Appendix C – Climate Assessment

1 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 Kaskaskia River Regional Port Continuing Authority Project (CAP) Section 107 Study. The project area is located near River Mile (RM) 18.5 on the Kaskaskia River Navigation Project, approximately 45 miles southwest of St. Louis, Missouri. This assessment highlights existing and future climate change driven risks for the study area. 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.

2 STUDY BACKGROUND

Kaskaskia Regional Port District Terminal 2 (KRPD #2) is located west of Baldwin, Illinois, in Randolph County near river mile 18 on the Kaskaskia River, approximately 45 miles southeast of St. Louis, Missouri. The port terminal is located on an oxbow side channel on the west side (right descending bank) of the Kaskaskia River. The Kaskaskia River at KRPD#2 is included in the Kaskaskia River Project. This Project, authorized for construction by the River and Harbor Act of 1962, consists of the Jerry F. Costello Lock and Dam (formerly known as Kaskaskia Lock and Dam) at RM 0.8, and a navigation channel 9 feet deep, 225 feet wide, and 36 miles in length from Fayetteville, Illinois to the confluence of the Mississippi River. The Kaskaskia River is a Marine Highway Route with the designation M-3.

The study area includes two oxbow side channels of the Kaskaskia River. These oxbows are U-shaped meanders of the river that are no longer part of the main river channel. The south ends of both oxbows remain open to the river.

The oxbow on which the KRPD#2 port terminal is located is called the south oxbow in this report. KRPD#2 is an intermodal facility, which means movement of freight by two or more different modes of transportation. At the port terminal, there is a dock and 50-ton overhead crane to move cargo between the water and land, and on land there are road and rail connections. There are currently four tenants at the terminal: The Material Works (TMW), Kaskaskia Shipyard, Gateway FS, and Southern Illinois Transfer Company.

The oxbow directly north of the south oxbow, approximately 1,200 feet from the existing port terminal on the north side of IL-154, is called the north oxbow in this report. The north oxbow is not currently used for shipping. KRPD plans to expand its operations to waterway traffic in the north oxbow and buildings, road, and rail development on the adjacent land. A prospective tenant, STAG Steel, has committed to building a facility at the north oxbow site.

As result of growing industries and increasing demands, KRPD Terminal 2 is at risk of experiencing limitations on future capacity needs. KRPD has requested assistance from the St. Louis District to evaluate navigation improvements.

KRPD has experienced significant increase in tonnage and current facilities could limit future growth with potential impact to local and national economy. Without funding and project, potential limitations on future growth and capabilities.

Measures being considered include those that would be located below the Ordinary High Water Mark and would be federally funded, and Local Service Facilities which could be above the Ordinary High Water Mark and would be funded by the Sponsor.

Navigation improvements are the focus of this analysis because with project and funding, better connectivity and channel improvements would support growing tonnage and capacity needs. Future climate conditions may impact the establishment and design of project features. To analyze the effects of climate change on navigation improvement features for this study, the Annual Streamflow (instantaneous peak / max annual discharge) records are evaluated.

3 LITERATURE REVIEW

The *Fifth National Climate Assessment* (NCA5) and the USACE *Civil Works Technical Report CWTS-2015-13,* as well as state and watershed specific resources published by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI), the U.S. Geological Survey (USGS) 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-2015-13* 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 Kaskaskia River is located in 2-digit HUC 07, the Upper Mississippi Region (USACE, 2015) and in the NCA4 Midwest 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). Many researchers use multiple GCMs and RCPs in their studies to understand how various model assumptions impact results (Gleckler et al., 2008).

Temperature: There is strong consensus in the literature that air temperatures will increase in the study region and throughout this country over the next century. The studies reviewed generally agree on an increase in mean annual air temperature of approximately 2 to 6 ºC (3.6 to 10.8 ºF) by the latter half of the 21st century in the Upper Mississippi Region. Reasonable consensus is also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer, and more intense summer heat waves in the long-term future compared to the recent past. Increased air temperatures and increased frequencies of drought, particularly in the summer months, will probably result in increased water temperatures. This may lead to changes in dissolved oxygen levels, which is an important water quality parameter for aquatic life. Increased air temperatures are associated with the growth of nuisance algal blooms and influence wildlife and supporting food supplies. Observed increases in temperature are reported in multiple studies. A study by Wang et al. (2009) reported an increasing trend in temperatures for the winter through summer months and a slightly decreasing trend in temperatures in the fall. These findings were supported by later studies and an average temperature increase of 1.5°F between 1895 and 2012 was also reported (Pryor et al., 2014). General Circulation Models (also known as Global Climate Models, both terms use the acronym GCM) were used to project temperatures in the study region. GCM projections show a consensus on a significant warming trend on a national scale throughout the 21st century, with studies including the Upper Mississippi Region generally agreeing with this trend (USACE 2015). A study by Gao et al. (2012) showed a projected increase in heat wave intensity, duration, and frequency. Additionally, Pryor et al. (2014) reported a statistically significant increase in projected annual average temperature and number of extreme heat days. The same study showed a projected increase in the length of the frost-free season and a projected increase in the number of days with an average temperature above 65°F for the study region.

Precipitation: Projections of precipitation found in a majority of the studies forecast an increase in annual precipitation and in the frequency of large storm events; however, there is some evidence presented that the northern portion of the Upper Mississippi Region will experience a slight decrease in annual precipitation. Additionally, seasonal deviations from the general projection pattern have been presented with some studies indicating a potential for drier summers. Lastly, despite projected precipitation increases, droughts are also projected to increase in the basin as a result of increased temperature and evapotranspiration rates. A significant increasing trend in the observed total annual precipitation was identified by various reports (USACE 2015). A study by McRoberts and Nielsen-Gammon (2011) reported an increase in annual precipitation of 5 – 20% per century for the region. There is a reasonable consensus among literature that the annual precipitation totals and frequency, as well as the extreme precipitation totals and frequency, are projected to increase (USACE 2015). Multiple studies reported both a projected increase in precipitation as well as a projected increase in droughts. A study by Wilson and Weng (2011) projected that the summer months will be drier, while the winter months will be wetter. A study by Easterling et al. (2017) projected that winter and spring precipitation would increase by up to 30 percent by the end of this century in the Midwest region. Joetzjer et al. (2013) reported an increase in the frequency and extent of droughts in the region, noting that the impact of projected temperature increases appears to exceed the impact of projected precipitation increases for the latter half of the 21st century.

Streamflow: A clear consensus is lacking in the hydrologic projection literature. Projections generated by coupling Global Climate Models with macro-scale hydrologic models in some cases indicate a reduction in future streamflow but in other cases indicate a potential increase in streamflow. Of the limited number of studies reviewed here, more results point toward reduction than increase, particularly during the summer months. Increased mean annual precipitation in the region may lead to variation in flows. This may be particularly true during dry years when water demands for conflicting uses may outweigh water supply. There is a reasonable consensus among literature of a general increasing trend in observed streamflow data for the Upper Mississippi Region (USACE 2015). Xu et al. (2013) identified statistically significant positive trends in the annual streamflow and baseflow in the region. A later study by Frans et al. (2013) aimed to examine how climate change and land use changes contributed to the positive trend. The study suggested that the increase in precipitation in the region contributed more than changes in land use to the observed trends. There is a lack of consensus among literature regarding the projected streamflow in the region, with both increasing and decreasing projected trends being reported. Given the high degree of variability and uncertainty in weather patterns in general and in predictions of future weather patterns in particular, quantifying future project impacts is inexact. As summarized above, there is no consensus with respect to forecasts for future streamflow in the basin.

Summary. Climate literature indicates moderate increases in temperature, precipitation, and streamflow for the Upper Mississippi Region over the previous century. There is evidence of increased frequency in the occurrence of extreme events, like extreme minimum temperatures (Grundstein and Dowd, 2011) and extreme storm events (Villarini et al. 2013). Based on projections, there is a strong consensus that air temperatures will increase in the study region over the next century. Precipitation projections also indicate an increase in annual precipitation and frequency of large storm events. A clear consensus is lacking in the streamflow projection literature for this region. These findings are summarized in **Figure C-1**.

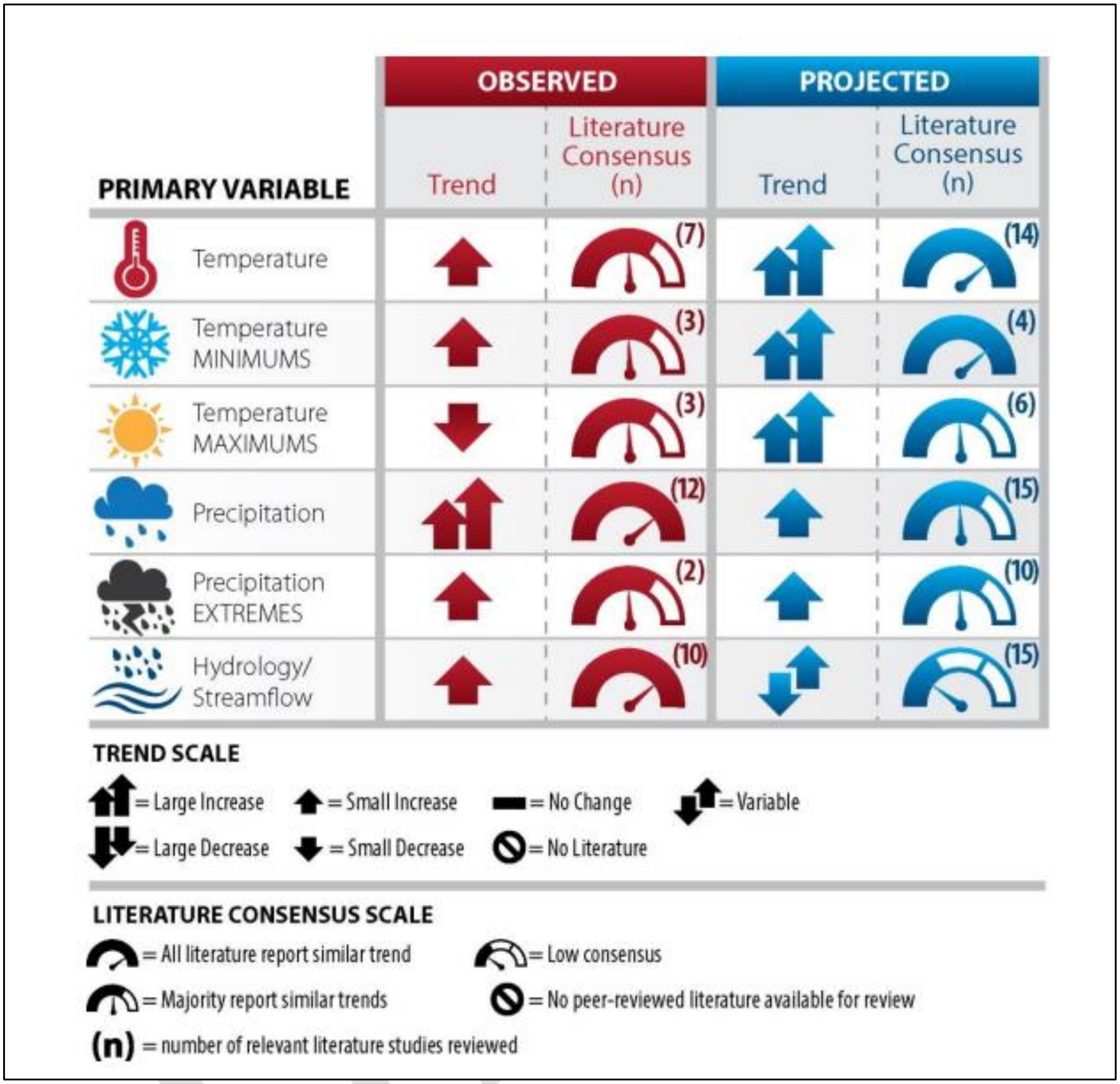


Figure C-1. Summary matrix of UMR observed and projected climate trends (USACE, 2015)

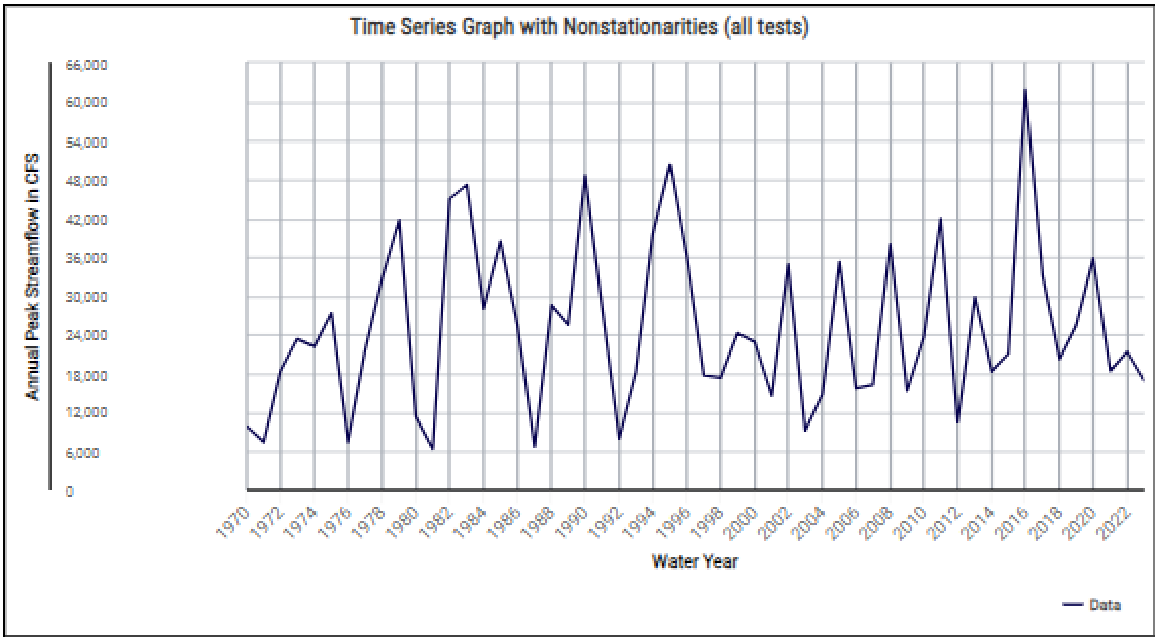
4 NONSTATIONARITY DETECTION AND TREND ANALYSIS

The assumption that hydrologic timeseries 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) tool is a web-based tool that performs the statistical tests described in the guidance. Annual streamflow (instantaneous peak / max annual discharge) is analyzed for Kaskaskia River. The study measures are based on dredging. The amount of dredging needed to maintain a navigable oxbow channel is based on water levels. Higher water conditions, which are associated with higher flows, will require less dredging than low water conditions.

For this project, the TST tool was applied using annual streamflow data from USGS gage 05594100, Kaskaskia River near Venedy, Illinois. The USGS gage captures 4,393 square miles of drainage area and is located approximately 30 miles upstream of Kaskaskia River Regional Port #2. The TST tool is applied to detect nonstationarities and trends for the period of record from 1970 to 2023.

As shown in **Figure C-2**, the annual streamflow (instantaneous peak / max annual discharge) for the Kaskaskia River near Venedy Station, IL exhibits no evidence of a nonstationary in years 1970-2023. Linear and monotonic trends are evaluated using the t-test, Mann-Kendall and Spearman Rank Order tests. The significance of trends is evaluated using a 0.05 level of significance threshold (p-value<0.05 is considered statistically significant). Trend analysis indicates no statistically significant trends for the 1970-2023 period of record by the by the t-Test (p-value= 0.503), Mann-Kendall test (p-value=0.581), and Spearman Rank-Order (p-value=0.606) tests, see trendline in **Figure C-3**.

USGS 05594100-KASKASKIA RIVER NEAR VENEDY STATION, IL



No nonstationarities detected!

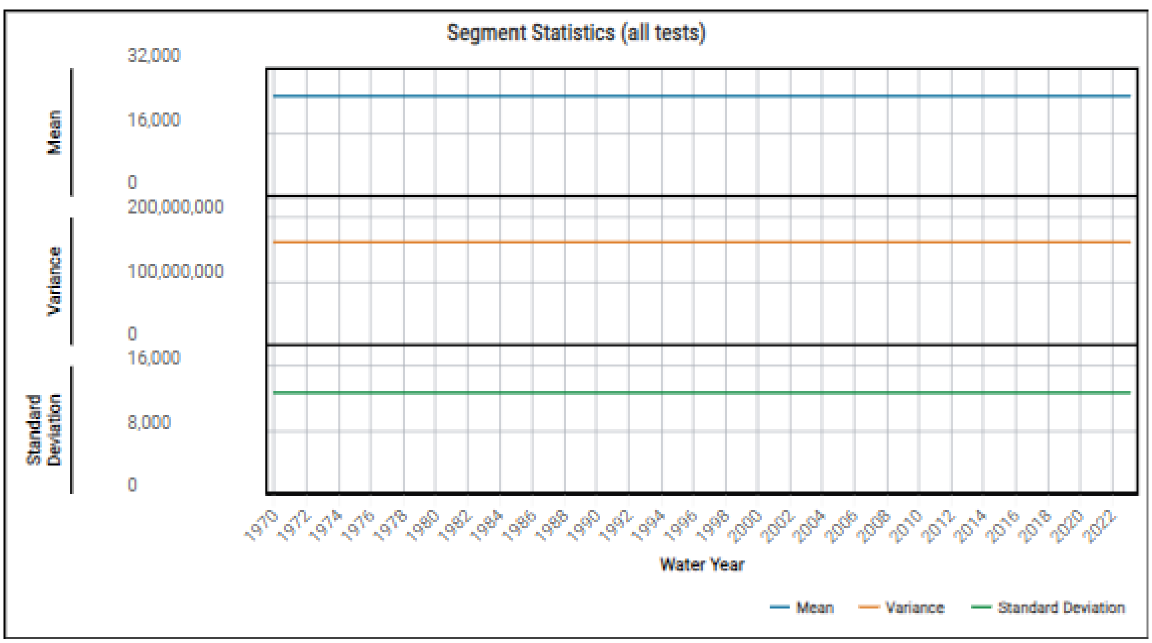


Figure C-2. Time Series Toolbox Output for Annual Streamflow (instantaneous peak / max annual discharge) for Kaskaskia River near Venedy Station, IL.

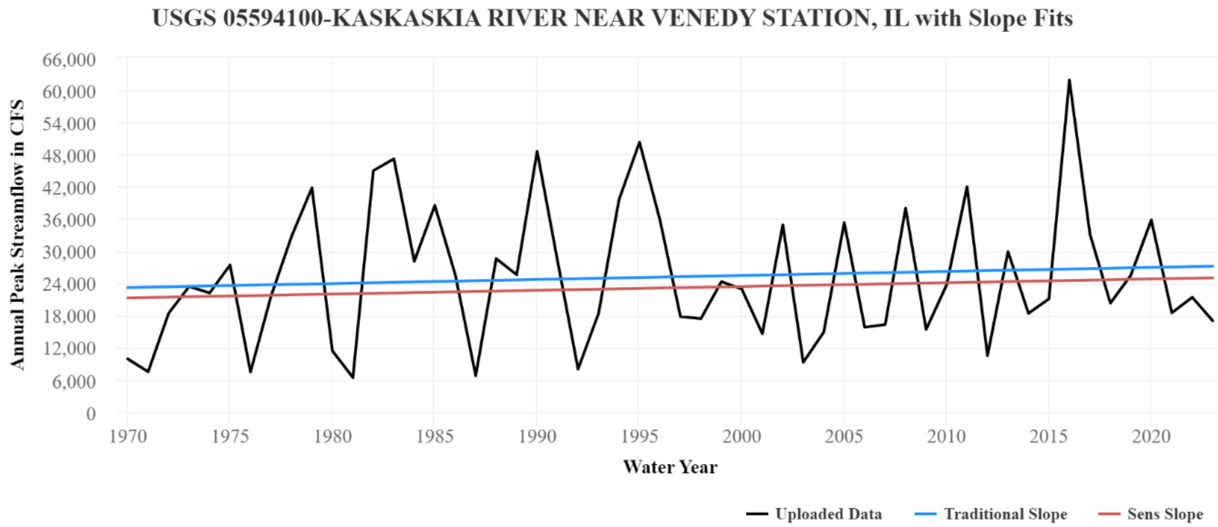


Figure C-3. Trend Analysis for Annual Streamflow (instantaneous peak / max annual discharge) for the Kaskaskia River near Venedy Station, IL.

5 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 Kaskaskia River Regional Port project is in 4-digit HUC 0714 (Upper Mississippi Kaskaskia River). The 8-digit HUC of interest specific to the study area is the Kaskaskia watershed (HUC 07140204). Mississippi River stream segment 07002544 07003502 transects in Red Bud, Illinois. **Figure C-4** and **Figure C-5** show the range of the modeled, annual-maximum of mean streamflow and annual-maximum 1-day temperature output presented for the historic period (1951-2005) and the future period (2006-2099). The annual maximum of mean streamflow is analyzed for this assessment to investigate if and how potential, future streamflow conditions will change. Maximum-annual 1-day temperature is analyzed for this assessment as a proxy for water temperature. The range of data is indicative of the uncertainty associated with projected, climate-changed streamflow and temperature.

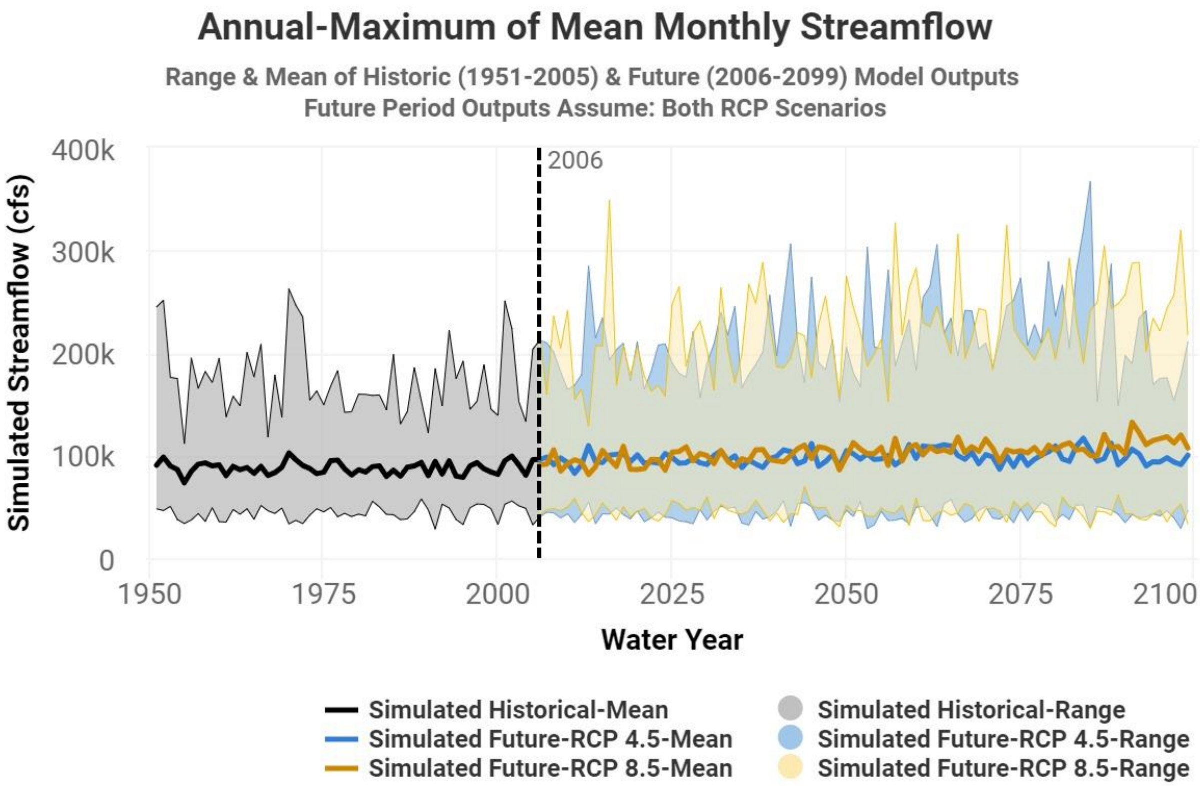


Figure C-4. Range of Annual Maximum of Mean Monthly Streamflow Model Output for the Kaskaskia River watershed (HUC07140204) Stream Segment: 07003502

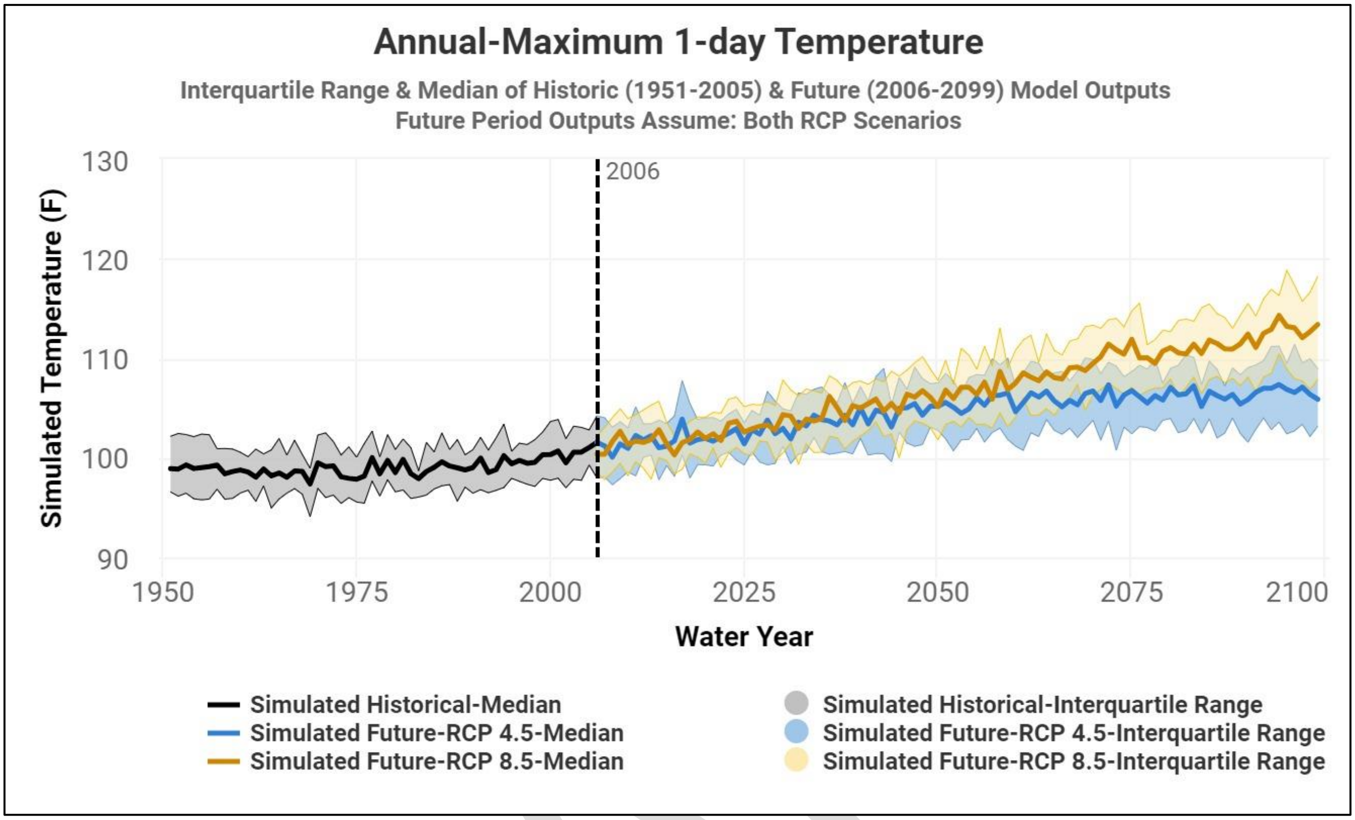


Figure C-5. Range of Annual Maximum 1-Day Temperature Model Output for the Kaskaskia River watershed (HUC07140204)

For the Kaskaskia River watershed (HUC07140204) 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 C-6**, the directionally and magnitude of change in statistically significant trends in annual-mean 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 C-1**. The mean of the 32 projections of simulated, annual-maximum of mean monthly streamflow for the future period (2006-2099) shows a statistically significant, positive trend for the Kaskaskia River watershed (HUC07140204) Stream Segment- 07003502 when RCP 8.5 is assumed. The trendline has a slope of 34 cfs a year, which equates to a 1,750 cfs change in the average of the 32 projections of annual- mean streamflow over a 50-year period. When the CHAT is used to evaluate the change in Epoch-Mean of simulated annual-mean streamflow it is found that the median change from the base Epoch (1950-2005) to the mid-century epoch (2035-2064) is 15.87%. By the end-century epoch (2070-2099) the change relative to the base period is 16.89%. There is no statistically significant trend in simulated, historic flows (1951-2005) or annual-mean streamflow for the future period (2006-2099) when RCP 4.5 is assumed.

Table C-1. Trend Analysis of Average Model Output: Annual – Maximum of Mean Monthly Streamflow Kaskaskia River watershed (HUC07140204) Stream Segment: 07003502

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/year)	Direction	Statistically Significant? (<0.05)	Slope (cfs/year)	Direction	Statistically Significant? (<0.05)	Slope (cfs/year)	Direction
t-Test	0.339	0.277	1.95×10^{-11}	No	Not applicable (no trend)	Not applicable (no trend)	No	Not applicable (no trend)	Not applicable (no trend)	Yes	34.32	↑
Mann-Kendall	0.182	0.207	$<2.2\times10^{-16}$	No	Not applicable (no trend)	Not applicable (no trend)	No	Not applicable (no trend)	Not applicable (no trend)	Yes	34.32	↑
Spearman Rank Order	0.234	0.189	1.28×10^{-11}	No	Not applicable (no trend)	Not applicable (no trend)	No	Not applicable (no trend)	Not applicable (no trend)	Yes	34.32	↑

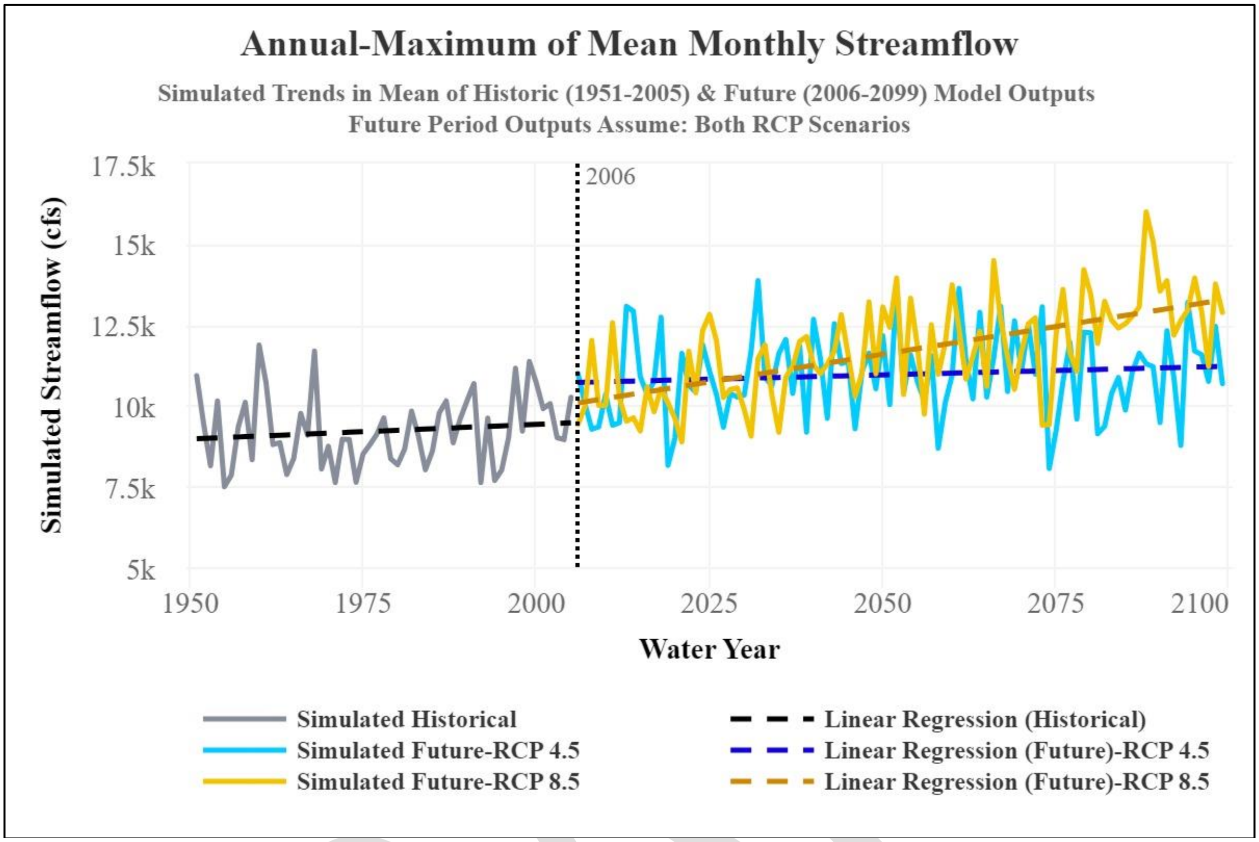


Figure C-6. Trend Analysis of Average Model Output: Annual-Maximum of Mean Monthly Streamflow Kaskaskia River watershed (HUC07140204) Stream Segment: 07003502

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 C-2** and **Figure C-7**. The mean of the simulated, annual-maximum temperature projections (future period: 2006-2099) shows a statistically significant, positive trend for the Kaskaskia River watershed 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 0.0645 °F per year for the lower emission scenario, which would be a 3.23 °F increase in maximum temperature over a 50-year period. The CHAT computes a trendline slope of 0.1377 °F per year for the RCP 8.5 emission scenario, which would be a 6.89 °F increase in maximum temperature over a 50-year period. There is also a statistically significant increasing trend in simulated, historic temperatures between 1951 and 2005 (slope of 0.0287 °F per year). When the CHAT is used to evaluate the change in Epoch-Mean of simulated annual-maximum temperature it is found that the median change from the base Epoch (1950-2005) to the mid-century epoch (2035-2064) is 4.9 °F for RCP 4.5 and 6.2 °F for RCP 8.5. By the end-century epoch (2070-2099) the change relative to the base period is 6.0 °F for RCP 4.5 and 10.9 °F for RCP 8.5.

Table C-2. Trend Analysis of Average Model Output: Annual Maximum 1-Day Temperature for Kaskaskia River watershed (HUC07140204)

Trend Analysis	Historic	Future (2006-2099)		Historic (1951-2005)			Future (2006-2099)					
	(1951-2005)	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	$5.29\text{x}10^{-6}$	$<2.2\text{x}10^{-16}$	$<2.2\text{x}10^{-16}$	Yes	0.0287	↑	Yes	0.0645	↑	Yes	0.1377	↑
Mann-Kendall	$1.06\text{x}10^{-4}$	$<2.2\text{x}10^{-16}$	$<2.2\text{x}10^{-16}$	Yes	0.0287	↑	Yes	0.0645	↑	Yes	0.1377	↑
Spearman Rank Order	$3.88\text{x}10^{-5}$	$<2.2\text{x}10^{-16}$	$<2.2\text{x}10^{-16}$	Yes	0.0287	↑	Yes	0.0645	↑	Yes	0.1377	↑

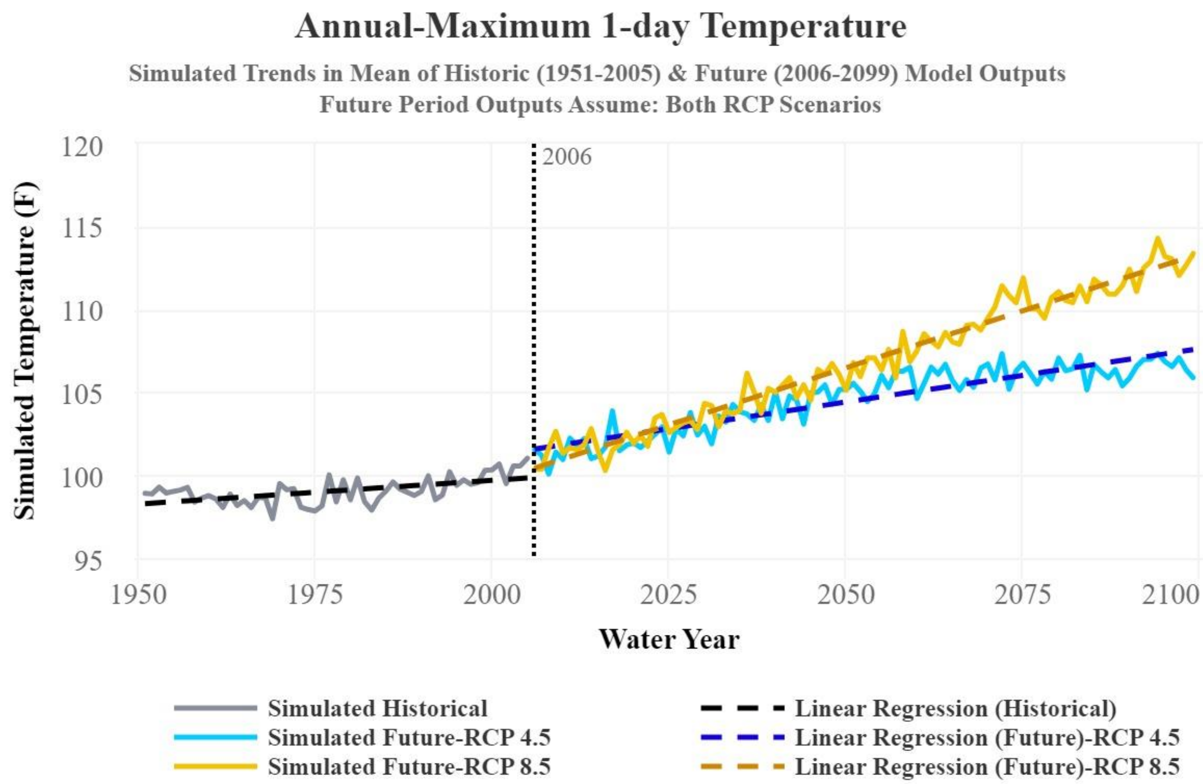


Figure C-7. Historic and Projected trends in historic and projected annual maximum 1-day temperatures for the Kaskaskia River watershed (HUC07140204) Stream Segment: 07003502

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 stream segment 07003502 in the Kaskaskia River watershed (HUC07140204), changes in epoch-mean of simulated monthly mean streamflow are presented in **Figure C-8**. For the stream segment of the Kaskaskia River analyzed, it appears that, for both the mid-century and end-century epochs, flows are increasing outside of July to October. For January to April and November and December, RCP 8.5 predicts bigger increases than RCP 4.5 for both epochs.

For the Kaskaskia River watershed, median simulated monthly-maximum temperatures for both the mid-century epoch (2035-2064) and the end-century epoch (2070-2099) are presented in **Figure C-9**. Both epochs are increasing relative to historic temperature simulations (1950-2005) for all months and both RCPs. For the mid-century comparisons, 4° F increases or greater in temperature are projected under RCP 8.5 for all months but February, March, and December. Larger changes in temperature are projected by the end of century. When RCP 8.5 is assumed, a median increase of over 10° F of warming is projected in May through October. All RCP 8.5 comparisons show greater than 5° F of warming. When RCP 4.5 is assumed, greater than 4.5° F of warming is projected for all months except March. Increases in maximum air temperature, particularly in the summer (June-August), are likely to increase water surface temperatures. This has the potential to adversely impact water quality by decreasing DO in backwater areas within the study area.

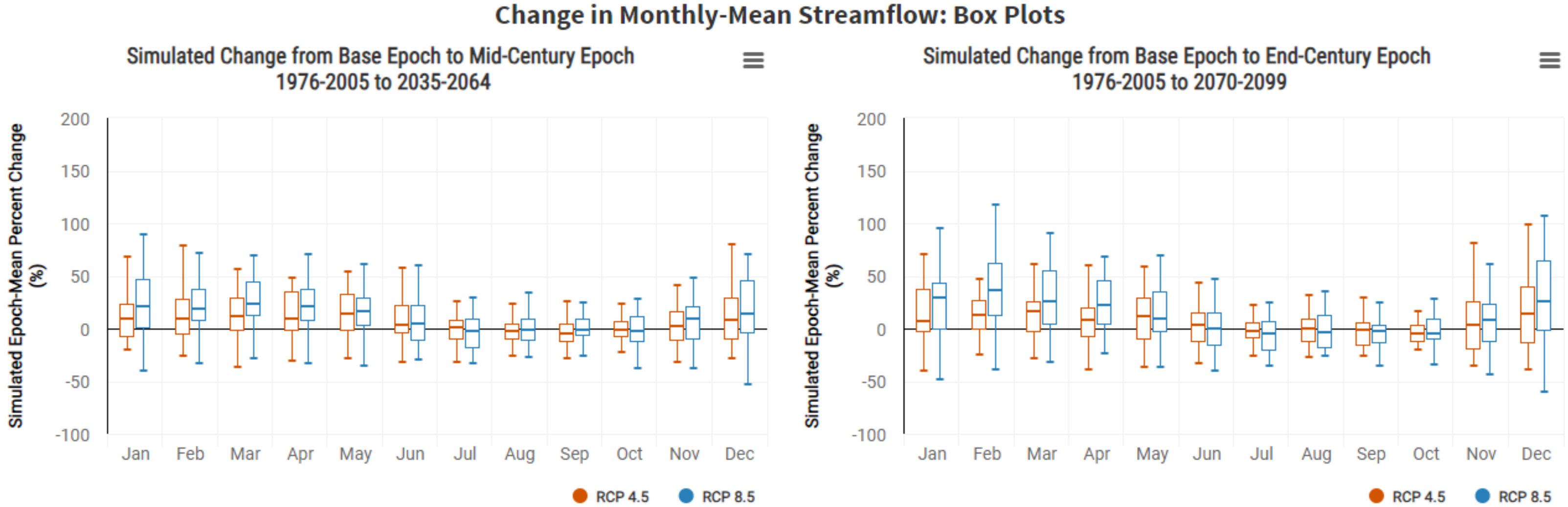


Figure C-8. Change in Epoch-Mean of Simulated Monthly Mean Streamflow - HUC 07140204 – Kaskaskia River- Stream segment ID: 07003502

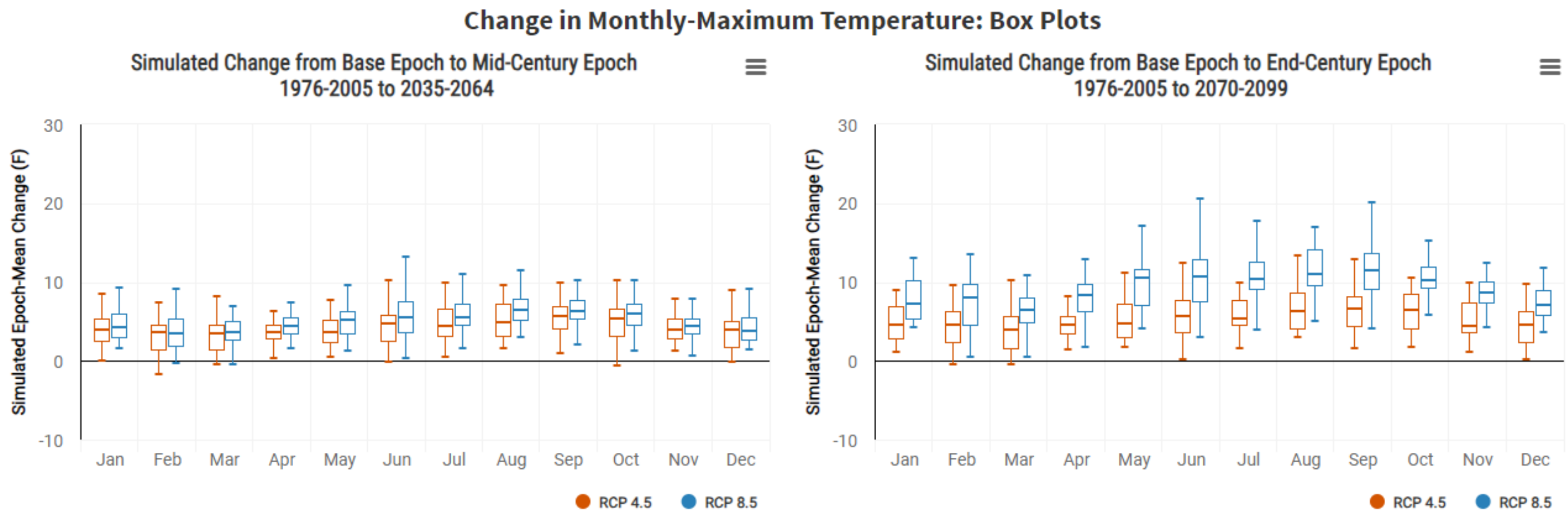


Figure C-9. Change in Epoch-Mean of Simulated Monthly Maximum Temperature - HUC 07140204 – Kaskaskia River- Stream segment ID: 07003502

6 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 is applied using the default, National Standards Settings and for the navigation business line. Indicators used to compute the navigation WOWA score include: the cumulative flood magnification factor, drought severity index, the cumulative and local monthly flow exceeded 90% of the time, change in sediment load due to change in future precipitation, the cumulative low flow reduction factor, the % change in runoff divided by the % change in precipitation, the cumulative monthly coefficient of variation of runoff, the area in 0.2% Annual Exceedance Probability floodplain, and the % of land that is urban or suburban.

As shown in **Figure C-10**, compared to the other 4-digit HUC watersheds in the CONUS, the Kaskaskia River (HUC 0714) watershed does not have a climate change vulnerability score in the top 20% for the navigation business line. This is a comparative evaluation and thus does not imply that the watershed is not vulnerable to future, climate change impacts. Results indicate that for the select metrics incorporated into the tool, this watershed may be less exposed to potential climate change impacts relative to other watersheds in the CONUS. This is true for both the wet and dry subsets and both the 2050 and 2085 epochs.

As can be seen in **Figure C-10** and **Table C-3**, the dominant indicator variable contributing to the Navigation business line VA score for the Kaskaskia River (HUC 0714) watershed is (586C) FLOOD_MAGNIFICATION and (700C) LOW_FLOW_REDUCTION for each epoch and subset combinations. The WOWA score changes by less than 2% between the 2050 and 2085 epochs for both the wet and dry subsets. The percentage by which the indicator variable contributes to the VA score does not significantly change overtime. Because this indicator variable is not dependent on computed, GCM based changes in future hydrology (temperature, precipitation, streamflow) this indicator variable value is constant over time.

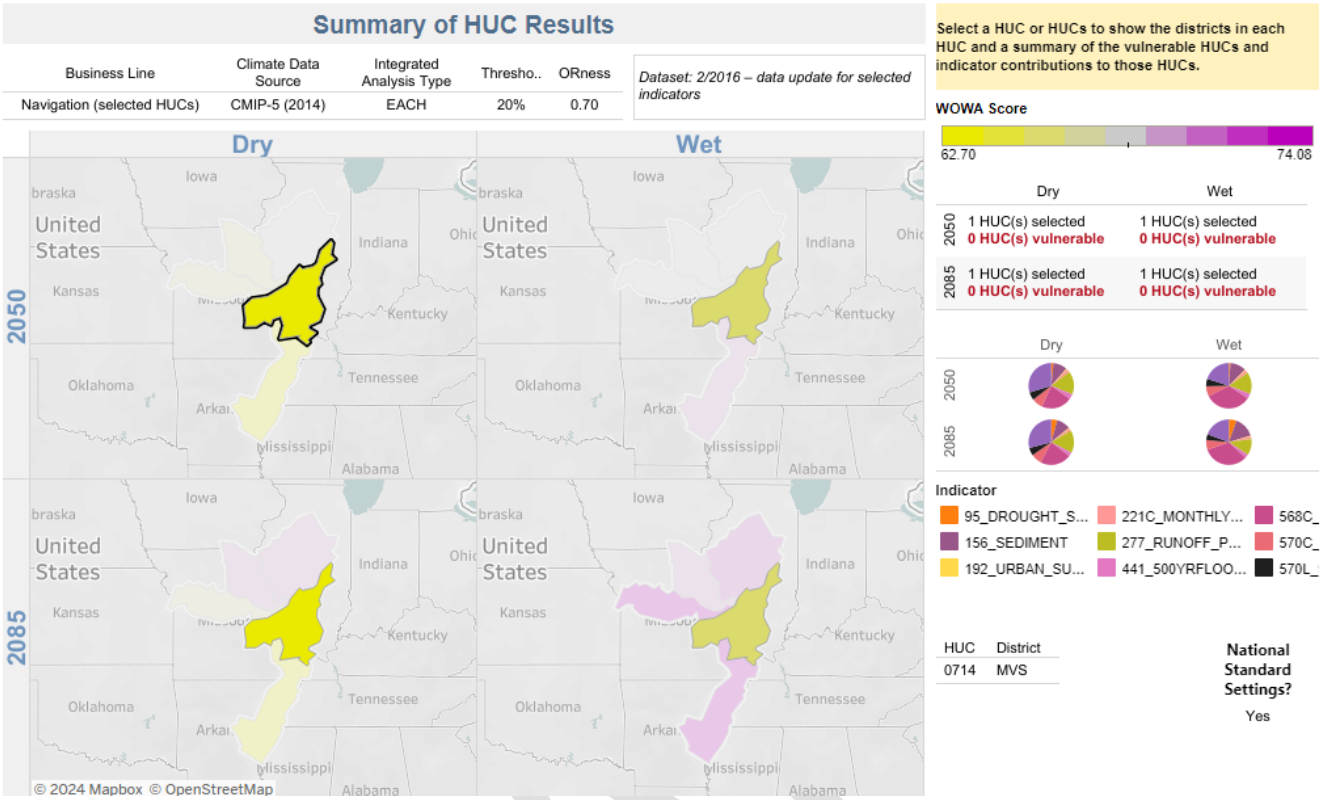


Figure C-10. Output of the Vulnerability Assessment tool - Upper Mississippi-Kaskaskia River watershed

Table C-3. VA Tool Output- HUC: 07140204 – Kaskaskia River- Stream segment ID: 07003502- Navigation

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	65.26	+0.80%	586C_FLOOD_MAGNIFICATION	-0.78%	Constant Overtime
	2085	65.79		586C_FLOOD_MAGNIFICATION		
DRY	2050	62.79	+1.68%	700C_LOW_FLOW_REDUCTION	-0.53%	Constant Overtime
	2085	63.84		700C_LOW_FLOW_REDUCTION		

7 CONCLUSION

The purpose of the Kaskaskia River Regional Port Continuing Authority Project (CAP) Section 107 Study is to analyze alternatives to improve navigation efficiencies in KRPD #2. The study area encompasses wetland, floodplain forest, shoreline, floodplain terrestrial vegetation and fish habitat. The project includes channel dredging, barge infrastructure construction, and disposal of dredged material. Output based on both historic, observed hydrometeorological data and projected, climate-changed hydrometeorological data is reviewed to support qualitative statements about how to incorporate resilience to climate change impacts over the potential Kaskaskia River Regional Port CAP Section 107 project lifecycle.

Based on the weight of evidence presented in this assessment, climate change impacts are anticipated to affect the study area's hydrology over the project's 50-year life cycle. Available climate change literature suggests a warmer and wetter climate in the future. There are statistically significant increasing trends in both the observed and projected flow data analyzed specific to this study area. As flow increases, floodplain forest habitat may be inundated more often. There is also evidence that temperatures are increasing in the study area which may negatively affect water quality and aquatic habitat. **Table C-4** 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 project features resulting in harm to the study area.

Within the Upper Mississippi River Region, climate change poses a potential risk to navigation due to the likelihood of the region experiencing shifts in the flow regime and increases in temperature in the future. Projects, like the potential Kaskaskia River Regional Port CAP Section 107 project will serve to offset some of this risk by improving navigability. The standard practices used to design and construct USACE navigation projects include a degree of resilience because features are typically designed to accommodate a wide range of flow conditions. Thus, it is unlikely that climate change-induced increases in flow will undermine project features.

Table C-4. Residual Risk Due to Climate Change

Project Feature	Trigger	Hazard	Harm	Qualitative Likelihood	Justification of Likelihood Rating
Dredge Disposal Area Berm	Increased discharge and WSEL	Water volumes and depth may be higher than at present.	Higher WSEL has the potential to overtop berm around dredge disposal area	Unlikely	No scenario outside of initial sediment loading where berms will be hydraulically loaded internally but not externally.
Oxbow Access (Navigation Channel)	Increased discharge and WSEL	Prolonged flood / high water levels	Loss of navigation channel due to Jerry F. Costello L&D going out of service, resulting in loss of access to oxbow	Likely	Lock closes at EL 380.0 ft NAVD88 on the tailwater gage; this has occurred roughly every two years, for ~3% of days from 2004-2024, and thus is seen as a relatively common occurrence already.
Oxbow Access (Navigation Channel)	Decreased discharge and WSEL	Prolonged drought / low water levels	Increased risk of Disruptions in Navigation, groundings, vessel damage in navigation channel, resulting in risk of access to oxbow.	Unlikely	Water levels for navigation are hinge point operated and adjusted by the operation of Costello Lock and Dam to maintain navigable water depths.
Oxbow Access (Navigation Channel)	Increase in extreme low temperatur es	Ice jams in navigation channel	Loss of navigable channel due to blockage results in loss of access to oxbow	Unlikely	No historic reporting of ice jams.

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