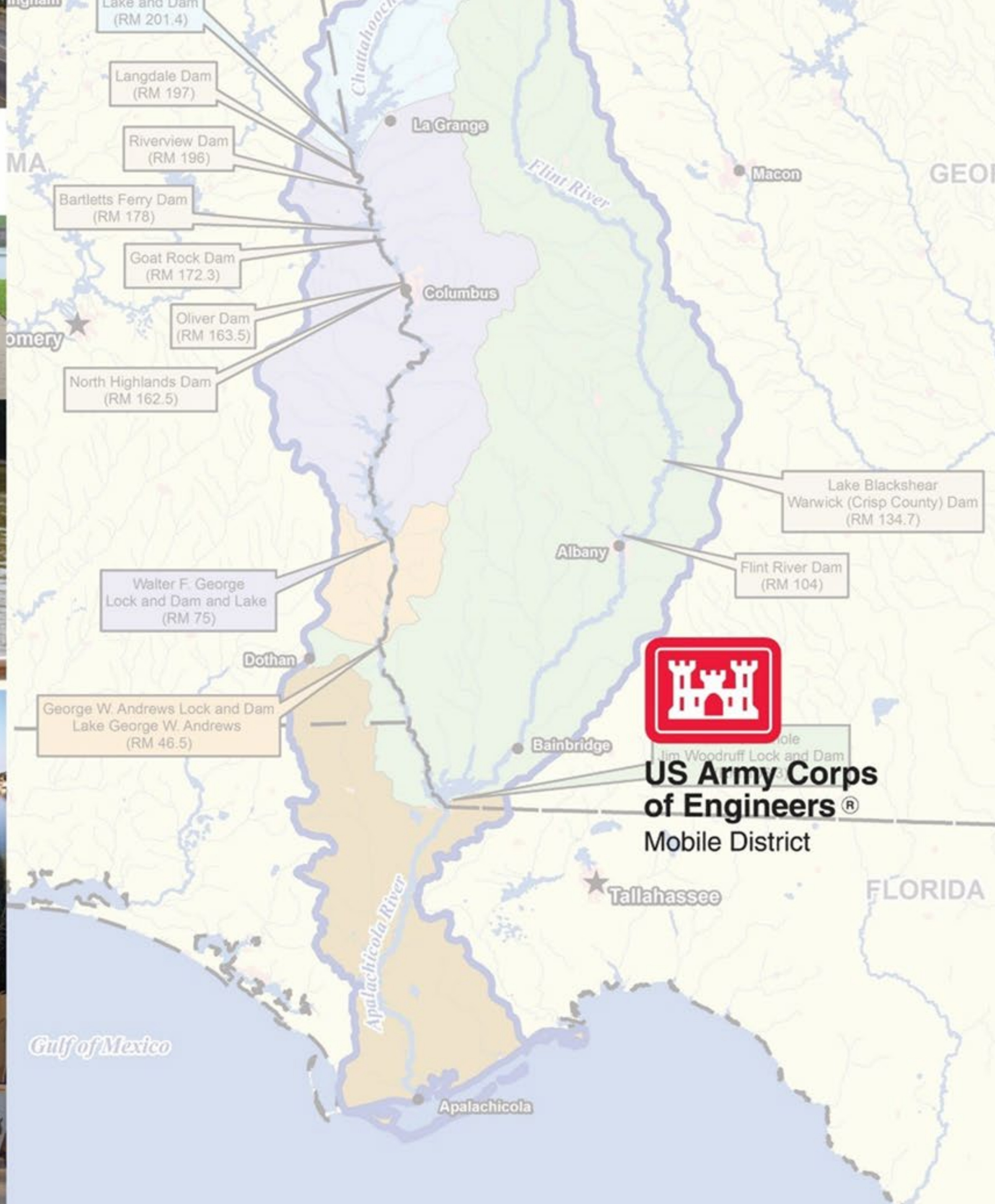
INTEGRATED LETTER REPORT AND TIERED ENVIRONMENTAL ASSESSMENT

OF THE

OPERATIONAL ANALYSIS AND TARGETED WATER CONTROL PLAN UPDATES FOR THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN IN ALABAMA, FLORIDA, AND GEORGIA

EAXX-202-00-K5P-1727867613



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Appendix I
Climate Change Analysis

ECB 2018-14 Analysis of Potential Climate Change Vulnerabilities

This assessment is performed to highlight existing and future challenges facing the study area due to climate change and is conducted in accordance with United States Army Corps of Engineers' (USACE) Engineering Construction Bulletin (ECB) 2018-14, *Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects*, revised 19 August 2022. In accordance with ECB 2018-14, this evaluation identifies potential climate change vulnerabilities for the Integrated Letter Report and Tiered Environmental Assessment (ILR/TEA) for the Operational Analysis and Targeted Water Control Plan Updates for the Apalachicola-Chattahoochee-Flint (ACF) River Basin in Alabama, Florida, and Georgia. The ACF Watershed includes the Apalachicola, Flint, and Chattahoochee Rivers and covers a portion of the states of Alabama, Georgia, and Florida. For this assessment, the Chattahoochee River near Columbus, GA and Columbia, AL will be the primary focus area with supplemental information used from within the ACF Basin. This assessment highlights existing and future climate change driven risks for the study area. Since the study area along the Chattahoochee River is not affected by tidal influence and is confined between several damming structures, a sea level change analysis was not completed. Study background information can be found in the main report, and more general background information on climate change driven risk can be found in ECB 2018-14.

Study Area

The Apalachicola-Chattahoochee-Flint River (ACF) Basin comprises 19,573 square miles in Alabama, Florida, and Georgia. USACE operates five reservoir projects in the ACF Basin and manages those projects as a system to meet their authorized purposes, which include flood risk management, hydropower, navigation, fish and wildlife conservation, recreation, water quality, and water supply. Several privately owned dams are located in the basin but are not operated by USACE. The purpose of this analysis is to analyze climate change impacts within the basin that could have an impact on the ACF targeted Water Control Plan Updates. The four objectives for this project include:

1. An objective to maintain a minimum average daily flow of 1,350 cfs over any 7- day period at the gage located on the Chattahoochee River at 14th, Street at Columbus, Georgia (Gage No. 02341460) when the ACF Basin is not in "Drought Zone Operations" as that term is defined in the 2017 ACF Master Manual.
2. An objective to maintain a minimum average weekday flow of 2,000 cfs at the gage located on the Chattahoochee River near Columbia, Alabama (Gage No. 02343801) when the ACF Basin is not in "Drought Zone Operations" as that term is defined in the 2017 ACF Master Manual.
3. 3. An objective to maintain the minimum average flows at Columbus, Georgia and Columbia, Alabama, described in items (1) and (2) above, on two days each calendar week starting each Monday, when the ACF Basin is in "Drought Zone Operations" as that term is defined in the 2017 ACF Master Manual; and
4. 4. An objective to maintain Lake Seminole at or above an elevation of 76 feet NVGD in the same manner and to the same extent as provided in the 2017 ACF Master Manual, and in particular the following paragraphs from Appendix A, the Water Control Manual for Jim Woodruff Lock and Dam and Lake Seminole: Chapter lll, paragraph 3-03; Chapter VII, paragraphs 7-03, 7-0S(a), 7-10, and 7-11; and Chapter VIII, Paragraph 8-11 b.

The main focus for this analysis was the Chattahoochee River near Columbus, Georgia and Columbia, Alabama. The USACE business line analyzed for this effort was water supply since the primary objective was analysis of low flow conditions. For the Vulnerability Assessment tool, the navigation business line was analyzed as a proxy since no analysis was available for the water supply business line. This was deemed acceptable since the two business lines have overlapping metrics and the other business lines do not match with the project's objectives.

To analyze the effects of climate change on minimum flow targets on the Chattahoochee and Flint Rivers, the monthly minimum and annual minimum streamflow records at three gages were analyzed in addition to utilization of the Climate Change Toolboxes. Since streamflow is strongly influenced by temperature and precipitation, the total annual and dry seasonal total precipitation was evaluated to determine potential climate change impacts within the basin.

Standard Datums and Units (Unless Specified Otherwise)

All vertical elevations referred to herein and in project plans and specifications are referenced to the North American Vertical Datum of 1988 (NAVD88).

Literature Review

The Fifth National Climate Assessment (NCA5), the USACE Civil Works Technical Report CWTS-2015-03, and the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) are the basis for this literature review. The focus of these references is on summarizing trends in historic, observed temperature, precipitation, and streamflow records, as well providing an indication of future, climate-changed hydrology based on the outputs from Global Climate Models (GCMs). For this assessment, background on observed and projected temperature and precipitation is provided as context for the impact that they have on observed and projected streamflow.

The NCA5 considers climate change research at both a national and regional scale (USGCRP, 2023). *Civil Works Technical Report CWTS-2015-03* was published as part of a series of regional summary reports covering peer-reviewed climate literature. The 2015 USACE Technical Reports cover 2-digit, United States Geological Survey (USGS), hydrologic unit code (HUC) watersheds in the United States (U.S). The Apalachicola-Chattahoochee-Flint Watershed is located in 2-digit HUC 03, the South Atlantic-Gulf Region (USACE, 2015) and in the NCA5 Southeast climate region.

In many areas, temperature, precipitation, and streamflow have been measured since the late 1800s and provide insight into how the hydrology in the study area has changed over the past century. GCMs are used in combination with different representative concentration pathways (RCPs) reflecting projected radiative forcings up to year 2100 to model future climate. Radiative forcings encompass the change in net radiative flux due to external drivers of climate change, such as, for example changes in carbon dioxide or land use/land cover. Projected temperature and precipitation results can be transformed to regional and local scales (a process called downscaling) for use as inputs in precipitation-runoff models (Graham, Andreasson, and Carlsson, 2007). Uncertainty is inherent to projections of temperature and precipitation due to the GCMs, RCPs, downscaling methods, and many assumptions needed to create projections (USGCRP, 2017). When applied, precipitation-runoff models introduce an additional layer of uncertainty. However, these methods represent the best available science to predict future hydrologic variables (e.g. precipitation, temperature, streamflow).

Temperature

There is a lack of consensus on annual average temperature trends. A majority of the studies present a positive mild trend for annual average temperatures which range by season. A 2009 study by Wang et.

al identified a positive mild warming trend for the southern portion of the area for spring, summer, and fall season and a warming trend for the eastern portion for winter using mean monthly gridded climate data for the period 1950-2000. A study in 2013 by Westby et. al identified a general cooling trend for winter for the entire southeast area. The study by Grundstein and Dowd (2011) investigated one-day extreme maximum and minimum temperatures for the period 1949-2010. For the southeast, they found a significant increasing trend in the number of one-day extreme minimum temperatures. A 2012 study by Laseter el al. identified significant warming trends since the 1970s for annual average, maximum, and minimum temperatures. Future projections in the area have a strong consensus that temperature will increase. (USACE, 2015)

According to the State Summaries presented by NOAA NCEI, temperatures in Alabama have not changed much since the beginning of 20th century. Temperatures have risen by 0.8 degrees Fahrenheit for Georgia and more than 2 degrees Fahrenheit for Florida since the beginning of the 20th century. For both Alabama and Georgia, the warmest consecutive 5-year interval was also the most recent interval, occurring 2016-2020. Projections for the area show unprecedented warming is projected during this century including increases in heat wave intensity and decreases in cold wave intensity. Rising temperatures can also increase the rate of soil moisture loss and will likely increase the intensity of naturally occurring droughts.

Precipitation

There is some consensus on an increase in significant precipitation events and increasing trends in total annual precipitation in the area. The 2009 study by Grundstein identified some regions in Alabama exhibited significant increasing trends, however other trends were not identified. A 2009 study by Wang et al. analyzed gridded data from 1950-2000 and identified a mild increasing trend in winter precipitation in the area. However, there were mixed results across the region for the other seasons. A study by Wang and Zhang (2008) identified significant changes in the reoccurrence of the 20-year maximum daily precipitation event for the South Atlantic-Gulf Region. A 2006 study by Small et al. identified statistically significant increasing trends in annual and fall precipitation. Projections for future changes in precipitation generally lack consensus across several studies, however there is a general consensus on projected increases in storm frequency and intensity. (USACE, 2015)

According to the State Summaries presented by NOAA NCEI, there are no robust trends for the State of Alabama for total annual precipitation and the number of extreme events. Projections for total annual precipitation is uncertain, however frequency and intensity of extreme rainfall is projected to increase.

Streamflow

Observed streamflow trends are strongly influenced by precipitation, temperature, and other factors such as land use and land cover in a region, groundwater dynamics, drainage patterns, channel geomorphology, and regulation. The 2013 Study by Xu et al. identified negative trends in streamflow for two stations in Florida, however the other stations investigated did not show any significant trends in either direction. A study conducted in 2008 by Kalra et al. found statistically significant negative trends in annual and seasonal streamflow for most stations investigated. This study also identified a significant change which occurred in the mid-1970s coinciding with the temperature increases observed. Projections for future changes in streamflow are lacking consensus with some showing little to no trend or decreasing trends. (USACE, 2015)

Summary

Within the literature reviewed, there is evidence that temperature and precipitation frequency/intensity has increased over the observed period of record within the Apalachicola-Chattahoochee-Flint

Watershed. Some studies show there is a negative trend in streamflow for nearby areas and potentially seasonality changes, however there is little to no consensus on future streamflow. Figure 1 from the 2015 USACE *Civil Works Technical Report CWTS-2015-03* provides a visual summary of the trends in observed and projected hydrometeorological variables for 2-digit HUC 03, Atlantic-Gulf Region.

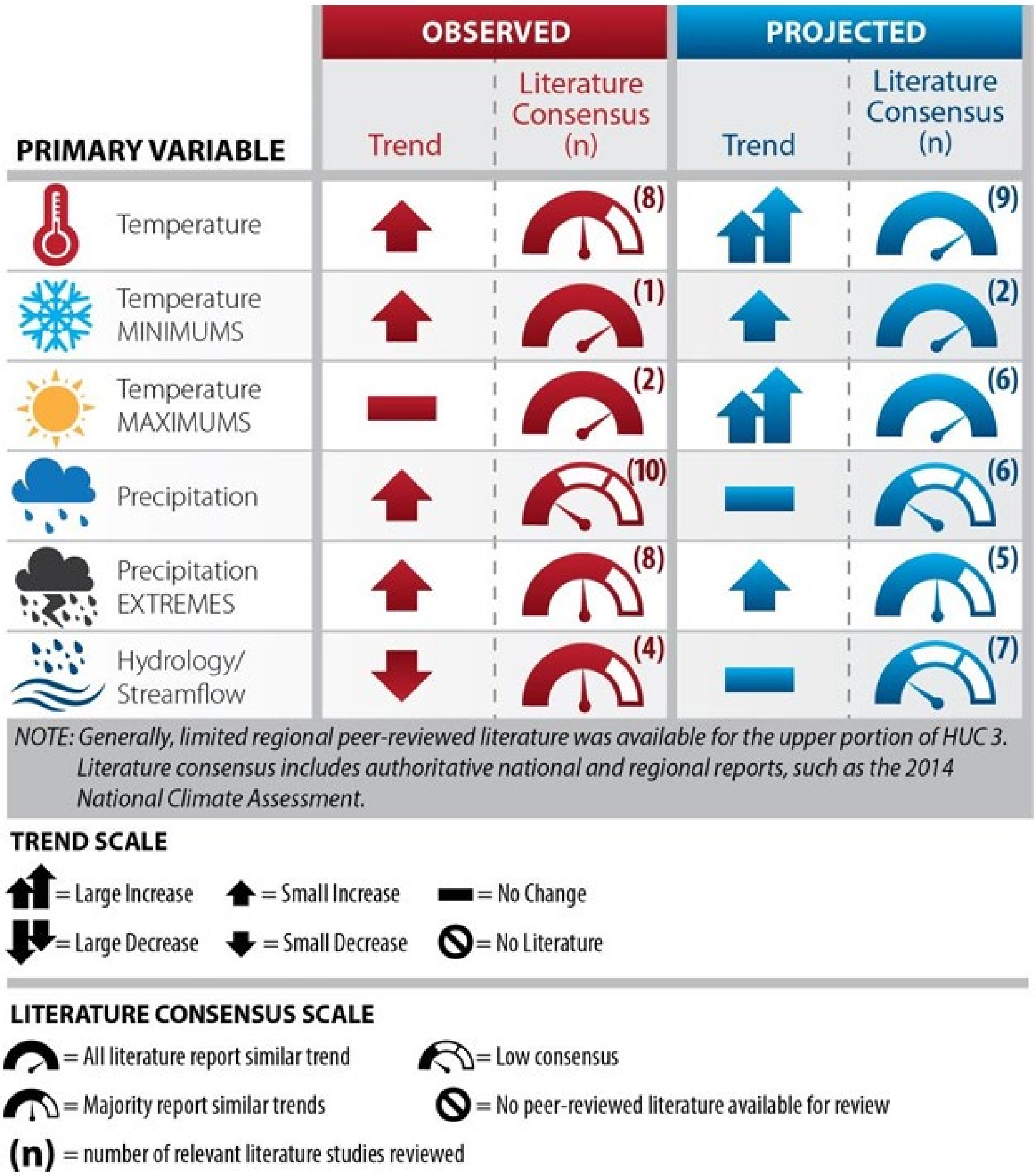


Figure 1: Summary matrix of South Atlantic-Gulf Region 03 observed and projected climate trends (USACE, 2015)

Nonstationarity Detection and Trend Analysis

The assumption that hydrologic time series are stationary (their statistical characteristics are unchanging) in time underlies many traditional hydrologic analyses. Statistical tests can be used to test this assumption using the techniques outlined in USACE Engineering Technical Letter (ETL) 1100-2-3, *Guidance for Detection of Nonstationarities* (2017). The USACE Time Series Toolbox (TST) is a web-based tool that performs the statistical tests described in the guidance.

For this analysis both streamflow and precipitation were analyzed using TST to determine trends and nonstationarities. The primary concern for this project is minimum flows during dry periods. Therefore, the variables analyzed utilizing the TST were the annual minimum streamflow and select monthly minimum streamflow. The months of September and October were selected for further analysis since the lowest yearly flows are typically observed during these months. Streamflow is heavily influenced by precipitation; therefore, total annual and total dry season (July-October) precipitation was analyzed.

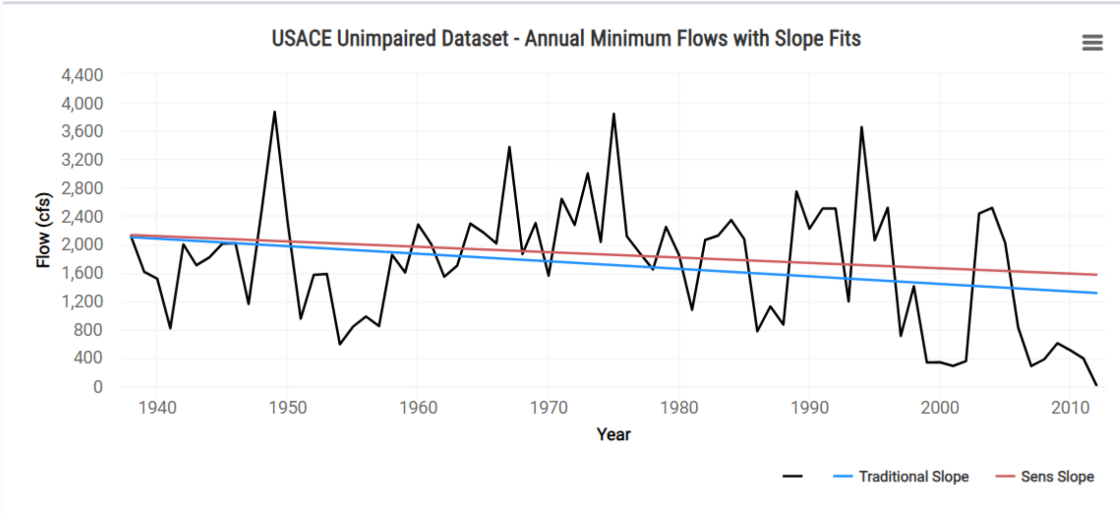
Streamflow

Annual Minimum Streamflow

For this analysis two streamflow datasets were analyzed. The first dataset was the USACE Unimpaired Streamflow on the Chattahoochee River at Columbus, Georgia with the period of record 1939-2012. The unimpaired flows for Columbus, GA were obtained from the Mobile District Water Management. This dataset was created by removing all storage in the ACF basin in order to make one homogeneous dataset without regulation. The period of record for this gage indicated a statistically significant decreasing trend as seen in Figure 2. Robust nonstationarities were detected for the year 1996 in both distribution and mean.

The second dataset was observed data including regulation at USGS Gage 02341460 – Chattahoochee River at 14th Street at Columbus, GA for the period 1930-2024. The purpose of analyzing this dataset and the unimpaired dataset was for comparison purposes to determine potential climate change stressors without regulation impacts. The period of record for this gage indicated a statistically significant increasing trend as seen in Figure 3. Robust nonstationarities were detected in distribution for the years 1936, 1953, 1975, and 2016; in mean for the years 1953, 1994, and 2016; and in variance for year 1975. West Point Dam was finished in 1974 and could correlate with the change in distribution and variance within the dataset for the year 1975. Buford Dam was under construction in the early 1950s and was filled between 1956 to 1959. This correlates to the change in distribution and mean detected in 1953, however may not be the only contributor to the change. The other dates triggered does not correlate with any other major events that may have altered the hydrology in the area.

Based on these two datasets, it appears that streamflow may be decreasing due to climate change related impacts. Regulation in the watershed appears to have increased minimum flows.



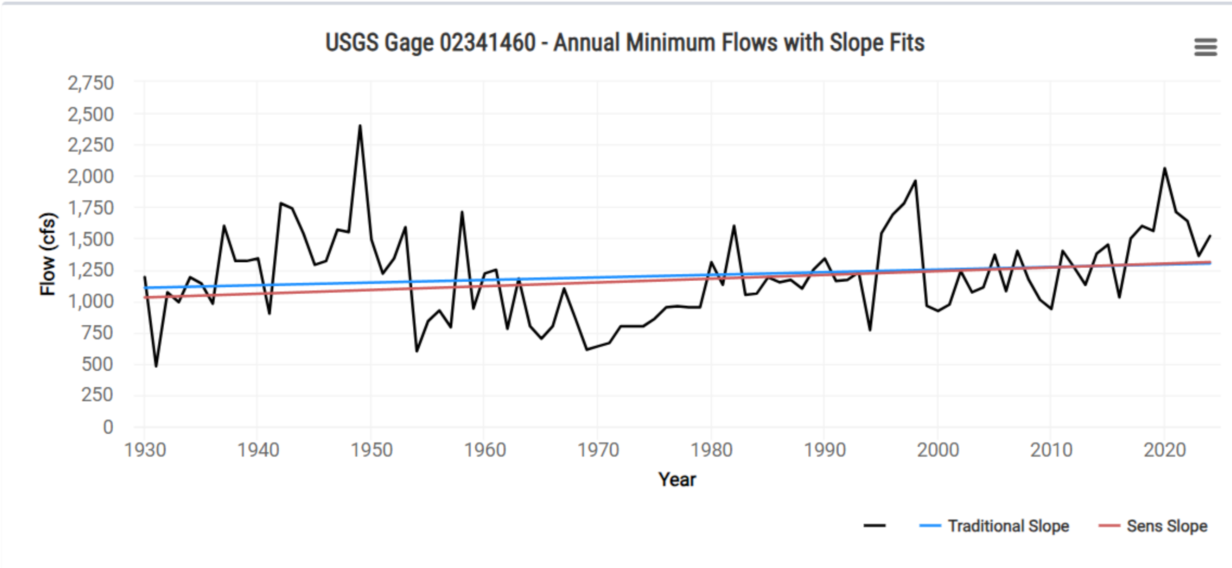
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Negative	-11	22709
Sen's Slope	Negative	-8	16782

Trend Hypothesis Test

Test	P-Value
t-Test	0.0205
Mann-Kendall	0.167
Spearman Rank-Order	0.0955

Figure 2: Time Series Toolbox Output for Annual Minimum flow for USACE Unimpaired Streamflow at Columbus, Georgia



Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	2	-2888
Sen's Slope	Positive	3	-4761

Trend Hypothesis Test

Test	P-Value
t-Test	0.112
Mann-Kendall	0.033
Spearman Rank-Order	0.098

Figure 3: Time Series Toolbox Output for Annual Minimum flow for USGS Gage 02341460

Monthly Minimum Streamflow

For this analysis, two datasets for Columbus, Georgia were analyzed for the months of September and October. The first dataset was the USACE unimpaired dataset discussed in the previous section. The second dataset was USGS Gage 02341460 – Chattahoochee River at 14th Street at Columbus, GA.

The observed data at USGS Gage 02341460 – Chattahoochee River at 14th Street at Columbus, GA has a period of record of 1930-2023. The TST indicated that annual minimum streamflow is increasing for both September and October. The month of September has a statistically significant positive trend for the entire period of record. However, the trend was not significant for the period 1975-2024 which was post-filling of the West Point Reservoir upstream of this gage location. Robust nonstationarities were not detected for the month of October, however several were detected in the month of September. Three statistical tests indicated a nonstationary in distribution for the years 1952 and four statistical tests indicated a nonstationarity in distribution for the year 1975. Additionally, three tests detected a nonstationarity in mean for the year 1975. West Point Dam was finished in 1974 and could be the reason for the change in distribution and mean within the dataset. Buford Dam was under construction in the early 1950s and was filled between 1956 to 1959. This correlates to the change in distribution detected in 1952, however may not be the only contributor to the change.

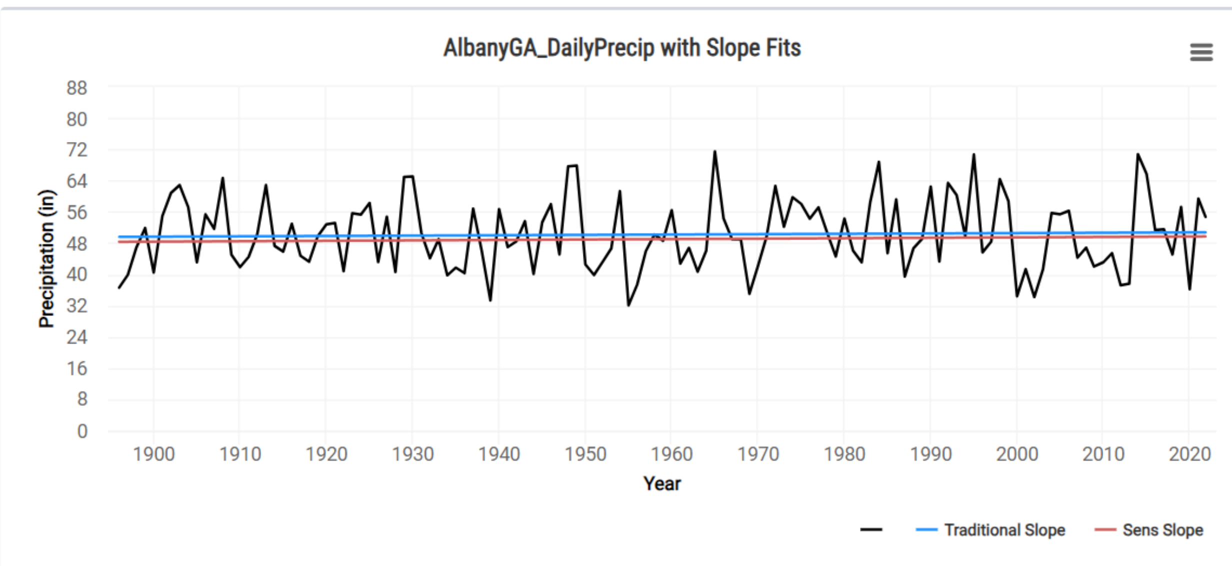
Analyzing the observed data within the basin builds a baseline to understand how regulation may have impacted minimum flows. Based on the current information, it appears the minimum flows trend indicate an increase since project operations have occurred in the basin.

The unimpaired dataset has a period of record 1939-2012. The TST indicated a decreasing trend for both September and October; however, neither were statistically significant. Robust nonstationarities were not detected for the month of October, however one was detected in the month of September in 1996 in mean and distribution.

Precipitation

Total Annual Precipitation

The precipitation gage USC00090140 Albany 3 SE, GA US located at Albany, Georgia near the Flint River was selected for analysis. Several other precipitation gages are located in the vicinity of the Middle-Lower Chattahoochee River and Lower Flint River. However, most of the gages have large gaps in the datasets or do not include recent data. The gage located in Albany, Georgia has observed daily data 1895 to 2021. The total annual precipitation was calculated using the dataset and input into the TST to determine trends and nonstationarities. The gage shows no significant trend for the period of record as shown in Figure 4 and no nonstationarities were detected.



Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.009	32
Sen's Slope	Positive	0.011	28

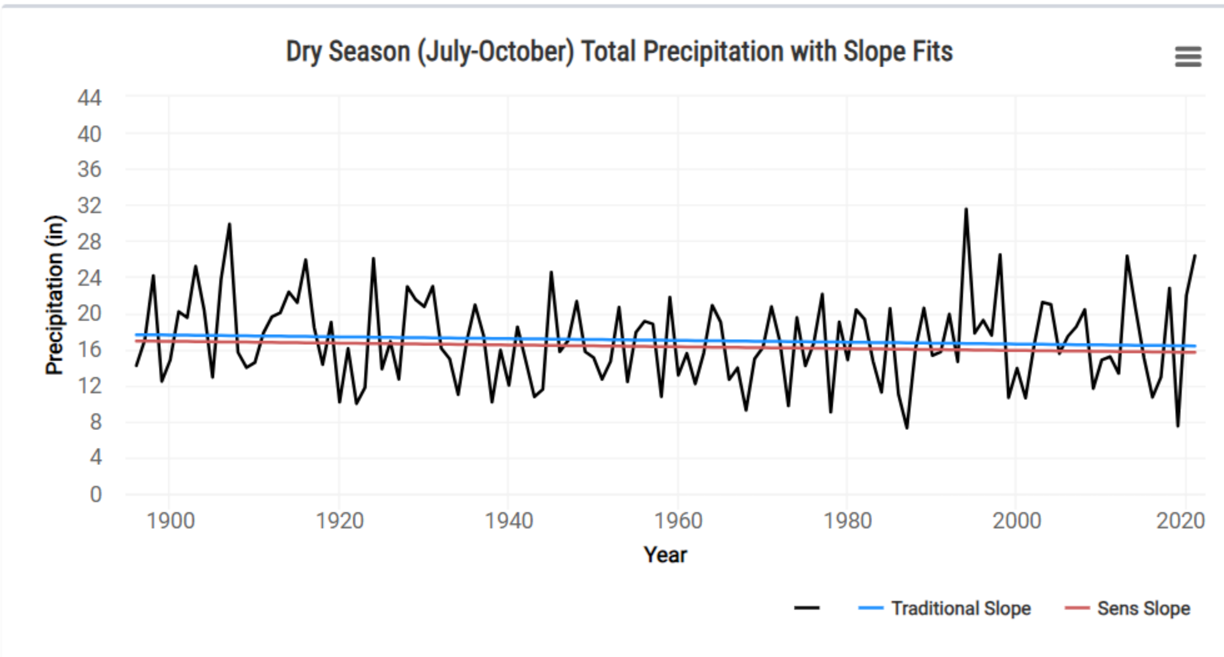
Trend Hypothesis Test

Test	P-Value
t-Test	0.676
Mann-Kendall	0.677
Spearman Rank-Order	0.728

Figure 4: Time Series Toolbox Results for Total Annual Precipitation for Gage USC00090140 Albany 3 SE, GA US

Total Precipitation during dry period (July - October)

The precipitation gage USC00090140 Albany 3 SE, GA US located at Albany, Georgia near the Flint River was selected for analysis. The gage located in Albany, Georgia has observed daily data 1895 to 2021. The total seasonal (July-October) precipitation was calculated using HEC-DSS and input into the TST to determine trends and nonstationarities. Figure 5 below shows a mild decreasing trend, however it is not statistically significant. No robust nonstationarities were detected for the period of record.



Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Negative	-0.01	36
Sen's Slope	Negative	-0.01	36

Trend Hypothesis Test

Test	P-Value
t-Test	0.392
Mann-Kendall	0.423
Spearman Rank-Order	0.455

Figure 5: Time Series Toolbox Results for Dry Season (July-October) Total Precipitation for Gage USC00090140 Albany 3 SE, GA US

Climate Hydrology Assessment Tool (CHAT)

The USACE Climate Hydrology Assessment Tool (CHAT) displays various simulated, historic and future, climate-changed streamflow, temperature, and precipitation outputs derived from 32 GCMs. The CHAT uses Coupled Model Intercomparison Project Phase 5 (CMIP5) GCM meteorological data outputs that have been statistically downscaled using the Localized Constructed Analogs (LOCA) method. GCMs rely on scenarios representing different pathways to a given atmospheric concentration of greenhouse gas emissions (GHG) referred to as representative concentration pathways (RCPs). RCPs describe the change in radiative forcing at the end of this century, as compared with pre-industrial conditions. Projected hydroclimate data in the CHAT for 2006 to 2099 are produced using two future scenarios: RCP 4.5 (where greenhouse gas emissions stabilize by the end of the century) and RCP 8.5 (where greenhouse gas emissions continue to increase throughout the century). Simulated output representing the historic period of 1951 to 2005 is generated using a reconstitution of historic GHG emissions.

To analyze runoff, LOCA-downscaled GCM outputs are used to force an unregulated, Variable Infiltration Capacity (VIC) hydrologic model. Areal runoff from VIC is then routed through a stream network using MizuRoute. Outputs represent the daily in-channel, routed streamflow for each stream segment – valid at the stream segment endpoint. Since the runoff is routed, the streamflow value associated with each stream segment is a representation of the cumulative flow, including all upstream runoff, as well as the local runoff contributions to that specific segment. Within the CHAT, streamflow output can be selected by stream segment and precipitation/temperature output can be selected for a given 8-digit HUC watershed.

The Apalachicola-Chattahoochee-Flint Watershed is the 4-digit HUC 0313 (Apalachicola). For this analysis, the location at Columbus, Georgia with 8-digit HUC were 03130003 segment 030000796 is presented below. The other locations of interest along the Chattahoochee River and Flint River presented similar trends. The trends within CHAT for Columbus, Georgia are more defined compared to the other locations of interest.

Figure 6 through Figure 8 show the range of the modeled annual-mean 1-day streamflow, drought indicator, and annual-mean 1-day temperature output from CHAT. The two periods analyzed were the historic period (1951-2005) and the future period (2006-2099). The annual-mean 1-day streamflow was analyzed for this assessment to investigate if and how potential future streamflow conditions will change. The drought indicator was analyzed for this assessment to investigate how future drought conditions may change within the project area. This metric is important for this project since minimum flow during drought conditions is one of the primary objectives. Annual-mean 1-day temperature is analyzed for this assessment since there is a correlation between streamflow, precipitation, and temperature. The range of data is indicative of the uncertainty associated with projected, climate-changed streamflow, precipitation, and temperature.

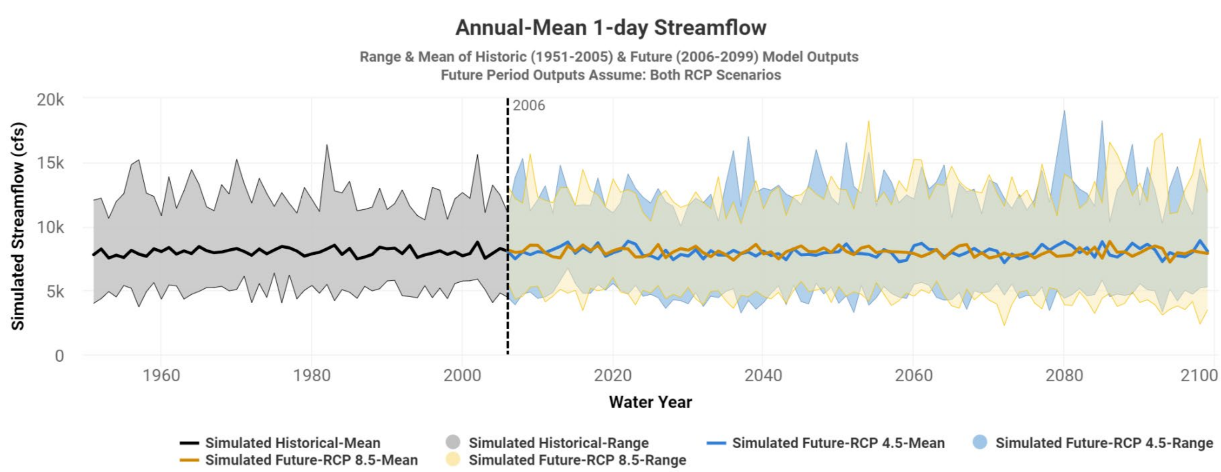


Figure 6: Range of Annual-Mean 1-Day Streamflow Model Output for HUC 03130003 Stream Segment: 03000796

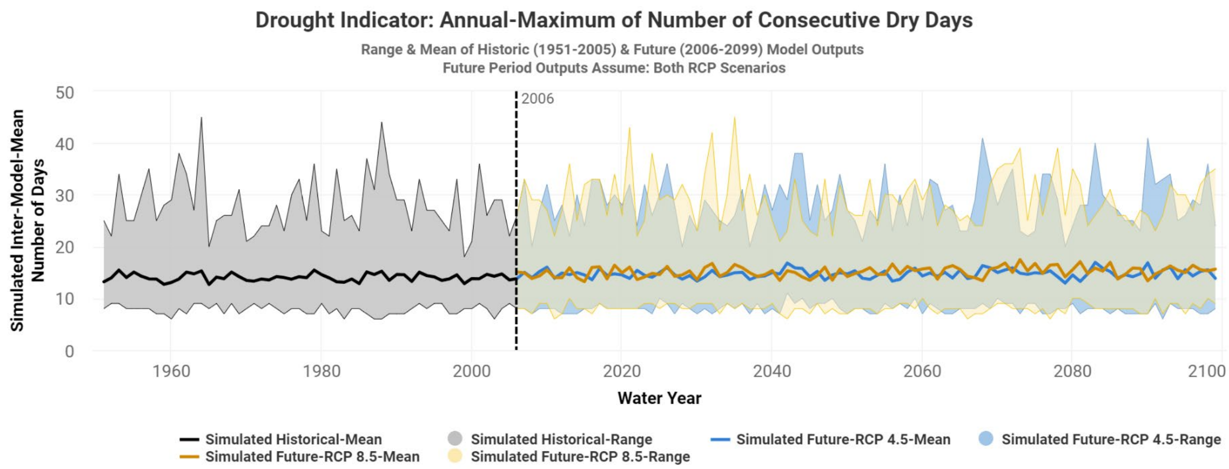


Figure 7: Range of Drought Indicator: Annual-Maximum of Number of Consecutive Dry Days Model Output for HUC 03130003 Stream Segment: 03000796

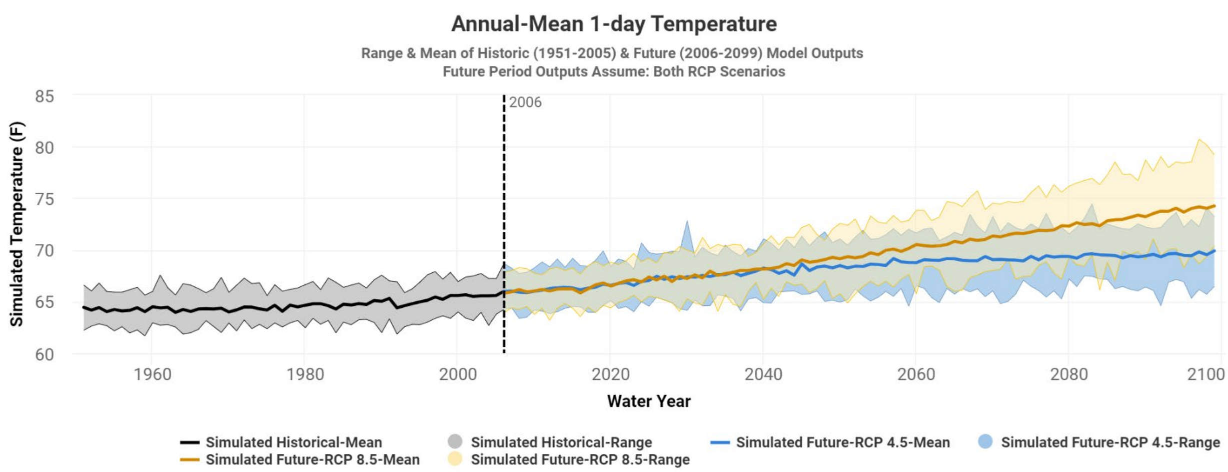


Figure 8: Range of Annual-Mean 1-Day Temperature Model Output for HUC 03130003 Stream Segment: 03000796

For HUC03130003, trends are evaluated using the t-Test, Mann-Kendall and Spearman Rank-Order tests. All three statistical tests are applied using a 0.05 level of significance (p-values<0.05 are considered statistically significant).

As displayed in Figure 9, the directionality and magnitude of change in statistically significant trends in the annual mean 1-day streamflow are evaluated using the slope of the fitted linear regression relationship. The results of the three statistical tests and the slopes associated with identified, statistically significant trends are presented in Table 1. The mean of the 32 projections of simulated, streamflow for the future period (2006-2099) shows no statistically significant trends for HUC 03130003 Stream Segment: 03000796.

As displayed in Figure 10, the directionally and magnitude of change in statistically significant trends in the drought indicator are evaluated using the slope of the fitted linear regression relationship. The results of the three statistical tests and the slopes associated with identified, statistically significant trends are presented in Table 2. The mean of the 32 projections of simulated, drought indicator for the future period (2006-2099) shows a statistically significant, positive trend for HUC 03130003 Stream

Segment: 03000796 when RCP 8.5 is assumed. There is no statistically significant trend in simulated RCP 4.5 or historic (1951-2005) annual maximum of number of consecutive dry days for the future period (2006-2099).

For the mean of the 32 projections (per RCP) of annual-maximum temperatures, the results of the three statistical tests and the slopes associated with statistically significant trends are presented in Table 3 and Figure 8. The mean of the simulated, annual-mean 1-day temperature projections (future period: 2006-2099) shows a statistically significant, positive trend under both the moderate (RCP 4.5) and higher (RCP 8.5) emission scenarios. Both outputs project a significant magnitude of change in temperature over the next fifty years. The CHAT computes a trendline slope of 0.042 °F per year for the lower emission scenario, which would be a 2.1 °F increase in annual mean 1-day temperature over a 50-year period. The CHAT computes a trendline slope of 0.094 °F per year for the RCP 8.5 emission scenario, which would be a 4.7 °F increase in annual mean 1-day temperature over a 50-year period. There is also a statistically significant increasing trend in simulated, historic temperatures between 1951 and 2005 (slope of 0.026 °F per year).

Table 1: Trend Analysis of Average Model Output: Annual-Mean 1-Day Streamflow HUC 03130003 Stream Segment: 03000796

Trend Analysis	Historic (1951-2005)	Future (2006-2099)		Historic (1951-2005)			Future (2006-2099)					
		RCP 4.5	RCP 8.5				RCP 4.5			RCP 8.5		
		p-values		Statistically Significant? (<0.05)	Slope (cfs/yr)	Direction	Statistically Significant? (<0.05)	Slope (cfs/yr)	Direction	Statistically Significant? (<0.05)	Slope (cfs/yr)	Direction
t-Test	0.685	0.531	0.126	No			No			No		
Mann-Kendall	0.622	0.544	0.0945	No	1.02	↑	No	0.94	↑	No	-1.90	↓
Spearman Rank Order	0.737	0.618	0.0895	No			No			No		

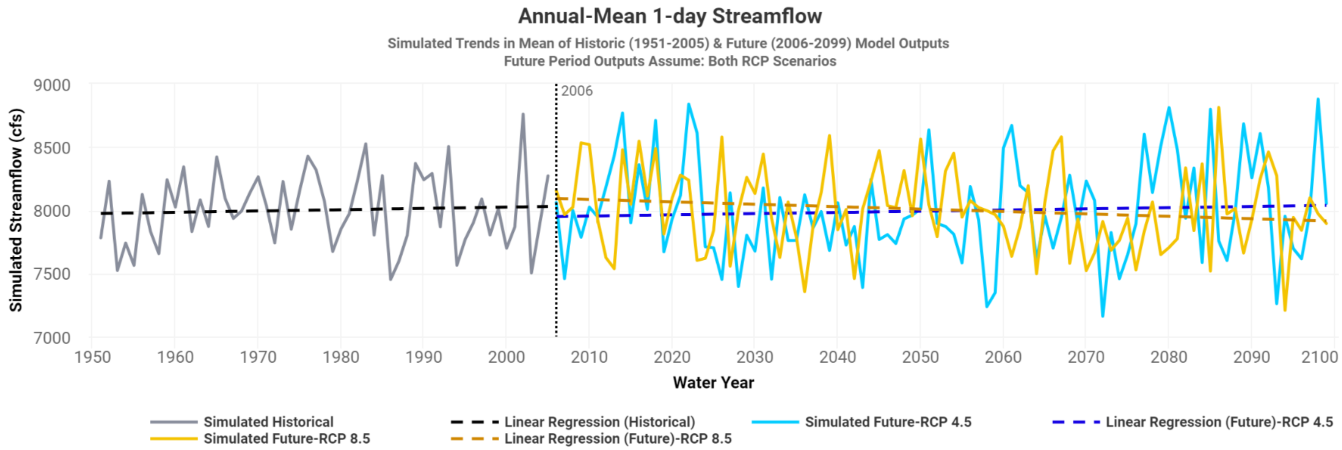


Figure 9: Trend Analysis of Annual Mean 1-Day Streamflow Model Output for HUC 03130003 Stream Segment: 03000796

Table 2. Trend Analysis of Average Model Output: Drought Indicator: Annual-Maximum of Number of Consecutive Dry Days HUC 03130003 Stream Segment: 03000796

Trend Analysis	Historic (1951-2005)	Future (2006-2099) RCP 4.5	Future (2006-2099) RCP 8.5	Historic (1951-2005)			Future (2006-2099) RCP 4.5			Future (2006-2099) RCP 8.5		
	p-values			Statistically Significant? (<0.05)	Slope	Direction	Statistically Significant? (<0.05)	Slope	Direction	Statistically Significant? (<0.05)	Slope	Direction
t-Test	0.907	0.231	0.0086	No	Not applicable (no trend)		No	0.0038	↑	Yes	0.0099	↑
Mann-Kendall	0.862	0.297	0.0141	No			No			Yes		
Spearman Rank Order	0.786	0.257	0.0128	No			No			Yes		

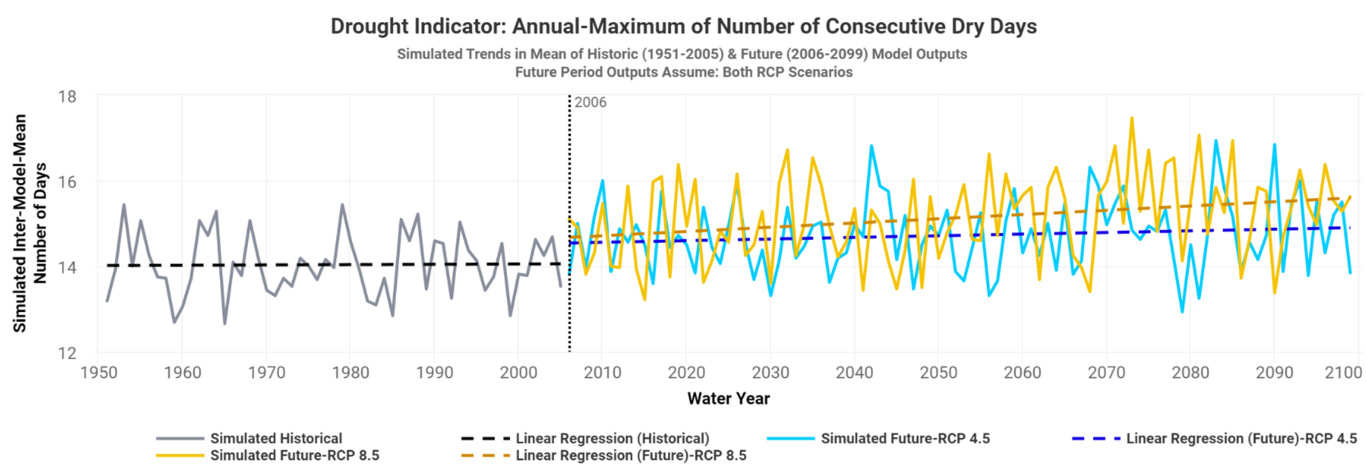


Figure 10: Trend Analysis of Drought Indicator: Annual-Maximum of Number of Consecutive Dry Days Model Output for HUC 03130003 Stream Segment: 03000796

Table 3. Trend Analysis of Average Model Output: Annual-Mean 1-Day Temperature HUC 03130003 Stream Segment: 03000796

Trend Analysis	Historic (1951-2005)	Future (2006-2099)		Historic (1951-2005)			Future (2006-2099)					
		RCP 4.5	RCP 8.5				RCP 4.5			RCP 8.5		
	p-values			Statistically Significant? (<0.05)	Slope (°F/year)	Direction	Statistically Significant? (<0.05)	Slope (°F/year)	Direction	Statistically Significant? (<0.05)	Slope (°F/year)	Direction
t-Test	<0.001	<0.001	<0.001	Yes	0.026	↑	Yes	0.042	↑	Yes	0.094	↑
Mann-Kendall	<0.001	<0.001	<0.001	Yes			Yes			Yes		
Spearman Rank Order	<0.001	<0.001	<0.001	Yes			Yes			Yes		

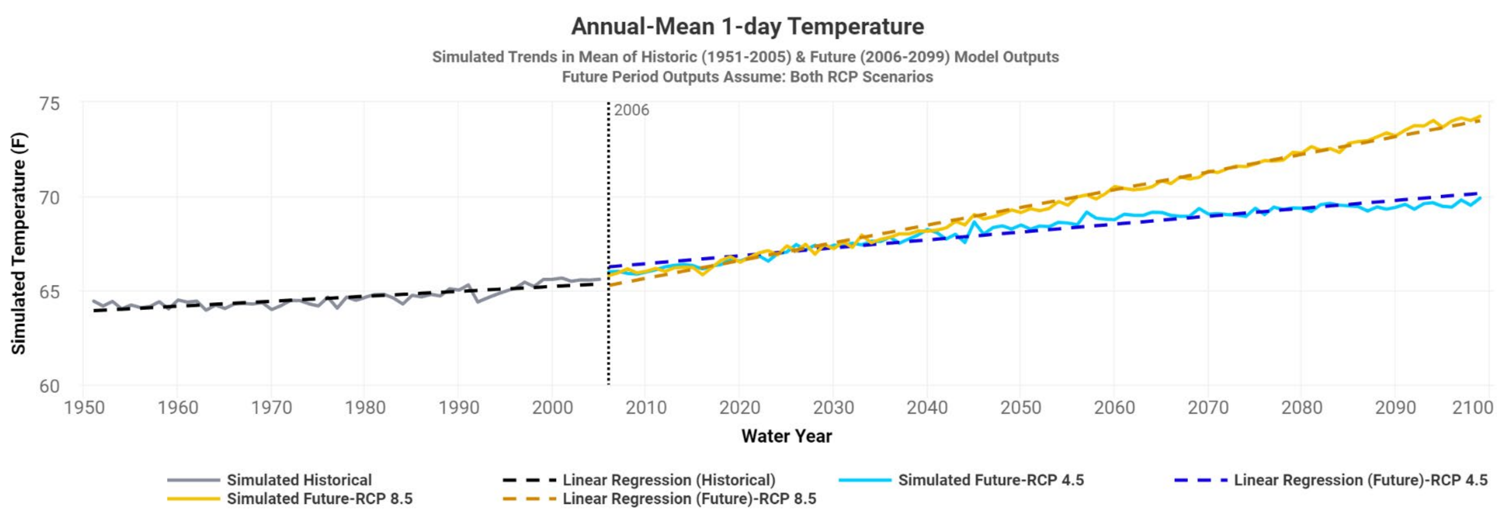


Figure 11: Trend Analysis of Annual Mean 1-Day Temperature Model Output for HUC 03130003 Stream Segment: 03000796

The CHAT provides streamflow and temperature outputs analyzed comparatively by describing simulated changes in monthly streamflow and temperature between different epochs (time periods). Monthly streamflow and temperature output is analyzed by determining the mean of the monthly value for the variable of interest for each GCM for three epochs: 1950-2005 (baseline), 2035-2064 (mid-century), and 2075-2099 (end of century). The difference between GCM/Month/Epoch means are determined for both the baseline vs. mid-century and baseline vs. end of century epochs and results are presented as boxplots. These boxplots provide insight into both the range of results and the seasonality of changes in streamflow and temperature overtime.

For HUC 03130003 Stream segment ID: 03000796, simulated maximum temperatures for both the mid-century epoch (2035-2064) and the end-century epoch (2070-2099) are increasing relative to historic temperature simulations (1950-2005) for all months and both RCPs as seen in Figure 12. Streamflow and Precipitation showed a wide range of values but did not shift in either direction.

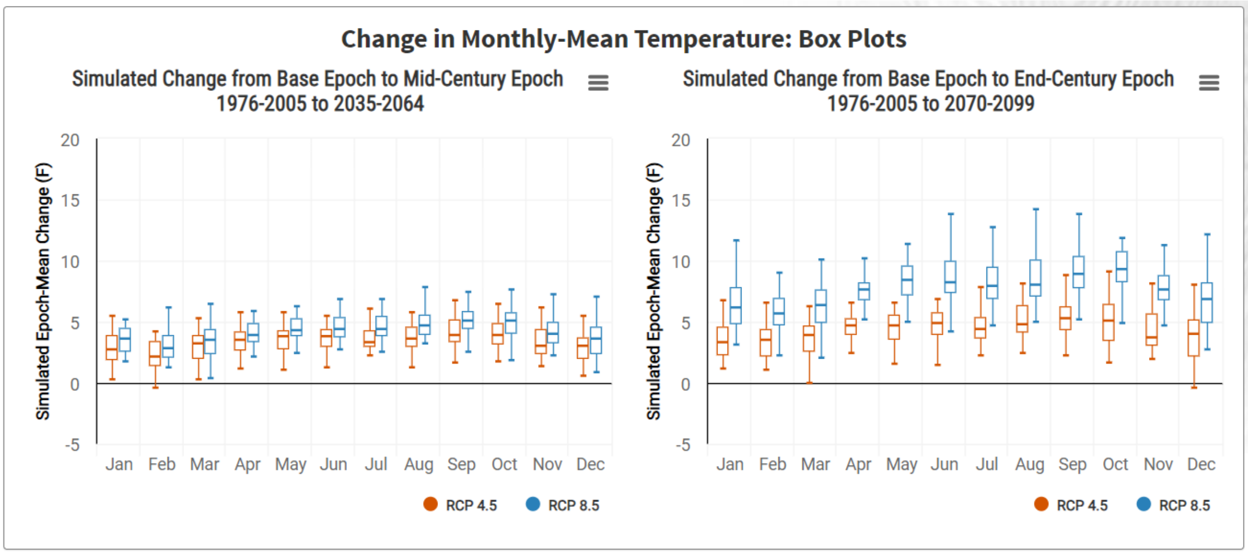


Figure 12: Change in Epoch-Mean of Simulated Monthly Mean Temperature- HUC 03130003 Stream segment ID: 03000796

Vulnerability Assessment

The USACE Climate Change Vulnerability Assessment (VA) Tool facilitates a screening level, comparative evaluation of climate change exposure to projects for a selected USACE business line in a given 4-digit HUC watershed relative to the other 4-digit HUC watersheds within the continental United States (CONUS). A series of indicator variables are computed and aggregated into a vulnerability score using the weighted-order, weighted-average (WOWA) approach. The tool uses the CMIP5 GCM based Bias Corrected, Spatially Disaggregated (BCSD) VIC dataset (2014) to define projected, hydrologic, and meteorologic inputs to the tool's WOWA scores.

The WOWA scores and indicator variable values are available for two subsets of simulations (wet- top 50% by cumulative runoff projections and dry- bottom 50% by cumulative runoff projections). Data are available for three epochs. The epochs include a historic period (Base epoch) and two 30-year, future epochs (centered on 2050 and 2085). The Base epoch is not based on projections and so it is not split into a wet and dry subset. Watersheds with WOWA scores specific to a given business line, that fall within the top 20% of WOWA scores for watersheds in the CONUS are identified as being vulnerable to climate change impacts. The projected datasets incorporated into VA scores contain considerable uncertainty. Some of this uncertainty is reflected by the differences in results for each of the subset-epoch combinations.

The tool was applied using the default, National Standards Settings and for the navigation business line only since the ACF Basin does not have a WOWA score for the water supply business line. The two business lines have similar indicators, therefore analyzing the navigation business line was used for this analysis. The indicators used to compute the navigation WOWA score include: drought severity index, change in sediment load due to change in future precipitation, monthly CV (Coefficient of Variation) of cumulative runoff, percent change in runoff divided by percent change in precipitation, and annual CV of unregulated cumulative runoff.

As shown in Figure 13, compared to the other 4-digit HUC watersheds in the CONUS, the Apalachicola-Chattahoochee-Flint Watershed (HUC 0313) watershed has one climate change vulnerability score in the top 20% for the navigation business line under dry condition for 2085. This is a comparative evaluation and thus does imply that the watershed is vulnerable to future, climate change impacts. Results indicate that for the select metrics incorporated into the tool, this watershed may be more exposed to potential climate change impacts relative to other watersheds in the CONUS. However, the other scenarios do not indicate vulnerability scores in the top 20% for the navigation business line for the wet subset for both the 2050 and 2085 epochs along with the dry subset for 2050.

As can be seen in Figure 13 and Table 4, the dominant indicator variable contributing to the navigation business line VA score for the Apalachicola-Chattahoochee-Flint (HUC 0313) watershed is Low Flow Reduction for the 2050 epoch and dry subset condition. The dominant indication for the 2085 epoch and dry subset condition is drought severity. The dominant indication for the 2050 and 2085 epochs for the wet subset is flood magnification. The percentage by which the indicator variable contributes to the VA score does not significantly change overtime for the wet subset, however it does significantly change for the dry subset. Because the dominant indicators for the watershed are dependent on computed, GCM based changes in future hydrology (temperature, precipitation, streamflow) the indicator variable values change overtime.

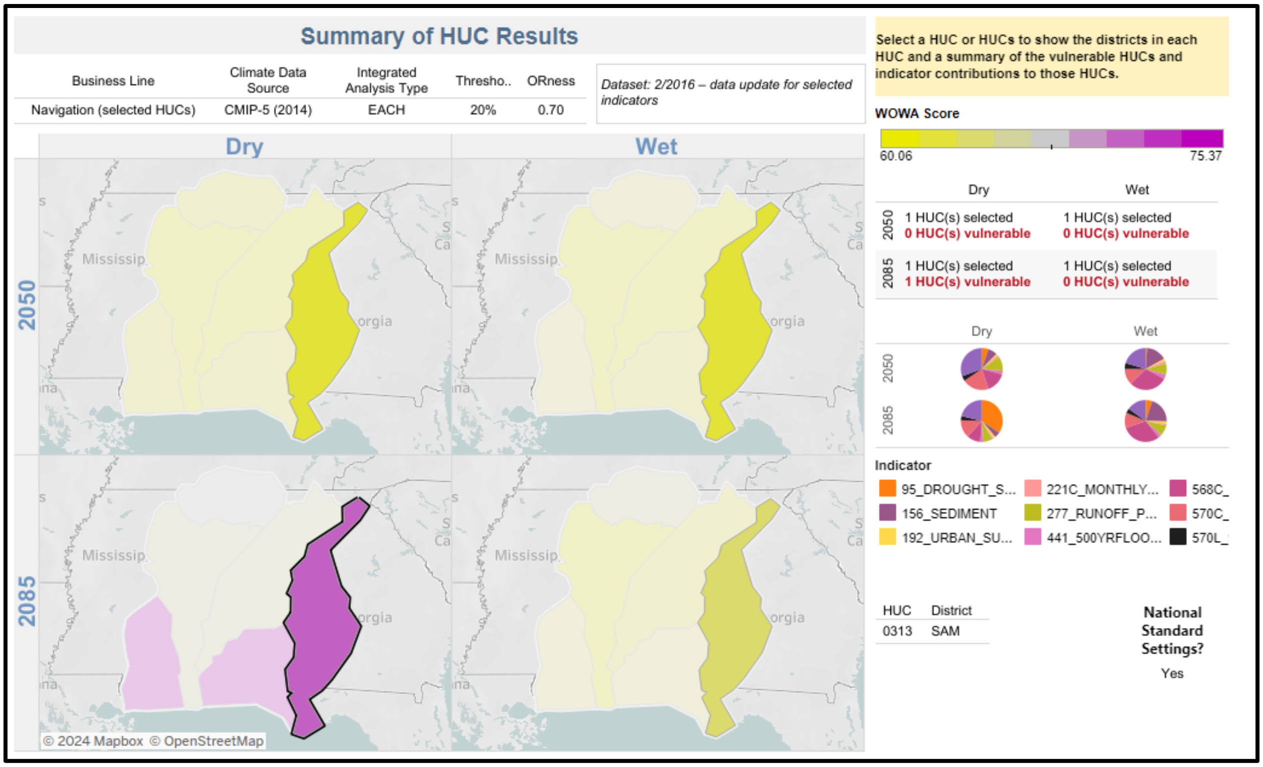


Figure 13: Output of the Vulnerability Assessment tool – Apalachicola-Chattahoochee-Flint watershed

Table 4: VA Tool Output- HUC 0313 Apalachicola-Chattahoochee-Flint Watershed – Navigation Business Line

Subset	Epoch	VA Score	% Change in VA Score (2050 to 2085)	Dominant Indicator	Dominant Indicator % Change (2050 to 2085)	
					Contribution to Overall WOWA Score	Indicator Value
WET	2050	62.76	+1.33%	568C_FLOOD_MAGNIFICATION	2.86%	Increases Overtime
	2085	63.59		568C_FLOOD_MAGNIFICATION		
DRY	2050	62.05	+15.35%	700C_LOW_FLOW_REDUCTION	-20.36%	Decreases Overtime
	2085	71.58		95_DROUGHT_SEVERITY	670.35%	Increases Overtime

Conclusion

The purpose of this analysis is to analyze climate change impacts within the basin that could have an impact on the ACF targeted Water Control Plan Updates. The project includes alternatives pertaining to minimum flow targets during drought periods.

Based on the weight of evidence presented in this assessment, climate change impacts are anticipated to affect the study area's hydrology over a 50-year life cycle. Available climate change literature suggests a warmer climate with more extreme precipitation frequency/intensity in the future. There is some evidence that streamflow is decreasing in the area due to climate change, however regulation in the system seems to reduce the impacts seen in the observed data. Observed and projected temperatures are showing statistically significant increasing trends. Precipitation did not indicate any significant trends. Utilizing CHAT, the drought indicator: Annual-Maximum of Number of Consecutive Dry Days indicated a statistically significant trend under RCP 8.5 (highest emission scenario where greenhouse gas emissions continue to increase throughout the century). Similarly, the VA toolbox indicated the basin is vulnerable to dry conditions for the 2085 epoch. Table 5 indicates potential residual risks for this project due to climate change, along with a qualitative rating of how likely those residual risks are to materialize and undermine the project resulting in harm to the study area.

Table 5. Residual Risk Due to Climate Change

Project Feature	Trigger	Hazard	Harm	Qualitative Likelihood[1]	Justification of Likelihood Rating
Maintain minimum flow targets at desired locations when the ACF Basin is not in "Drought Zone Operations" as that term is defined in the 2017 ACF Master Manual	Decreased Flow	Extreme Drought conditions may occur more frequently	Inability to meet minimum flow targets due to restrictions during extreme drought operations	Unlikely	The water control manual is reviewed every 5 years. If drought conditions continue to worsen, the water control manual may be modified to meet objectives.
While in extreme drought conditions, maintain minimum flow targets at each location for two days each calendar week beginning on Monday	Decreased Flow	Extreme Drought conditions may occur more frequently	Inability to meet minimum flow targets during extreme drought operations	Unlikely	The water control manual is reviewed every 5 years. If drought conditions continue to worsen, the water control manual may be modified to meet objectives.
Maintain target pool elevation at or above 76 ft-NVGD at Lake Seminole	Decreased Flow	Extreme Drought conditions may occur more frequently	Inability to maintain the target pool elevation	Unlikely	The water control manual is reviewed every 5 years. If drought conditions continue to worsen, the water control manual may be modified to meet objectives.

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