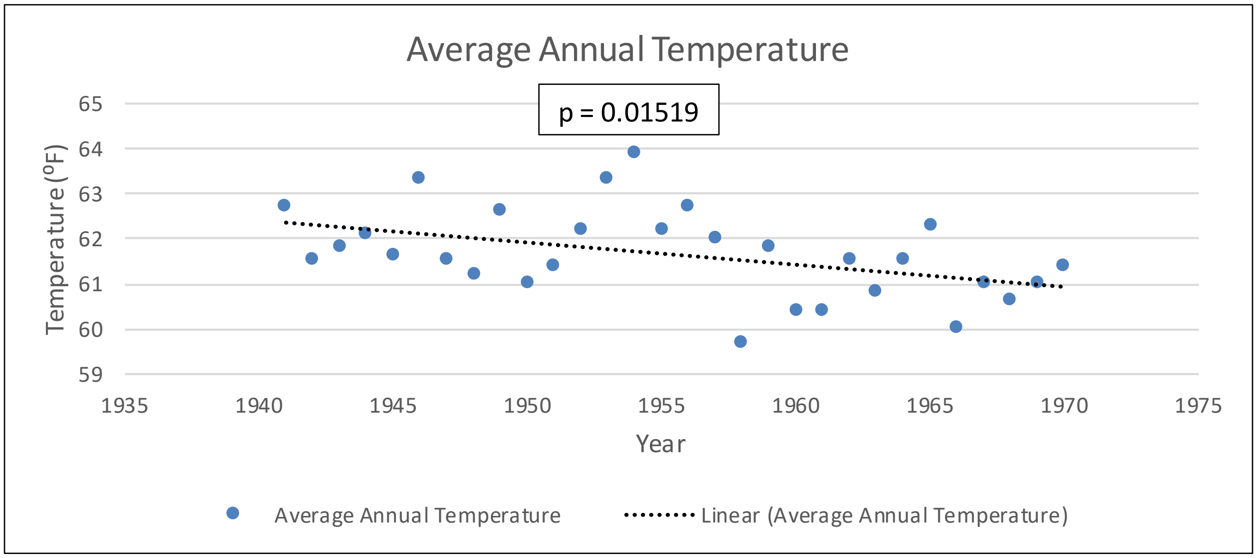


Figure H:1-3. Annual Average Temperature and P-Value from 1940 – 1970 (MEM)

Performing the same statistical test from 1970 – 2018, as shown in Figure H:1-4, produces a p-value of 0.000856. This is below the reference threshold and is very indicative of a statistically significant upward trend in temperatures.

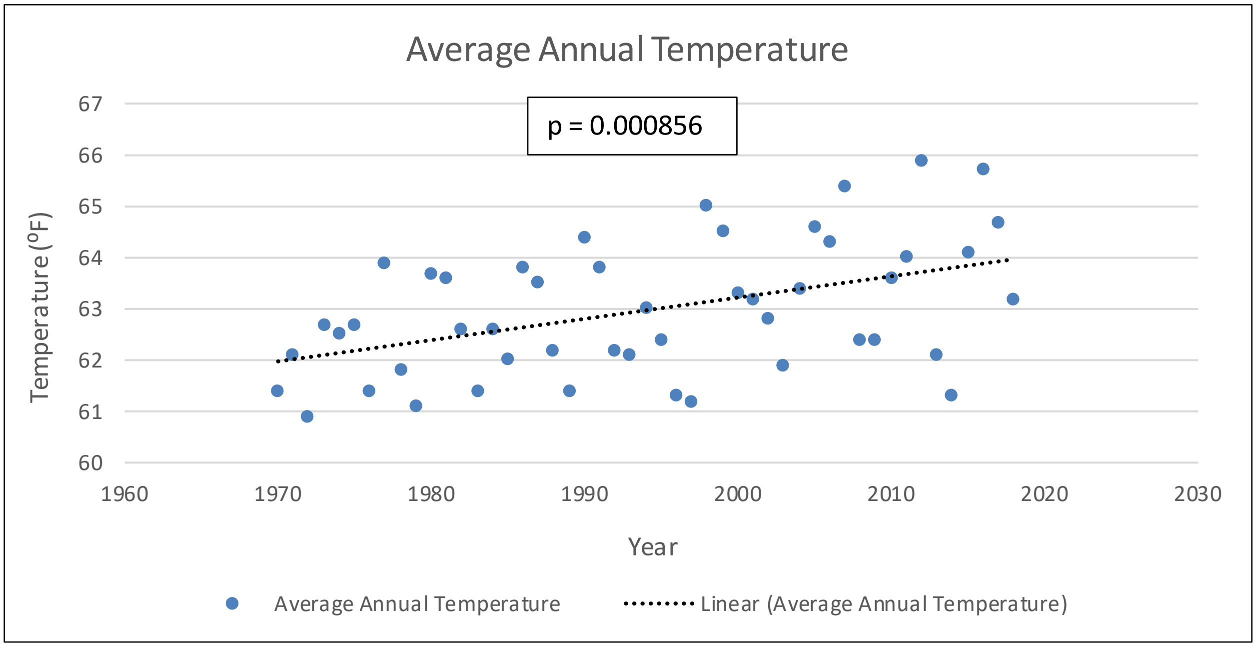


Figure H:1-4. Annual Average Temperature and P-Value from 1970 – 2018 (MEM)

1.2.1.2 Projected Temperature

Global Climate Models (GCMs) have been used to project future climate conditions in the U.S. including the Lower Mississippi River Region. Results show a significant warming trend at a national and regional scale. Figure H:1-5 shows the projected changes in seasonal maximum air temperatures based a report by Liu et al. (2013) assuming a “worst case” greenhouse gas emissions scenario. This shows that overall there is a projected warming trend of 2 to almost 4 degrees Celsius by 2055.

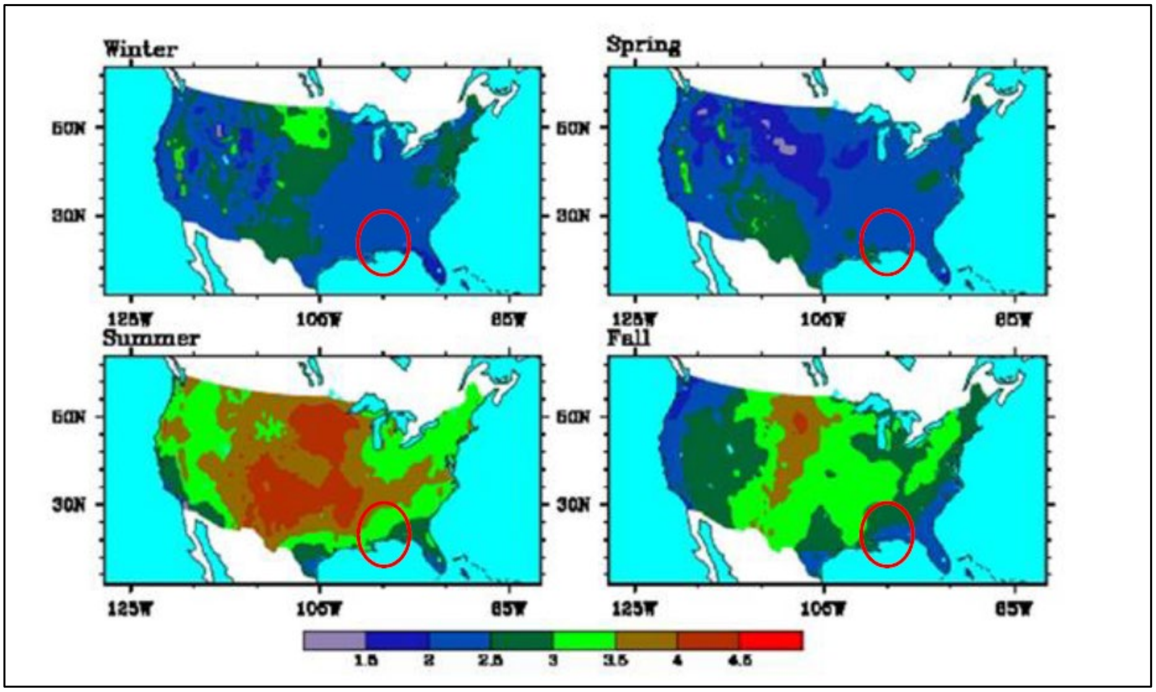


Figure H:1-5: Projected Changes in Seasonal Maximum Air Temperature, ºC, 2041 – 2070 vs. 1971 – 2000. The Lower Mississippi River Region is within the Red Oval. (Liu et al., 2013; reprinted from USACE, 2015).

1.2.2 Precipitation

1.2.2.1 Observed Precipitation

The IWR report (USACE, 2015) shows that there is a general increase in precipitation for the Lower Mississippi River region; however, it is highly variable for the region. Analysis of gridded data from years 1950 -2000 identified an increasing trend in fall precipitation in the northern Lower Mississippi River Region, where the study area is located (Wang et al., 2009). Other seasons; however, have shown increases in precipitation in some areas, decreases in some areas, and some areas with little change in precipitation. An analysis of an extended data period (1895 – 2009) identified linear positive trends in the Lower Mississippi River Region, and particularly in the study area. Figure H:1-6 shows the observed linear trends in annual precipitation.

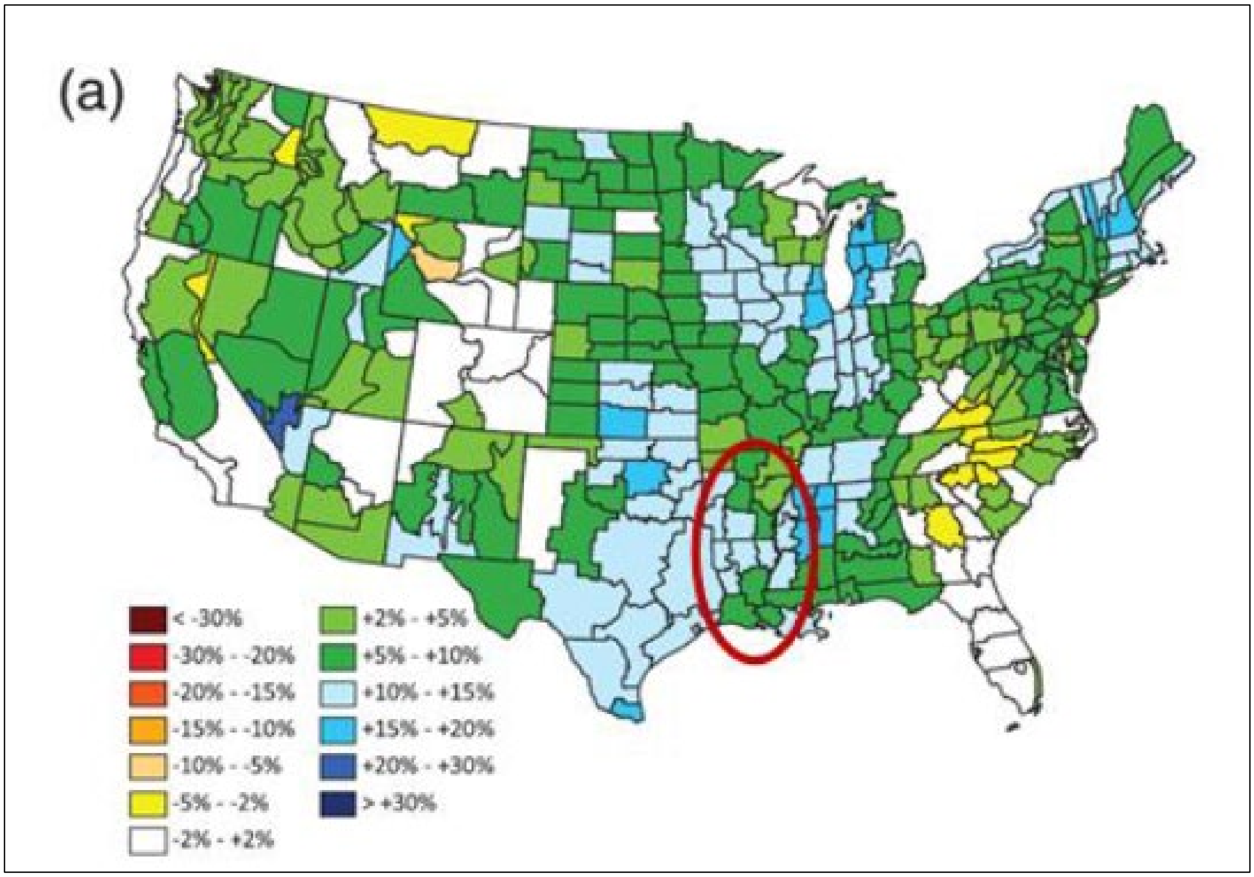


Figure H:1-6. Linear Trends in Annual Precipitation, 1895 - 2009, Percent Change per Century. The Lower Mississippi River Region is within the Red Oval (McRoberts and Nielsen-Gammon, 2011). DeSoto County, where the Horn Lake Creek is located, has Experienced a 10 - 15% Increase in Precipitation over the Century

The MEM Airport weather station shows fairly variable annual average precipitation since 1940 with no statistically significant upward trend based on a high p-value is 0.2928 (Figure H:1-7). Visually, it appears that extremes at either end are becoming more severe since the 1970s (Figure H:1-7).

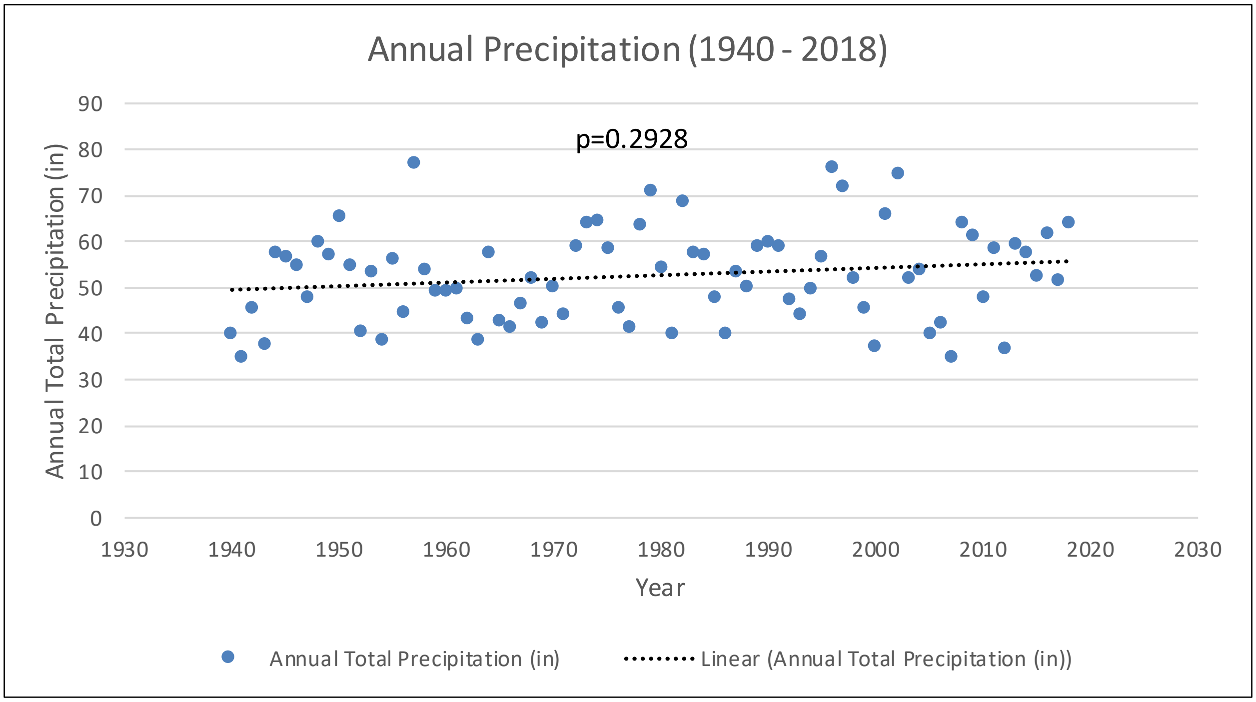


Figure H:1-7. Annual Total Precipitation and P-Value from 1940 – 2018 (MEM)

A study by Pryor et al. (2009) identified a statistically significant increasing trend in total annual precipitation and the number of precipitation days per year in the Lower Mississippi River region. The authors noted that the trend is not strictly linear, as the rate of change is increasing as well. The authors also identified no trend, or a possibly decreasing trend in the 90th percentile (high precipitation).

Most studies analyzed by the IWR (USACE, 2015) suggest that significance in increasing precipitation (the severity and frequency) trends in observed storm are not definitive; however, some analyzed literature shows mild increasing trends in these parameters. For instance, Li et al. (2011) investigated anomalous precipitation (based on deviation from the mean) in summer months in the southeastern U.S., and found that a greater number of climate stations within the region did not exhibit increasing trends in frequency of occurrence of heavy rainfall than those that did. Wang and Killick (2013) also investigated anomalous precipitation, but only detected a statistically significant positive trend for the 10th percentile (low precipitation) and none in the 90th percentile (high precipitation). Though there is not a strong consensus regarding trends in extreme precipitation observed events, it is important to remain mindful of the identified increasing trends in intensity and frequency of rainfall within the region.

1.2.2.2 Projected Precipitation

Projected future changes in precipitation for the Lower Mississippi River region are variable and lack consensus. The Liu et al. study (2013) quantified significant increases in spring precipitation associated with a 2055 future condition for the Lower Mississippi River Region.

Other seasons showed almost no increase or a slight decrease in precipitation. The Liu et al. study also project increases in the severity of future droughts, as projected temperature and evapotranspiration impacts outweigh the increases in precipitation. Figure H:1-8 illustrates the projected change in seasonal precipitation.

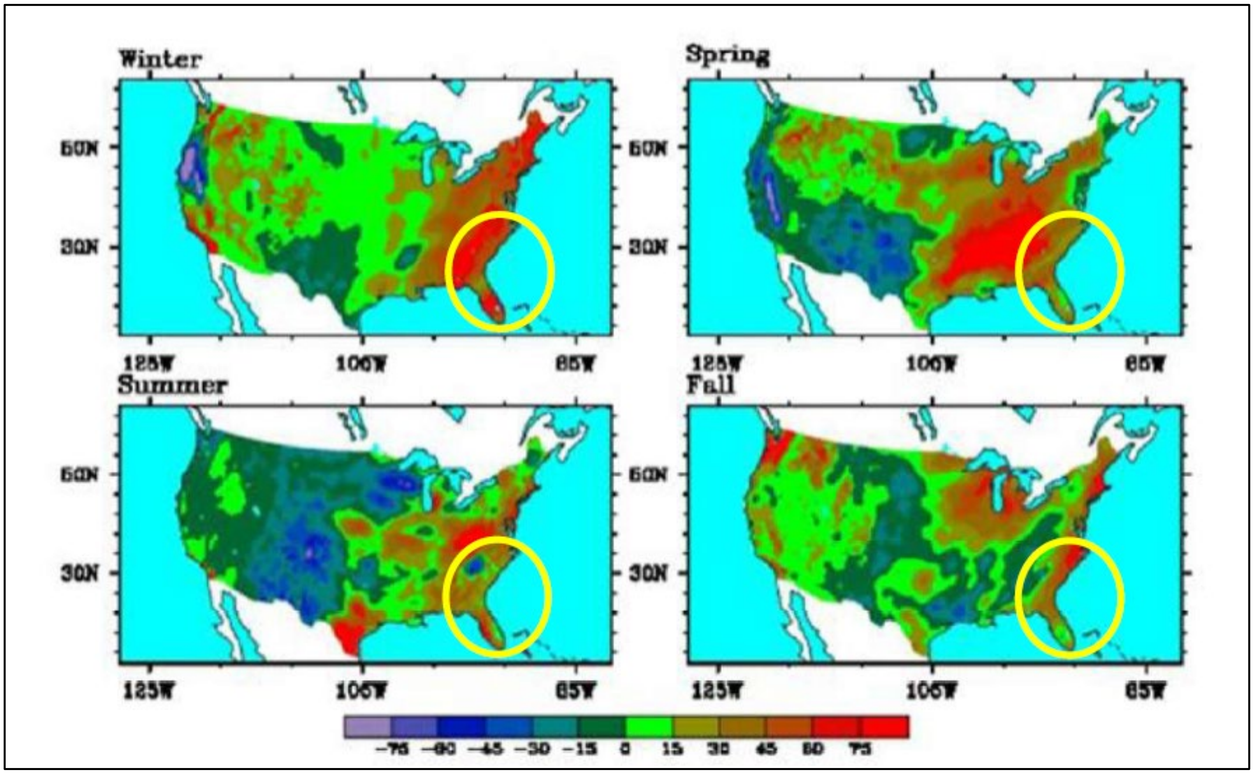


Figure H:1-8: Projected Changes in Seasonal Precipitation, 2055 vs. 1985, mm. The South Atlantic-Gulf Region is within the Yellow Oval (Liu et al., 2013; reprinted from USACE, 2015)

1.2.3 Hydrology

1.2.3.1 Observed Streamflow

Generalized observations of streamflow trends in the Lower Mississippi River Region lack a clear consensus, with some models showing positive trends in some areas and others showing negative trends for areas in the southeast. Generally, most studies in the Lower Mississippi River Region indicated an increasing trend in streamflow. Most notably, studies have shown the positive trend in streamflow being more consistent for the region since the 1940s (Mauget, 2004; and Quian et al., 2007).

For the study area, there is no noticeable trend for streamflow in the Horn Lake Creek area. Horn Lake Creek does not have a discharge gage, but USGS gage 07275900 on the Coldwater River near Olive Branch, MS does. USGS gage 07275900 is 10 miles southeast of the Horn Lake Creek basin. At USGS 07275900 the p-value is 0.74 (Figure H:1-9). This is much higher than the generally accepted significance level of 0.05, and indicates that there is no statistically significant trend. Data presented in the non-stationarity assessment in the next section strongly reflects the lack of statistically significant trends.

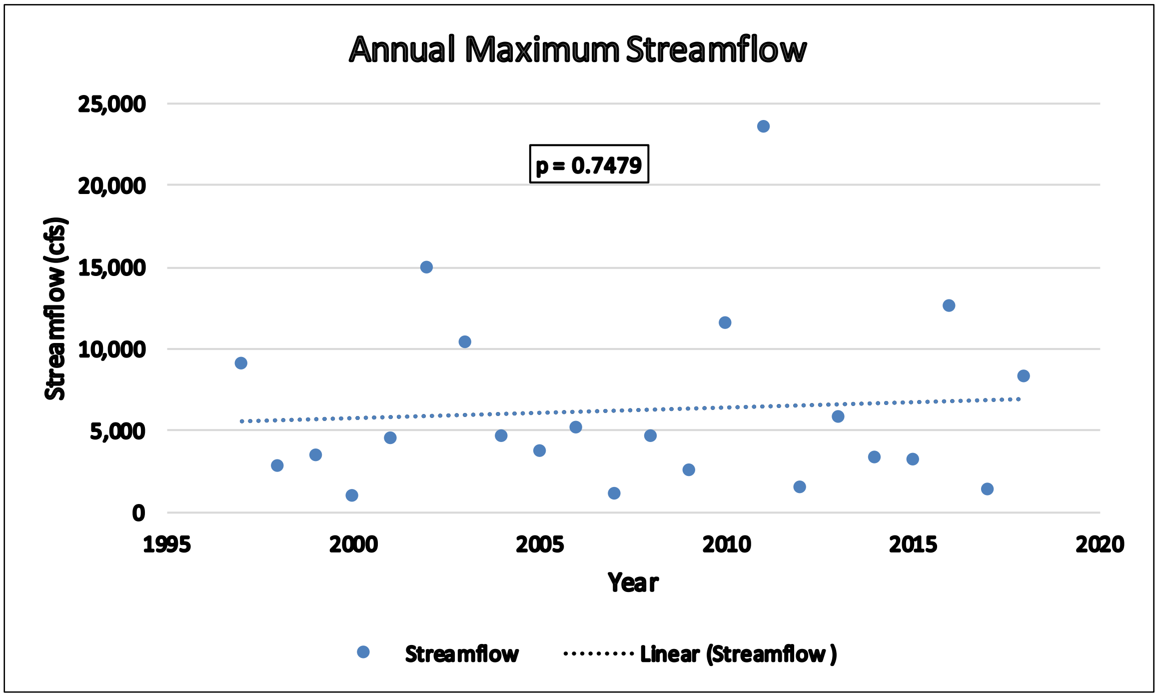


Figure H:1-9. Annual Peak Streamflow at USGS 07275900 Coldwater River near Olive Branch, MS

1.2.3.2 Projected Streamflow

No regional studies of future hydrology projections, specific to the Lower Mississippi River Region, were discussed in the IWR report (USACE, 2015). A national study by Thomson et al. (2005) indicated low consensus in projected hydrologic changes. This is due to the additional uncertainties that are added when coupling climate models to hydrologic models, both of which carry their own uncertainties. The IWR report did note that the National Climate Assessment (Carter et al., 2014) projects mild decreases in water availability for the Lower Mississippi region, in agreement with a Doll and Zhang (2010) study. Overall, the IWR literature review lacks consensus for projected streamflow, but did note that some studies suggest that streamflow may be decreasing over the next century in the Lower Mississippi River Region (USACE, 2015).

1.2.4 Summary

Figure H:1-10 shows the discussed variables and their overall consensus in trends for both observed and projected scenarios based on the findings of the 2015 USACE IWR literature synthesis. Overall, it can be said that there is the most evidence in the observed data of an increasing precipitation trend. There is less evidence in observed data pointing to trends in temperature or temperature maximums in the region. There is some evidence that hydrology and streamflow are increasing in the region, but unclear evidence whether temperature is increasing or decreasing.

Projections indicate a strong consensus of an increase in projected temperature of approximately 2 to 4 degrees Celsius by the late 21st century. There is some consensus that precipitation extremes may increase in future both in terms of intensity and frequency, however, in general projections of precipitation have been shown to be highly variable across the region. There is some consensus that streamflow is projected to decrease in the region. However, very few conclusions can be drawn regarding future hydrology in the region largely due to the substantial amount of uncertainly in these projections when coupling climate models with hydrology models.

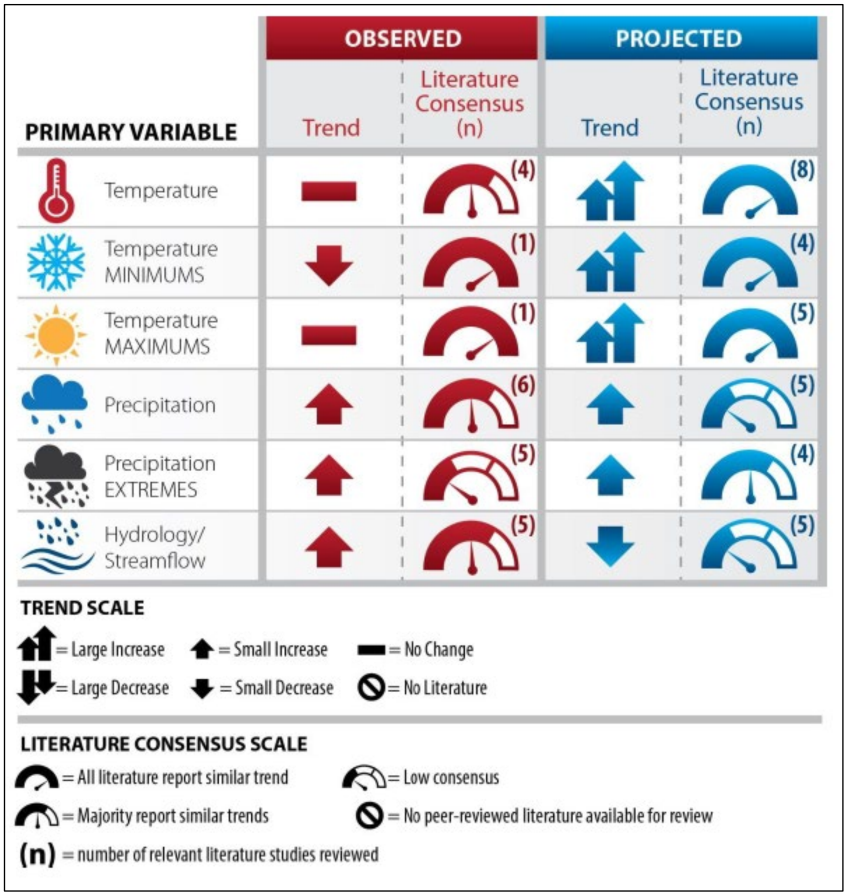


Figure H:1-10. Summary Matrix of Observed and Projected Climate Trends and Literary Consensus

1.3 NON-STATIONARITY ASSESSMENT

In accordance with ECB 2018-14, a stationarity analysis was performed to determine if there are long-term changes in peak streamflow statistics within the Horn Lake Creek basin and its vicinity. Assessing trends in peak streamflow is considered appropriate as one of the primary purposes of this feasibility study is to assess and reduce flooding in the Horn Lake Creek

Basin. The current flood risk management measures being considered include channel enlargement, inline storage, and off-channel storage and are significantly affected by changes in peak streamflow. An environmental restoration feature is a part of the project. This feature will address channel instability and aquatic habitat degradation.

1.3.1 USACE Non-Stationarity Tool

The USACE Non-stationarity Tool was used to assess possible trends and change points in peak streamflow in the region. Since the Horn Lake basin does not possess a stream gage, the USGS 07032200 located in the Nonconnah Creek basin was used for the analysis (Figure H:1-11). The green area encompasses the study area within the larger Horn Lake Creek Basin. The gage in this analysis, located on Nonconnah Creek, is approximately 8.6 miles northeast of the Horn Lake Creek Watershed boundary. The Nonconnah Creek gage was chosen as its topography and basin size are comparable to Horn Lake Creek. Additionally, this gage is the only site with similar basin characteristics in the area and at least 30 continuous years of record which is the minimum recommended years for this tool to detect non-stationarities.

The lower reaches of Horn Lake Creek are affected by Mississippi River backwater. The Mississippi River 2011 event (second highest of record) backwater was estimated to extend 14 miles upstream from Horn Lake Creek's mouth; two miles from the Mississippi-Tennessee State-line. Since the backwater only extends two miles into Mississippi, it does impact the current assessments and is not expected to impact project conditions nor future flooding. As stated previously, the IWR literature review lacks consensus for projected streamflow, but did note that some studies suggest that streamflow may be decreasing over the next century in the Lower Mississippi River Region.

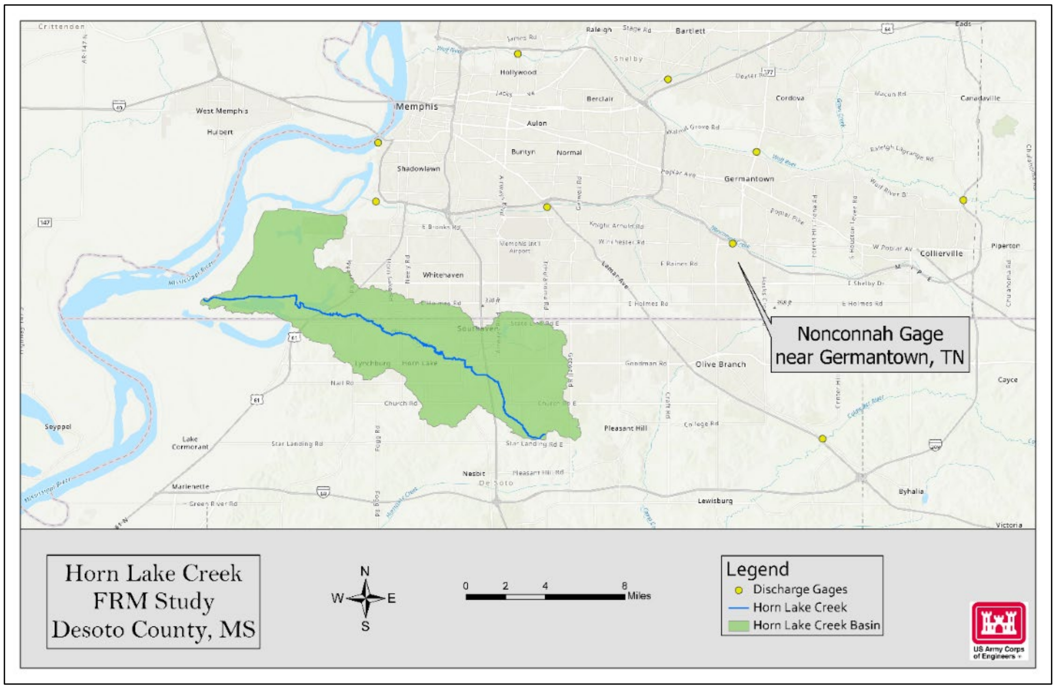


Figure H:1-11: The Horn Lake Creek Basin in relation to the Nonconnah Gage near Germantown, TN

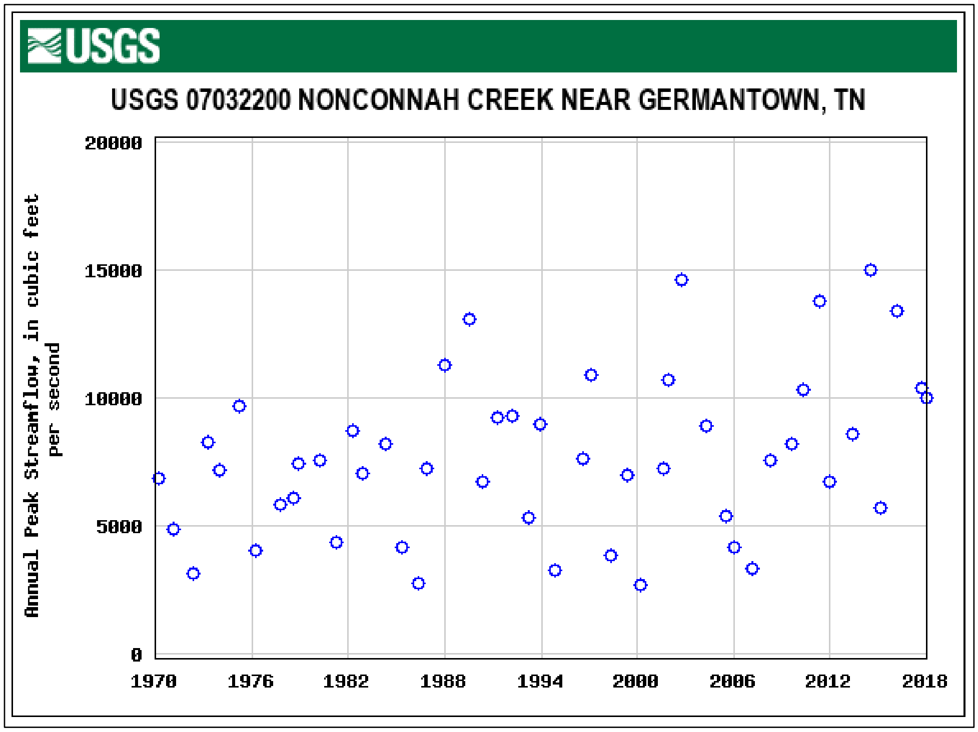


Figure H:1-12. APF at USGS 07032200 Nonconnah Creek near Germantown, TN

The following 16 statistical tests were conducted on the APF time series shown in Figure H:1-12 using the Non-Stationarity Tool:

1. Cramer-von-Mises distribution
2. Kolmogorov-Smirnov distribution
3. LePage distribution
4. Energy Divisive distribution
5. Lombard (Wilcoxon) abrupt mean
6. Pettitt mean
7. Mann-Whitney mean
8. Bayesian mean
9. Lombard (Mood) abrupt variance
10. Mood variance
11. Lombard (Wilcoxon) smooth mean
12. Lombard (Mood) smooth variance
13. Mann-Kendall trend
14. Spearman rank trend
15. Parametric trend
16. Sen's slope trend

Tests 1-12 are used to detect change points in the distribution, mean, and/or variance of the time series. These non-stationarity tests can be useful in detecting changes in annual instantaneous streamflow peaks driven by natural and human driven changes in the climate, addition/removal of water control structures, changes in land cover, as well as any other drivers of non-stationarity. Meanwhile, tests 13-16 are used to analyze monotonic trends. The variety of tests is essential for increasing confidence in the overall stationarity analysis. Significant findings in one or two tests are generally not enough to declare non-stationarity.

For this analysis the continuous period of water years 1970 – 2014 was analyzed. All sensitivity parameters were left in their default positions. Figure H:1-13 shows the results of tests 1-12. One abrupt non-stationarity was detected within the annual instantaneous peak stream flow record for Nonconnah Creek. The Lombard Wilcoxon test detected a change in the segment mean of the flow record. The detected non-stationarity is neither considered strong nor robust.

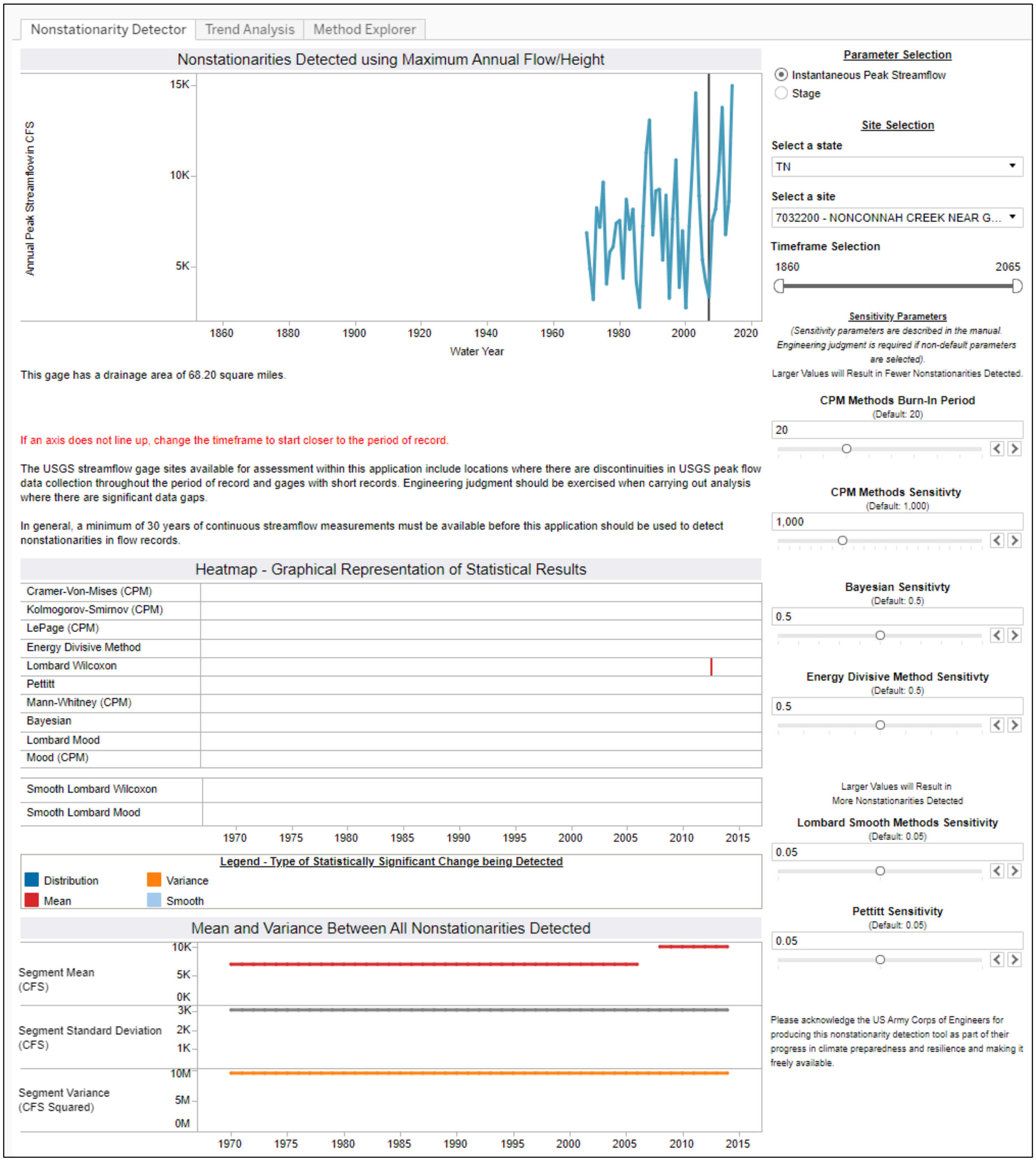
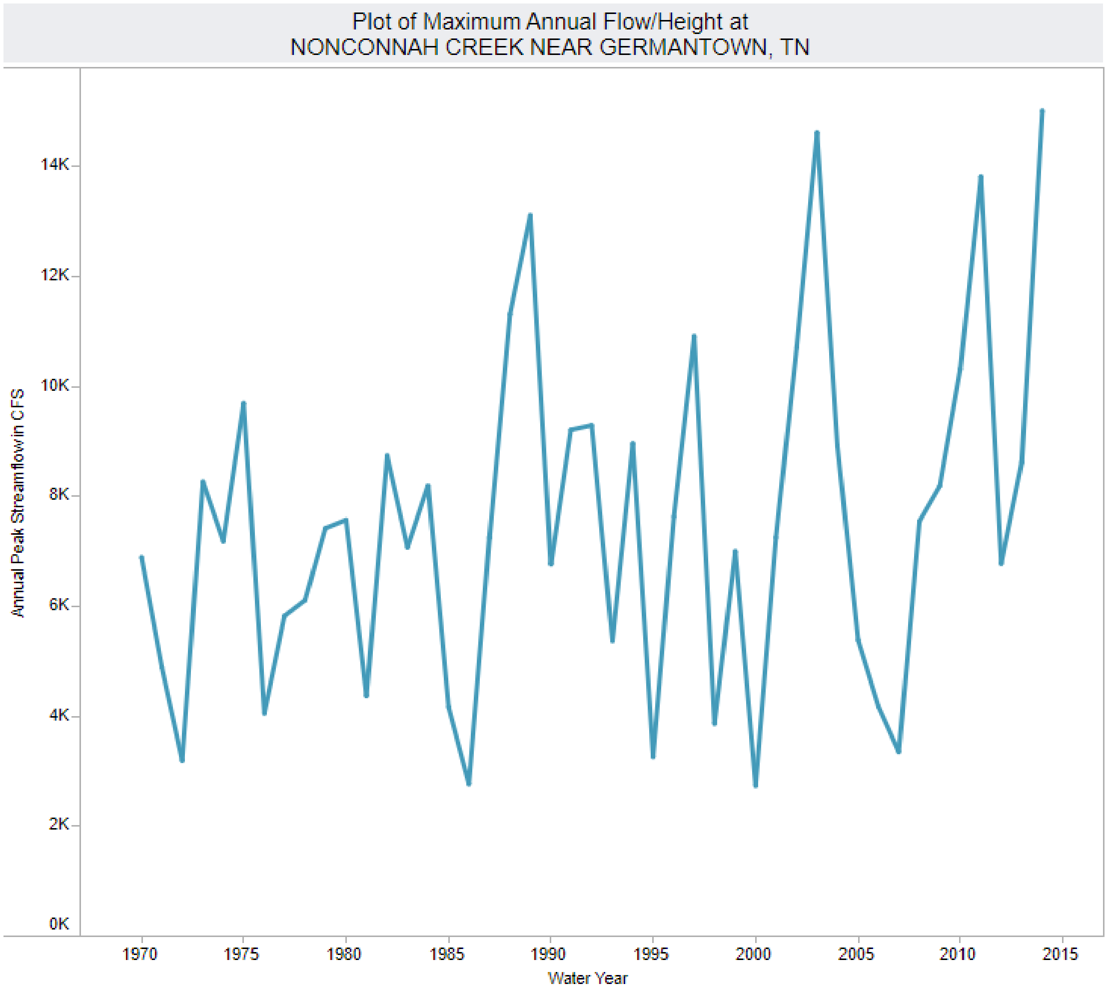


Figure H:1-13. Results of the Non-stationarity Assessment for USGS 07032200 Nonconnah Creek near Germantown, TN

Tests 13-16 (shown in Figure H:1-14 and Figure H:1-15) showed no monotonic trend in the period of record or the period before the non-stationarity in 2007. The period after the non-stationarity in 2007 is too short to detect a monotonic trend.

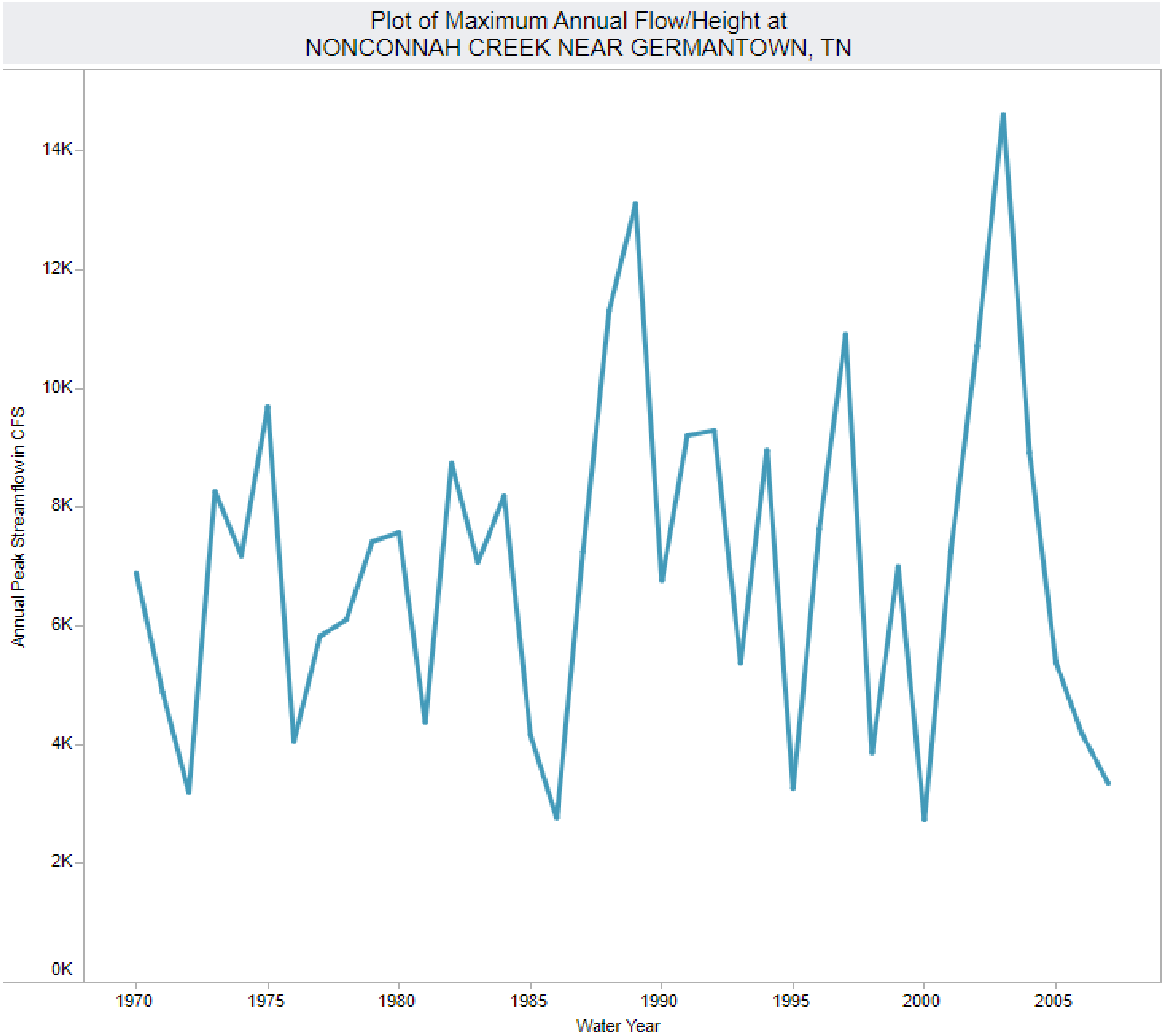


Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.080.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was Null.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Figure H:1-14. Monotonic Trend Analysis for the full POR (1970-2014), taken from the US Army Corps of Engineers Non-stationarity Detection Tool



Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.642.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.684.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Figure H:1-15. Monotonic Trend Analysis for the POR before the Non-Stationarity (1970-2007), taken from the US Army Corps of Engineers Non-stationarity Detection Tool

1.3.2 Analysis of Non-stationarity Tool Results

A non-stationarity is considered strong if two or more of the detection methods of the same type detect a non-stationarity in the data. For the gage at Nonconnah Creek, the 2007 non-stationarity is not considered strong. The Lombard Wilcoxon test detected a non-stationarity in the segment mean distribution in 2007 (Figure H:1-15). A non-stationarity is considered robust if tests targeting changes in two or more different statistical properties indicate a non-stationarity. As only the mean distribution test detected a changepoint in 2007, the non-stationarity is not considered robust (Figure H:1-15).

In terms of magnitude, the changes in mean peak annual streamflow do not appear to be statistically significant but rather the result of a series of significant hydrologic events in the basin. The Nonconnah Creek drainage area above the Germantown gage is relatively small (the drainage area is 68.20 square miles), so the basin is more sensitive to hydrologic events impacting its statistical changepoints. Historical rainfall data at USGS 07032200 was not available prior to 2012, so it is not certain if hydrologic events contributed to the non-stationarity in 2007. However, as both clusters were neither strong nor robust changepoints it is likely that significant hydrologic events contributed to the non-stationarity.

Using the USACE non-stationarity tool to compare segment mean, there is an increase of 2,998 cfs in mean peak annual streamflow after the 2007 changepoint compared to the period of record prior to the 2007 changepoint (10,027 cfs vs 7,029 cfs). For a small, urbanized basin like Nonconnah Creek an increase of only 2,998 cfs does not appear to be statistically significant.

1.3.3 Climate Hydrology Assessment

In addition to the stationarity assessment, the USACE Climate Hydrology Assessment Tool (CHAT) was used to assist in the determination of future streamflow conditions. For this assessment, the continuous period of record of 1970 – 2014 for USGS 07032200 was used. Figure 16 shows the Climate Hydrology Assessment Tool output for this gage.

The CHAT analysis indicates that there might be statistically significant increasing trend in annual peak instantaneous streamflow for Nonconnah Creek (Figure H:1-16). There is no recommended threshold for statistical significance, but typically 0.05 is used as it is associated with a 5% risk of a false positive. The p-value in Nonconnah is 0.044, just under the standard threshold, which indicates that there is likely a statistically significant increasing trend. However, the monotonic trend tab in the Non-stationarity Assessment Tool was applied to the entire period of record but did not indicate that there was a statistically significant trend in the annual peak streamflow record from 1970-2014.

The Nonconnah Creek basin continues to experience development and is projected to continue this growth for the near future. Future land use estimates produced in the Memphis Metro Stormwater Study (1997) predicted the basin would be 100% developed by 2050. It should be emphasized that this growth is primarily located in the headwaters of Nonconnah Creek, above the Germantown gage. The contributing drainage area includes the suburbs of the surrounding communities of Olive Branch, Mississippi and southeastern Shelby County municipalities of Germantown and Collierville Tennessee. The results are inconclusive, but it should be noted that there is likely a statistically significant increase in annual peak instantaneous streamflow at USGS 07032200.

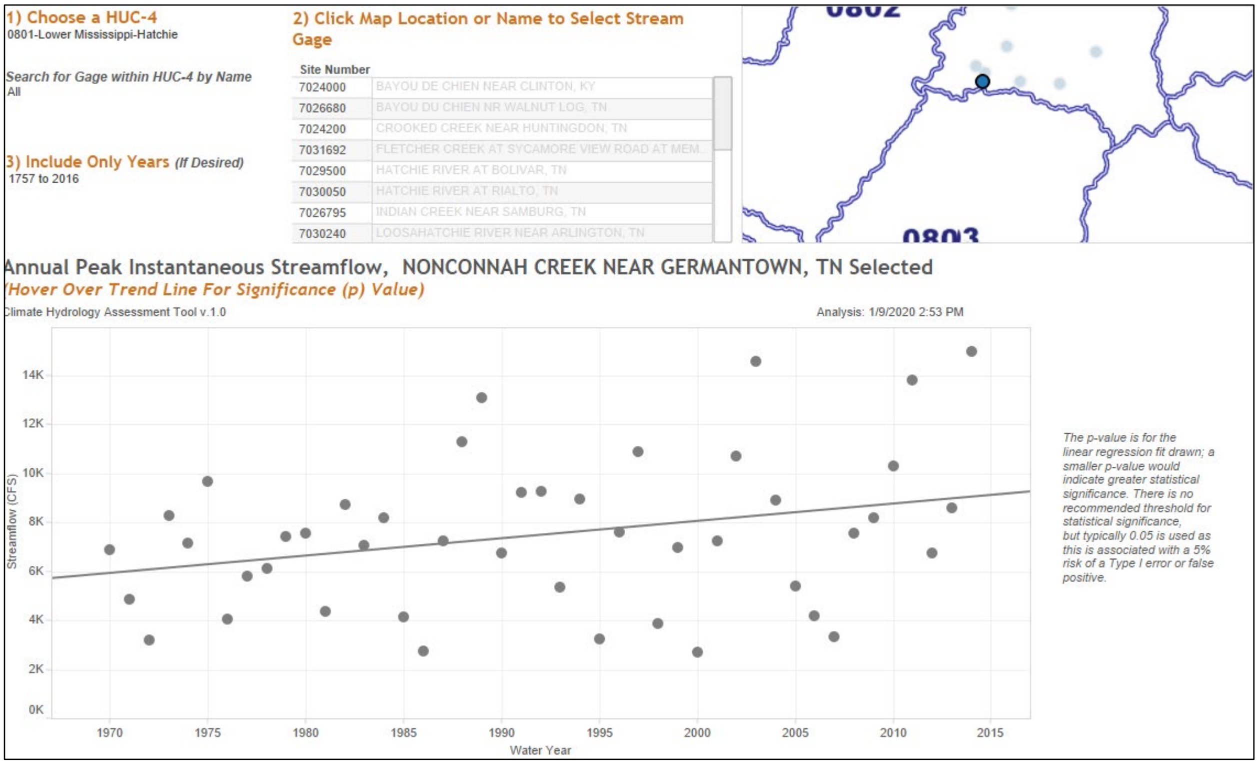


Figure H:1-16. CHAT Output for USGS 07032200 for Nonconnah Creek near Germantown, TN

A Hydrologic Unit Code 4 (HUC-4) level analysis of mean projected annual maximum monthly streamflow was also performed on the Mississippi River lower basin. The trends in mean projected annual maximum monthly streamflow presented in this analysis represent outputs from the Global Climate Models (GCMs) using different representative concentration pathways (RCPs) of greenhouse gasses that are then translated into a hydrologic response using the United States Bureau of Reclamation (USBR) Variable Infiltration Capacity (VIC) model. The VIC model, forced with GCM meteorological outputs is used to produce a streamflow response for both the hindcast period (1950-1999) and the future period (2000-2099). This dataset is unregulated and does not account for the many flood control structures located on the mainstem rivers within this HUC-4 basin.

The analysis indicates an upward trend in mean projected annual maximum monthly streamflow for the Lower Mississippi-Hatchie Basin, as shown in Figure H:1-17. This data represents flow near the downstream end of the Mississippi River basin, of which Nonconnah Creek is a tributary. The forecast visually indicates an upward trend in projected streamflow from years 2000 to 2099 within the basin, but the trend is not statistically significant (p-value of 0.19). The hindcast data shows no statistically significant trend from 1950 to 1999 (p-value: 0.973033).

Figure H:1-17 provides the mean value of the 93 projections of future, streamflow projections considered through water year 2099, as well as the range of projected streamflow values produced for the watershed. Looking at Figure H:1-17, the variability of the spread is fairly consistent for the projected portion of the record: 2000 to 2099.

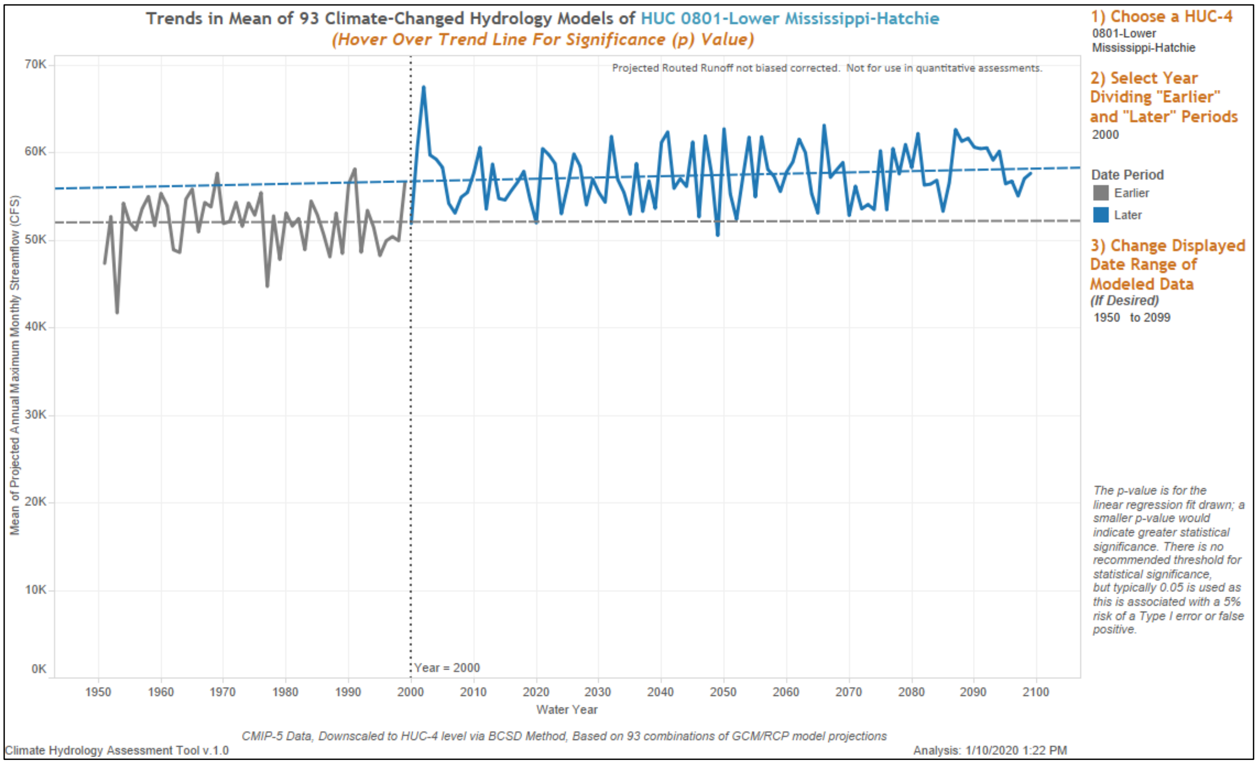


Figure H:1-17. Mean Projected Annual Maximum Monthly Streamflow for the Lower Mississippi-Hatchie HUC-4

It can be seen in Figure H:1-18 that there is significant uncertainty in projections of future streamflow (in Figure H:1-18 the yellow, shaded area is indicative of the spread in the data produced). It is important to understand that this uncertainty comes from each of the model sources that are used to develop the projected streamflow datasets. GCMs have uncertainty in the bounds of their atmospheric input such as the RCPs. Downscaling the output of these models to a smaller region may not account for some regional effects. Changes in future conditions that drive the hydrologic model are also a major uncertainty. Land use changes such as increased impervious areas can have a major effect on peak streamflow. There are many different land use projections for this region from many sources. Other uncertainties such as changes in temperature extremes and the seasonality of the extreme precipitation could also have a significant effect on the rainfall/runoff transformation. For these reasons, this quantitative analysis should be used with caution, with an understanding that this data should only be considered within the large uncertainly bounds of the analysis.

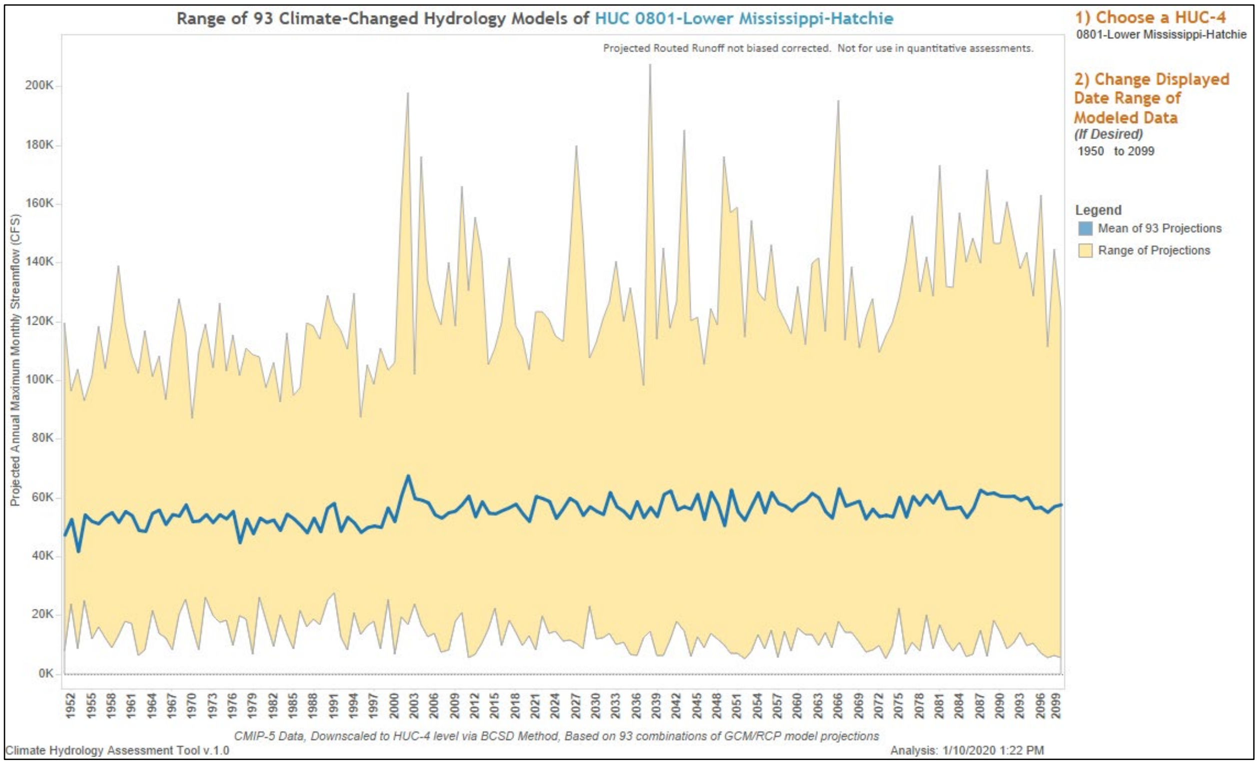


Figure H:1-18. Projected Hydrology for the Lower Mississippi-Hatchie HUC-4 Base on the Output from 93 Projections of Climate Changed Hydrology

1.4 VULNERABILITY ASSESSMENT

To understand potential climate change effects and to increase resilience/decrease vulnerability of flood risk management alternatives to climate change, the relative vulnerability of the basin to such factors was analyzed. In accordance with ECB 2018-14, the USACE Watershed Climate Vulnerability Assessment tool was used to identify vulnerabilities to climate change on a HUC-4 watershed scale relative to other HUC-4 basins across the nation. As this study is an assessment of flood risk management alternatives, vulnerability with respect to the Flood Risk Reduction business line is presented in this analysis.

To address vulnerabilities due to climate change, the Vulnerability Assessment tool utilizes two 30-year epochs centered on 2050 (2035-2064) and 2085 (2070-2099) as well as a base epoch. These epochs line up well with other national climate change assessments. For each epoch, the tool utilizes the results of 100 combinations of Global Circulation/Climate Models (GCM) run using different Representative Concentration Pathways of greenhouse gas emission to produce 100 traces per epoch for a given watershed. The results of the GCMs are translated into flow and are then sorted by cumulative runoff projections. Traces of the highest 50% of cumulative runoff are categorized as wet and traces with the lowest 50% of cumulative runoff are categorized as dry. This provides two scenarios (wet and dry) for each of the two epochs, excluding the base epoch. Consideration of both wet and dry scenarios reveals some of the uncertainties associated with the results produced using the climate changed hydrology and meteorology used as inputs to the vulnerability tool.

The tool uses specific indicators of vulnerability relative to the business line being considered. A total of 27 indicators are available in the tool, 5 of which are used to derive the vulnerability score in the Lower Mississippi-Hatchie HUC 4 with respect to the Flood Damage Reduction business line. Table H:1-1 lists the indicators and corresponding descriptions.

Table H:1-1. Indicator Variables used to Derive the Flood Risk Management Vulnerability Score for the Mississippi-Hatchie Basin as Determined by the Vulnerability Assessment Tool

Indicator Short Name	Indicator Full Name	Description
175C_ANNUAL_COV	Annual CV of unregulated runoff (cumulative)	Long-term variability in hydrology: ratio of the standard deviation of annual runoff to the annual runoff mean. Includes upstream freshwater inputs (cumulative).
277_RUNOFF_PRECIP	% change in runoff divided by % change in precipitation	Median of: deviation of runoff from monthly mean times average monthly runoff divided by deviation of precipitation from monthly mean times average monthly precipitation.
568L_FLOOD_MAGNIFICATION	Flood magnification factor (local)	Change in flood runoff: Ratio of indicator 571L (monthly runoff exceeded 10% of the time, excluding upstream freshwater inputs) to 571L in base period.
568C_FLOOD_MAGNIFICATION	Flood magnification factor (cumulative)	Change in flood runoff: ratio of indicator 571C (monthly runoff exceeded 10% of the time, including upstream freshwater inputs) to 571C in base period.
590_URBAN_500YRFLOODPLAIN	Acres of urban area within 500-year floodplain	Acres of urban area within the 500-year floodplain.

Figure H:1-19 and Figure H:1-20 show a comparison of WOWA scores for the flood risk reduction business line for HUC-4 watersheds nationally, and for the Mississippi Valley Division only, for the wet and dry scenarios as well as the 2050 and 2085 epochs. This shows that the WOWA score for the Lower Mississippi-Hatchie HUC-4 Basin (highlighted in yellow) is not relatively vulnerable to climate change impacts for the flood risk reduction business line. Within the Mississippi Valley Division, for both epochs for the wet subset of traces there are only two HUC04 watersheds, and for the dry subset of traces there are only eight HUC04 watersheds that are considered relatively vulnerable to climate change for the flood risk management business line. The vulnerable watersheds for the wet scenario are located in the Upper Mississippi Valley, upstream of the confluence with the Ohio River. The vulnerable watersheds for the dry scenario are located in the Upper Mississippi Valley and in the Red-Ouachita, Red-Sulphur, and Lower Mississippi. The Memphis District is not relatively vulnerable to climate change impacts for the risk reduction business line. This further reinforces that the Nonconnah Creek basin does not have significant vulnerabilities to the Flood Risk Reduction business line with respect to other watersheds in the United States or the region.

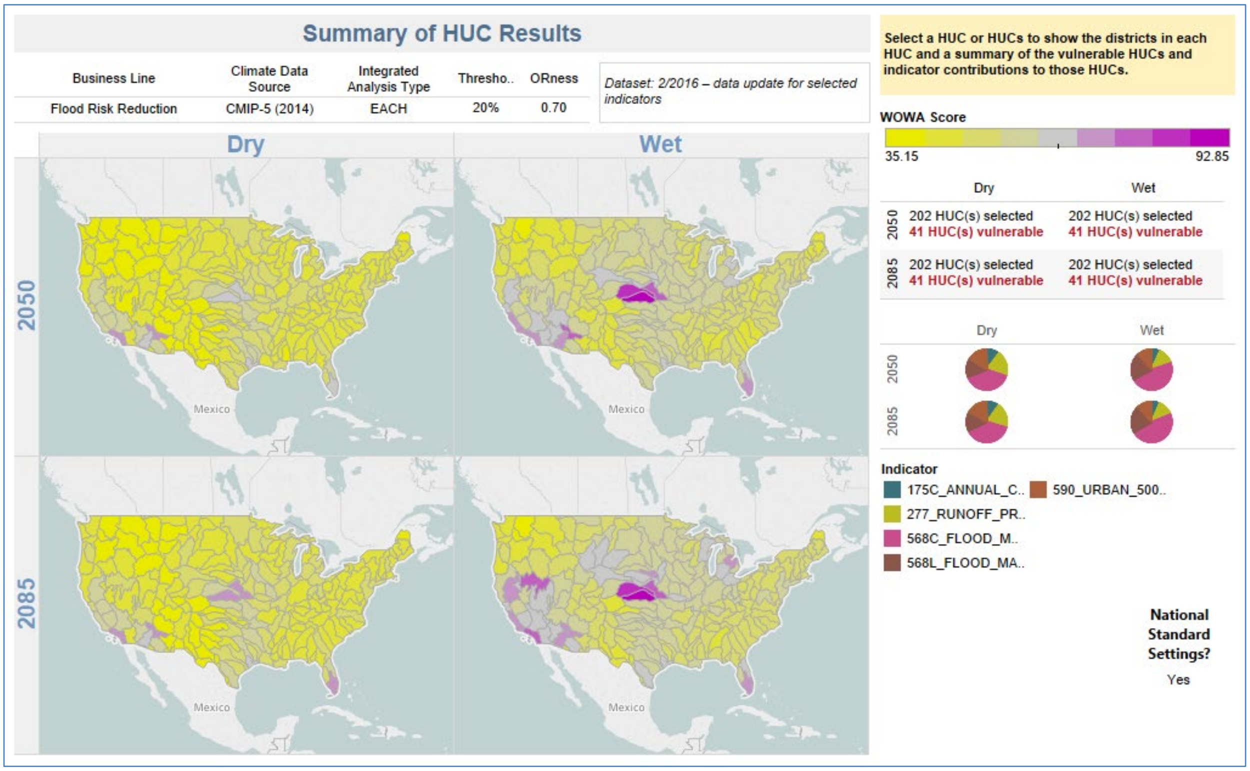


Figure H:1-19. Comparison of National Vulnerability Scores for CONUS HUC-4s

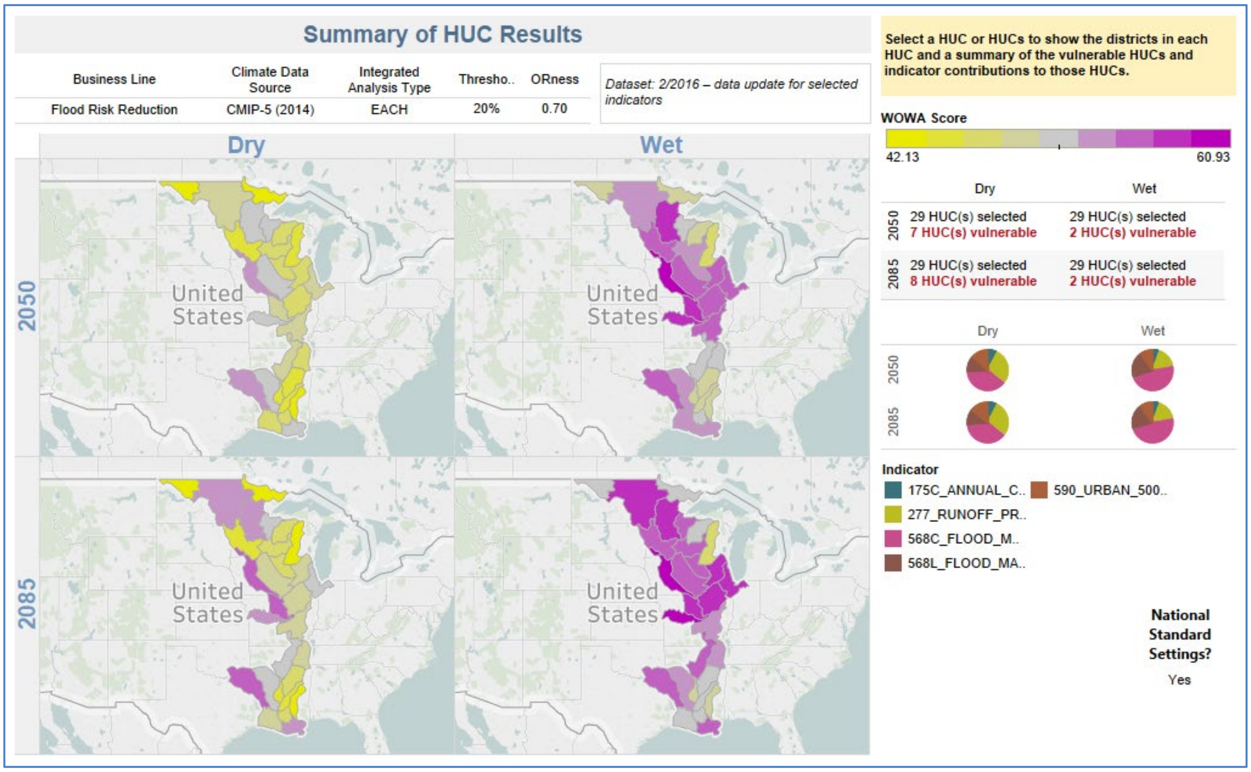


Figure H:1-20. Comparison of National Vulnerability Scores for Mississippi Valley Division HUC-4s

It is important to note that the vulnerability assessment only indicates vulnerability relative to the rest of the nation. It does not state that the basin itself is invulnerable to impacts of climate change on the Flood Risk Reduction business line. Therefore, it is beneficial to understand the composition of the relevant HUC04's (Lower Mississippi-Hatchie) vulnerability score in terms of how much each flood risk reduction indicator variable contributes to the vulnerability score for each subset of traces and for both epochs of time. Figure H:1-21 and Figure H:1-22 show the dominant indicators relative to Flood Risk Reduction. These figures both show that cumulative flood magnification is the prevailing indicator variable driving the Flood Damage Reduction vulnerability score, followed by the percent change in runoff, divided by the percent change in precipitation for the dry scenario and local flood magnification for the wet scenario.

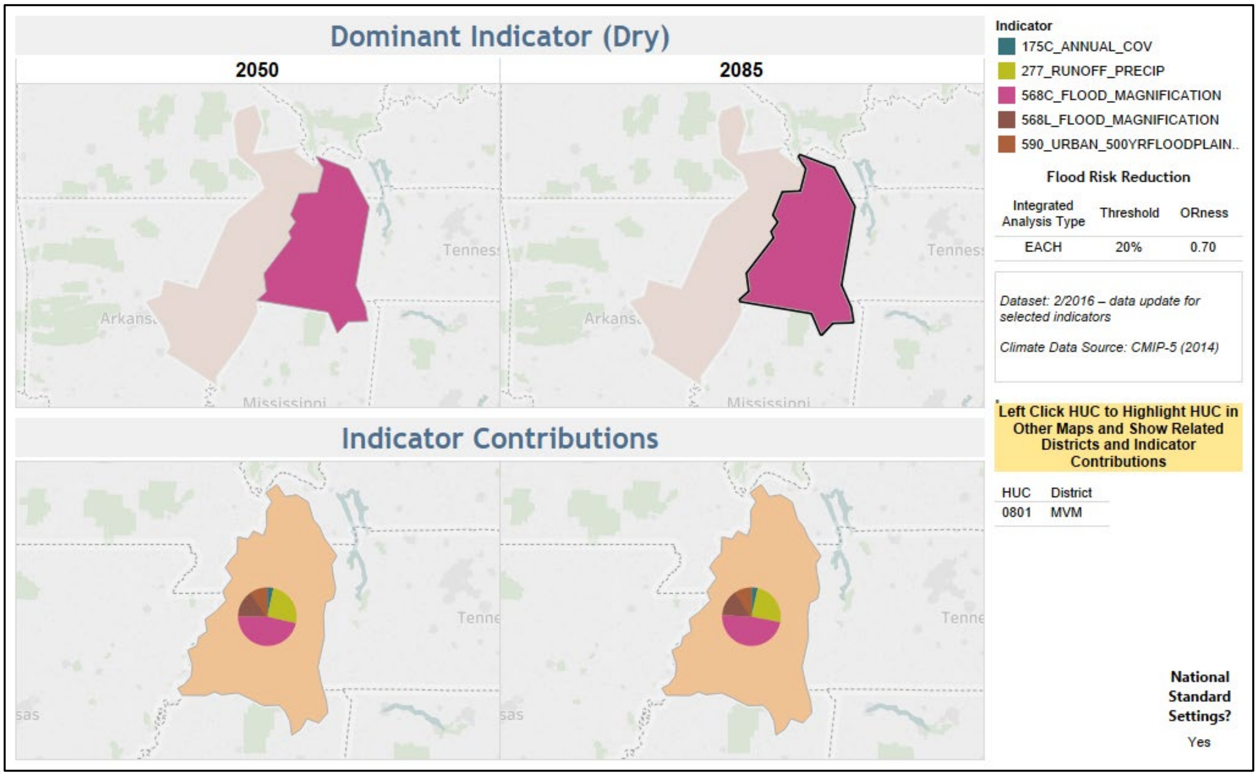


Figure H:1-21. Dominate Indicators for the Flood Risk Reduction Business Line for the Dry Scenario

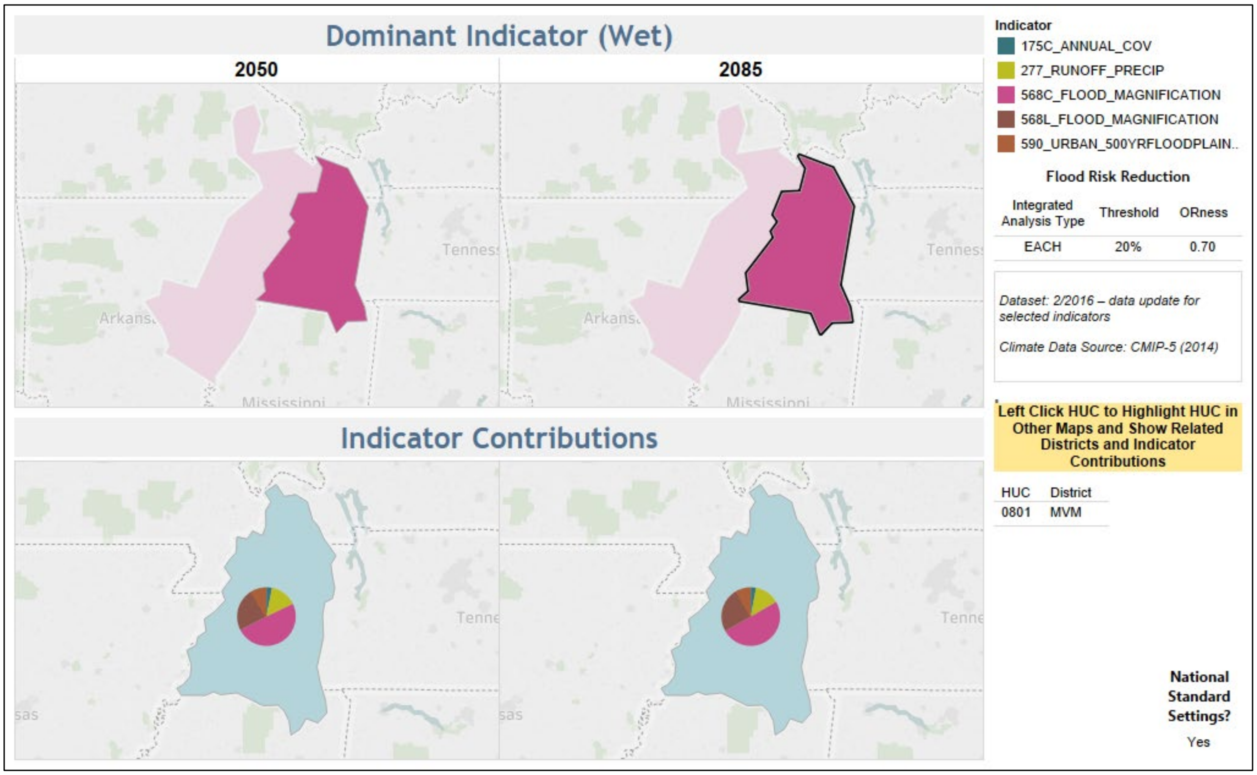


Figure H:1-22. Dominate Indicators for the Flood Risk Reduction Business Line for the Wet Scenario

1.5 CLIMATE CHANGE AND IMPACTS ON TSP

Table H:1-2 identifies climate change impacts on structural features of the Flood Risk Management Tentatively Selected Plan.

Table H:1-2. Impacts of Climate Change on Structural Features of the FRM TSP (Base and Future Conditions)

Feature or Measure (Alt ID)	Trigger	Hazard	Harm	Qualitative Likelihood
Channel Enlargement (5A, 5B, 6A, 6B-NED, 7A-LPP)	Increased precipitation from larger, slower moving storms.	Future flood volumes may be larger than present. Large flood volumes may occur more frequently.	Flood water will exceed the channel capacity and inundate structures causing damages.	Likely
Multiple Detention (6A, 6B-NED, 7A-LPP)	Increased precipitation from larger, slower moving storms.	Future flood volumes may be larger than present. Large flood volumes may occur more frequently.	Floodwater will exceed the detention capacity and overtop the impoundment structure.	Likely
NER (Numerous)	Increased precipitation from larger, slower moving storms	Future flood volumes may be larger than present. Large flood volumes may occur more frequently.	Floodwater will exceed the structure height. Erosion could occur and threaten a failure. Loss of property is possible.	Likely

Section 2
Conclusions

Based on a literature review of relevant climate data, there is a clear consensus that temperatures will rise over the next century. There is some consensus that there will be mild increases in the severity and frequency of storms in the region. However, there is no consensus on future changes in hydrology. Observed data from near the study area temperatures have been gradually rising since the 1970s after a cooling period in the earlier part of the century. Annual precipitation seems to be highly variable since the 1940s. Peak annual streamflow also seems to be highly variable for the available period of record at a nearby gage (1997-2017).

The non-stationarity assessment on the Nonconnah Creek watershed, a nearby watershed with similar basin characteristics and a sufficient period of record (30 year continuous), exhibited only one non-stationarity at USGS 07032200b. The single non-stationarity, in 2007, was neither strong nor robust. A monotonic trend analysis performed using the subsets of streamflow data before and after the non-stationarity detected in 2007 also did not show a general trend in the period before nor after. A monotonic trend analysis was also performed over the entire period of record but did not indicate that there was a statistically significant trend in the annual peak streamflow record from 1970-2014. However, it should be noted that there is likely a statistically significant increase in annual peak instantaneous streamflow at USGS 07032200.

The HUC-4 analysis on streamflow on the Lower Mississippi-Hatchie basin only shows a weak, increasing trend in projected streamflow based on GCM model output translated into a hydrologic response. These analyses provide almost no indication that there will be significant increases in peak annual streamflow in the future created by climate change. However, caution should be used in making any definitive statements on potential future hydrology as there is substantial uncertainty in both the climate and hydrologic models that drive these analyses. The vulnerability assessment helps to further reinforce a lack of evidence in increasing flood risk. Findings of the vulnerability assessment show that the Lower Mississippi-Hatchie HUC-4 basin is not considered vulnerable to increased flood risk as a result of climate change, with respect to other HUC-4s in the nation.

Based on the results of this assessment, including considerations of observed precipitation and streamflow in the basin, there is not strong evidence suggesting increasing peak annual streamflow will occur in for the future within the region. Furthermore, there is only some consensus the region might see a mild increase in the frequency and severity of precipitation events. This evidence, by itself does not indicate high confidence in an increase in peak flows in the Horn Lake Creek Basin.

Based on the lack of clear evidence showing an increase in streamflow, the effects of climate change can be considered within the standard uncertainty bounds associated with the hydrologic/hydraulic analysis being conducted as part of this study.

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