Mississippi Valley Division,
Regional Planning and Environment Division South

Tangipahoa Parish, Louisiana Feasibility Study

Appendix I – Tangipahoa Parish Feasibility Study Climate Change Assessment

August 2024

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1.1 CLIMATE ASSESSMENT INTRODUCTION

The USACE is committed to climate change preparedness and resilience planning, along with implementing protections in consultation with internal and external experts using the best available – and actionable – climate science and climate change information (USACE, 2015). “The highest rates of Mean Sea Level rise in the U.S. have occurred along the Gulf Coast in the Mississippi River delta region at 9-12 mm/yr (0.9-1.2 meters per century), with significant rises in Texas and the mid-Atlantic (3-6 mm/yr or 0.3 -0.6 meters per century)” (ER 1100-2-8162, 2019). Figure I: 1-1 below shows the local relative sea level (RSL) trends (NOAA, 2022). As a result, USACE has grown increasingly concerned about the potential impacts climate change may have on long-term planning, setting priorities, and making decisions that affect resources, programs, policies, and U.S. operations.

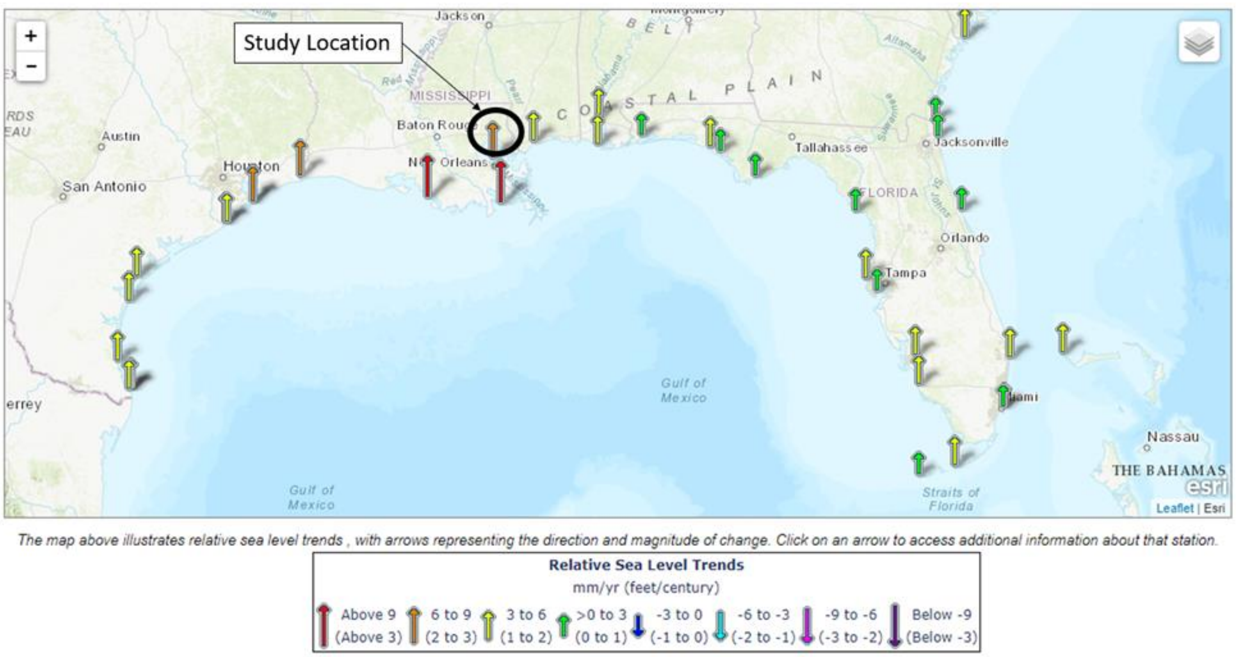


Figure I: 1-1. Sea level trends measured by tide gages presented as local RSL trends as opposed to global sea level trend.

In accordance with USACE guidance, an assessment of climate change impacts must be performed in support of the Tangipahoa Parish Feasibility Study (TPFS). Climate change impacts include sea level rise (SLR) and inland hydrologic changes such as increases in temperatures, precipitation, storm intensity, and flood volumes.

The TPFS climate assessment analyzes climate change impacts from two hydrologic aspects. One of those is relative sea level rise (RSLR), which uses quantitative analysis based on historical data and projections with guidance outlined in ER 1100-2-8162. The second is inland hydrologic change, which uses qualitative assessments based on precipitation changes and outlined in the most updated Engineering and Construction Bulletin (ECB) 2018-14. It should be noted that the relevant climate change variables identified for this study include sea level trends, precipitation, air temperatures, and streamflow/hydrology. Additionally, the Mississippi upstream hydrologic loading is another possible inland hydrologic impact due to shifts in upstream climate changes on the Mississippi River.

ERs outline the requirements and provide guidance to assess USACE projects with respect to climate change impacts. The study focuses on flood risk management (FRM) and coastal storm risk management (CSRM) improvements within the study area, which are at risk to impacts of climate change. The study area is located within two main United States Geological Survey (USGS) water resource regions: the Lower Mississippi Region or HUC-08, and the South Atlantic-Gulf or HUC-03, both shown in Figure I: 1-2. The farthest southwestern boundary of Region 03 covers the northeastern portion of Tangipahoa Parish (the boundary is located along the Pearl River Basin). Region 08 covers nearly the entirety of the coastline of Tangipahoa Parish along Lake Pontchartrain and the remaining inland region of the parish outside of the Pearl River basin floodplain. Figure I: 1-3 depicts the area of interest for the study along with tide gages near the project area.

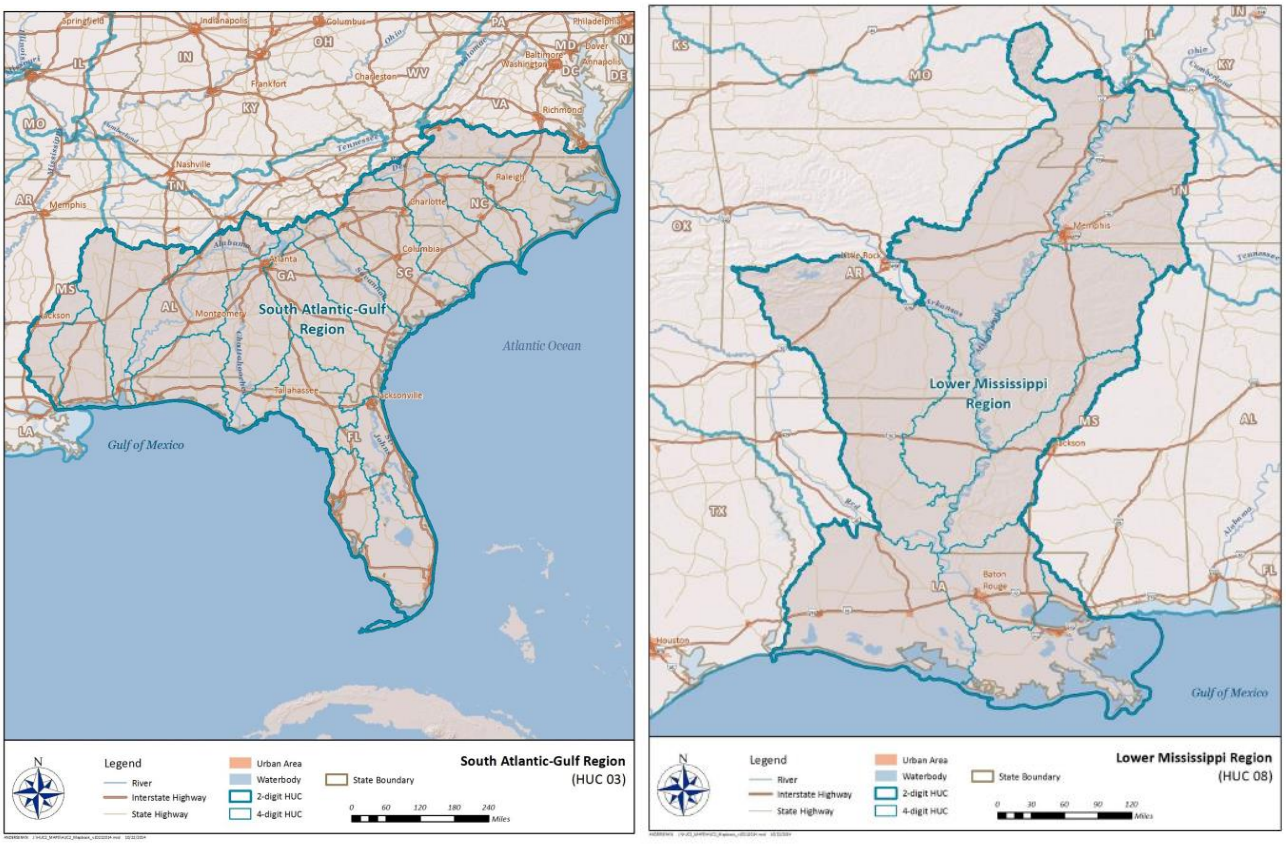


Figure I: 1-2. Lower Mississippi River Region and South Atlantic-Gulf Region Boundaries. (USACE, Recent Climate Change and Hydrology Literature Applicable to U.S. Army Corps of Engineers Missions – Lower Mississippi River Region 08, 2015)

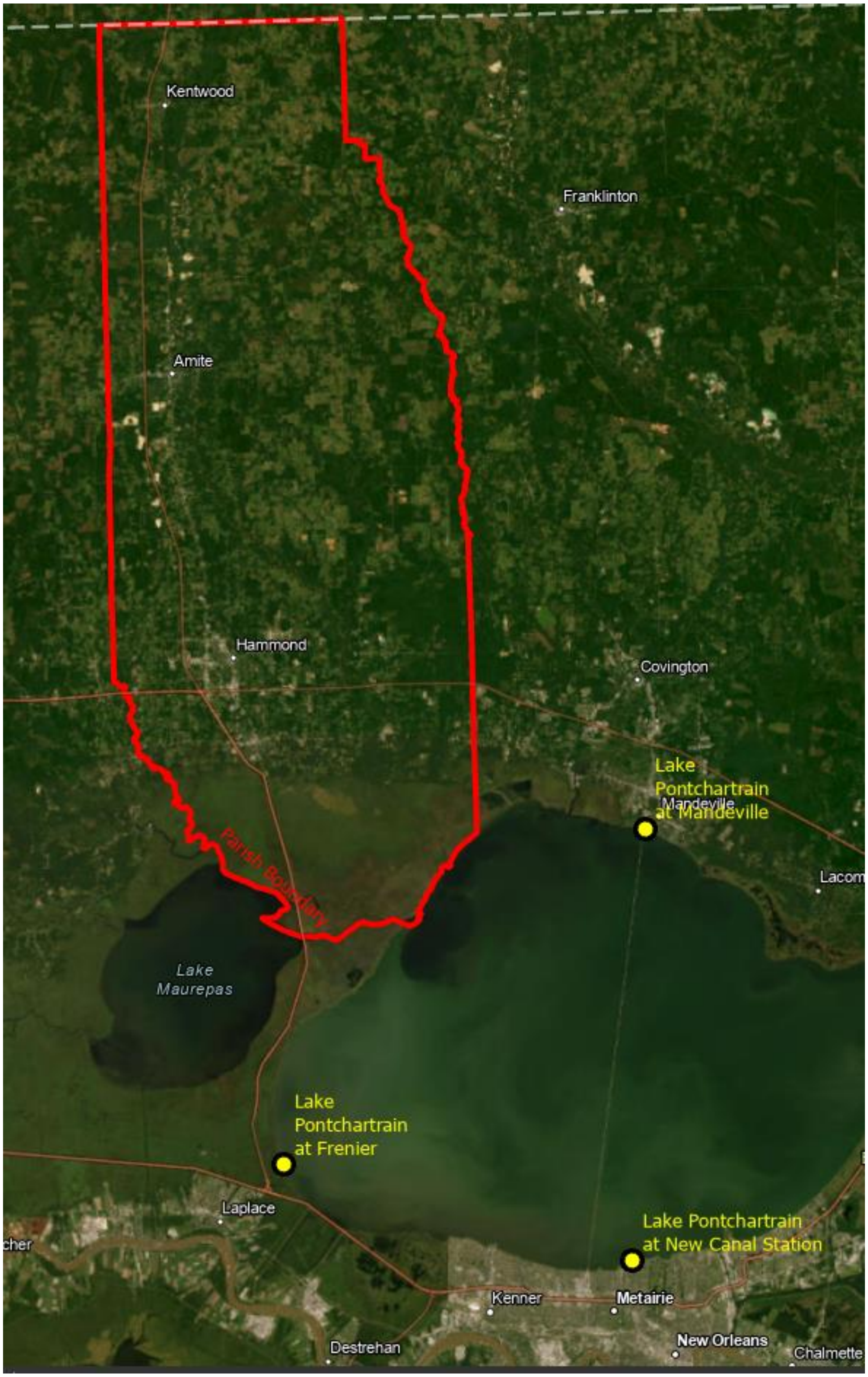


Figure I: 1-3. Tangipahoa Parish Extents and location of Lake Pontchartrain tidal gages in Mandeville, Frenier, and New Canal Station.

1.2 CLIMATE TOOLS & METHODOLOGY

According to the Engineering and Construction Bulletin (ECB) 2018-14, the Climate Preparedness and Resilience Community of Practice Applications Portal provides an online repository for tools and information required by the ECB to assess hydrologic climate impacts. Both quantitative and qualitative methodologies are acceptable according to the ECB.

Both quantitative and qualitative analyses were performed on the study area using approved climate tools. Relative sea level trends were analyzed using the sea-level calculator. The selected tool to provide qualitative, or Tier 1, assessments at the watershed scale for this study is the Civil Works Vulnerability Assessment (VA) Tool and details of this tool are outlined in ECB 2018-14. Generally speaking, the VA Tool provides information at the Hydrologic Unit Code (HUC) 4 Watershed scale for wet (wettest 50% of models) and dry (driest 50% of models) future scenarios. The Climate Hydrology Assessment Tool (CHAT) was also utilized in this study. CHAT allows users to visualize annual streamflow, precipitation, and temperature time series model outputs and to perform simulated trend analysis for these annual time series. The Time Series Toolbox (TST) was also used to evaluate inland hydrologic nonstationarities in gages used for the hydraulic calibration of this study.

1.3 LITERATURE REVIEW

The Fourth National Climate Assessment (NCA4) and the USACE's Civil Works Technical Report CWTS 2015 13, as well as state-specific resources published by the National Oceanic and Atmospheric Administration (NOAA). The NCA4 considers climate change research at both a national and regional scale (USGCRP, 2018). Civil Works Technical Report CWTS-2015-13 was published by USACE in 2015 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), HUC watersheds in the United States (U.S). Tangipahoa Parish is located between two 2-digit HUC basins: HUC 08, the Lower Mississippi River Region and HUC 03, South Atlantic-Gulf Region. The references below summarize trends in historic and observed temperature, precipitation, and streamflow records, as well as provide an indication of future hydrometeorology based on the outputs from Global Climate Models (GCMs). In this assessment, background on observed and projected temperature and precipitation is provided as context for the impact they have on observed and projected streamflow.

Temperature, precipitation, and streamflow measurements have been taken since the late 1800s and provide insight into how the climate 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. Radiative forcings encompass the change in net radiative flux due to external drivers of climate change, such as changes in carbon dioxide or land use/land cover. GCMs are used to approximate future temperature and precipitation. Projected temperature and precipitation time series can be transformed to regional and local scales (a process called downscaling). Downscaled time series can then be applied as inputs to macro-scale hydrologic models (Graham, Andreasson, and Carlsson, 2007).

Uncertainty is inherent to climate change modeling due to the coarse spatial scale of the GCMs and the many inputs and assumptions required to create climate changed 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). It is best practice to use multiple GCMs when studying climate change impacts to understand how various model assumptions impact results (Gleckler et al. 2008).

Additionally, ER 1100-2-8162 outlines the USACE regulations for climate change induced RSLR. The Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects was updated and effective immediately within the ECB 2018-4. This policy provides guidance for incorporating climate change information for hydrologic analyses in accordance with the USACE overarching climate preparedness and resilience policy and ER 1105-2-101. The flow chart below in Figure I: 1-4 represents the steps and order required to perform a qualitative assessment of the impacts of climate change in hydrologic analyses.

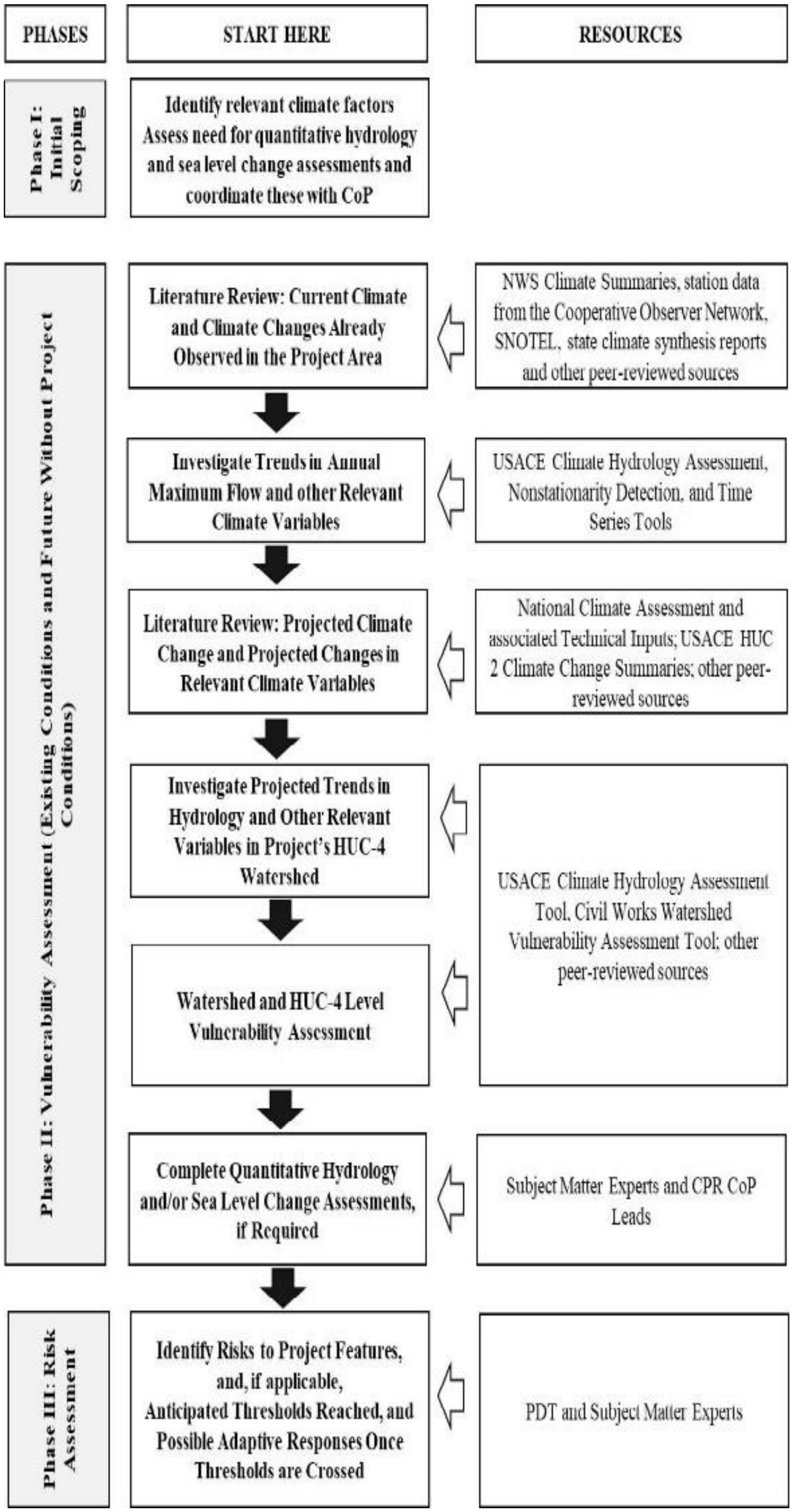


Figure I: 1-4. Qualitative Assessment Steps (ECB 2018-14 2020)

1.4 CLIMATE CHANGE IMPACTS

1.4.1 Sea Level Change and Relative Sea Level Trend

Outlined in ER 1100-2-8162, USACE is to incorporate “the direct and indirect physical effects of projected future sea level rise (SLR) across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of project” (ER 1100-2-8162 2019). ER 1100-2-8162 was developed by USACE with the assistance of coastal scientists from the NOAA National Ocean Service and the USGS to allow scientific data to be embedded into engineering guidance. Possible future rates of SLR are divided into three scenarios: 1) Low, 2) Intermediate, and 3) High SLR. Based on the data, the three scenarios are broken down into the following:

LOW: Based on historic rates of SLR (ETL 1100-2-1, Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaption).

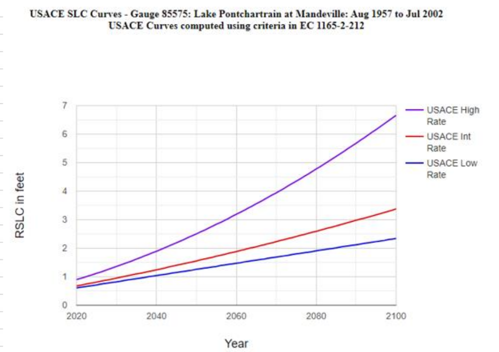
INTERMEDIATE: Calculated from the modified National Research Council (NRC) Curve I considering both the most recent Intergovernmental Panel on Climate Change (IPCC) projections and modified NRC projections with the local rate of vertical land movement added.

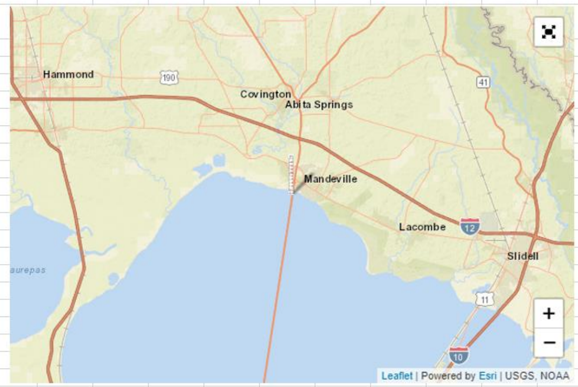
HIGH: Computed from the modified NRC Curve III considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement added.

The ER directs to use the USACE Sea Level Rise Curve Calculator online tool to develop the three rates. For the high-subsidence area of coastal Louisiana, the Sea-Level Calculator for Non-NOAA Long-Term Tide Gages was used specifically, results may be seen in Figure I: 1-5. A base year of 2033 is used in the tool as that is the selected base year of the project and the selected locations for computation of the Sea Level Change Curve Calculator are Mandeville and Frenier, Louisiana. Each rate of SLR and the impact these rates pose on proposed projects performance in the study is evaluated and discussed in Appendix B Section 4.7 Future Conditions.

USACE Curves computed using criteria in USACE EC 1165-2-212

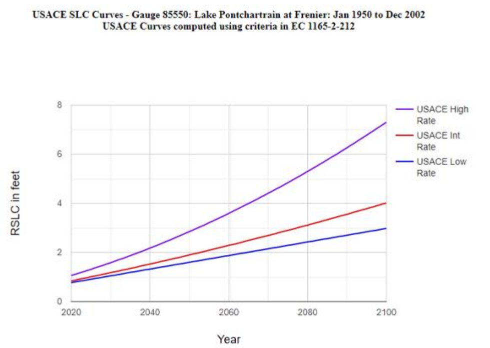
Gauge 85575: Lake Pontchartrain at Mandeville: Aug 1957 to Jul 2002 All values are in feet			
Year	USACE Low	USACE Int	USACE High
2020	0.61	0.68	0.9
2025	0.71	0.81	1.12
2030	0.82	0.95	1.36
2035	0.93	1.1	1.62
2040	1.04	1.24	1.89
2045	1.15	1.4	2.19
2050	1.26	1.55	2.5
2055	1.36	1.72	2.84
2060	1.47	1.88	3.19
2065	1.58	2.05	3.56
2070	1.69	2.23	3.94
2075	1.8	2.41	4.35
2080	1.91	2.59	4.78
2085	2.01	2.78	5.22
2090	2.12	2.98	5.68
2095	2.23	3.17	6.16
2100	2.34	3.38	6.66





USACE Curves computed using criteria in USACE EC 1165-2-212

Gauge 85550: Lake Pontchartrain at Frenier: Jan 1950 to Dec 2002 All values are in feet			
Year	USACE Low	USACE Int	USACE High
2020	0.77	0.84	1.06
2025	0.91	1.01	1.31
2030	1.05	1.18	1.58
2035	1.19	1.35	1.87
2040	1.32	1.53	2.18
2045	1.46	1.71	2.5
2050	1.6	1.9	2.85
2055	1.74	2.09	3.21
2060	1.87	2.29	3.59
2065	2.01	2.49	3.99
2070	2.15	2.69	4.41
2075	2.29	2.9	4.84
2080	2.43	3.11	5.3
2085	2.56	3.33	5.77
2090	2.7	3.55	6.26
2095	2.84	3.78	6.77
2100	2.98	4.01	7.3



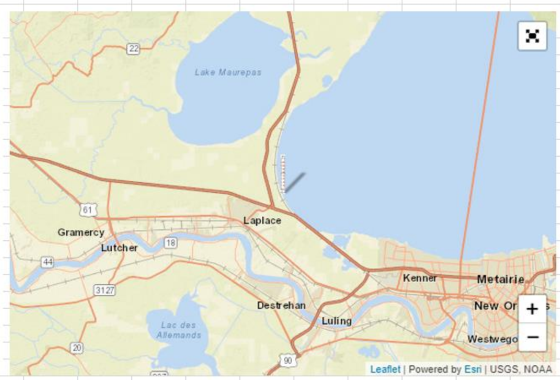


Figure I: 1-1. USACE Sea Level Change Curves for Mandeville and Frenier, Louisiana

1.4.2 Inland Hydrologic Change

Inland hydrologic change can include multiple climate change variables that are at risk of changes. Figure I: 1-6 represents a matrix of the results from the “Recent US Climate Change and Hydrology Literature Applicable to U.S. Army Corps of Engineers Missions – Lower Mississippi River Region 08” representing observed and projected trends. The portion of the study area that is covered within Region 08 is a majority of the Louisiana coastline and the inland portion of the parish west of the Pearl River floodplain. Figure I: 1-7 depicts a similar matrix of the results from the “Recent US Climate Change and Hydrology Literature Applicable to U.S. Army Corps of Engineers Missions – South Atlantic-Gulf Region 03” showing observed and projected trends. The portion of the Pearl River Basin floodplain within Tangipahoa Parish is within Region 03 and will be discussed later in this section.

Region 08 results indicate an observed mild upward trend in both precipitation and hydrology/streamflow within the Lower Mississippi River Region; however, a full supporting consensus was not reached based on the data evaluated (greater than half). The projected trends showed an increase in precipitation, but a full consensus was not established (less than half). Additionally, a decreasing trend was projected for hydrology/streamflow without a strong consensus (less than half). Observed air temperatures showed no significant change in the recent past without a strong consensus (greater than half). However, projected trend shows strong increases in air temperatures with a full consensus and siting multiple literary sources.

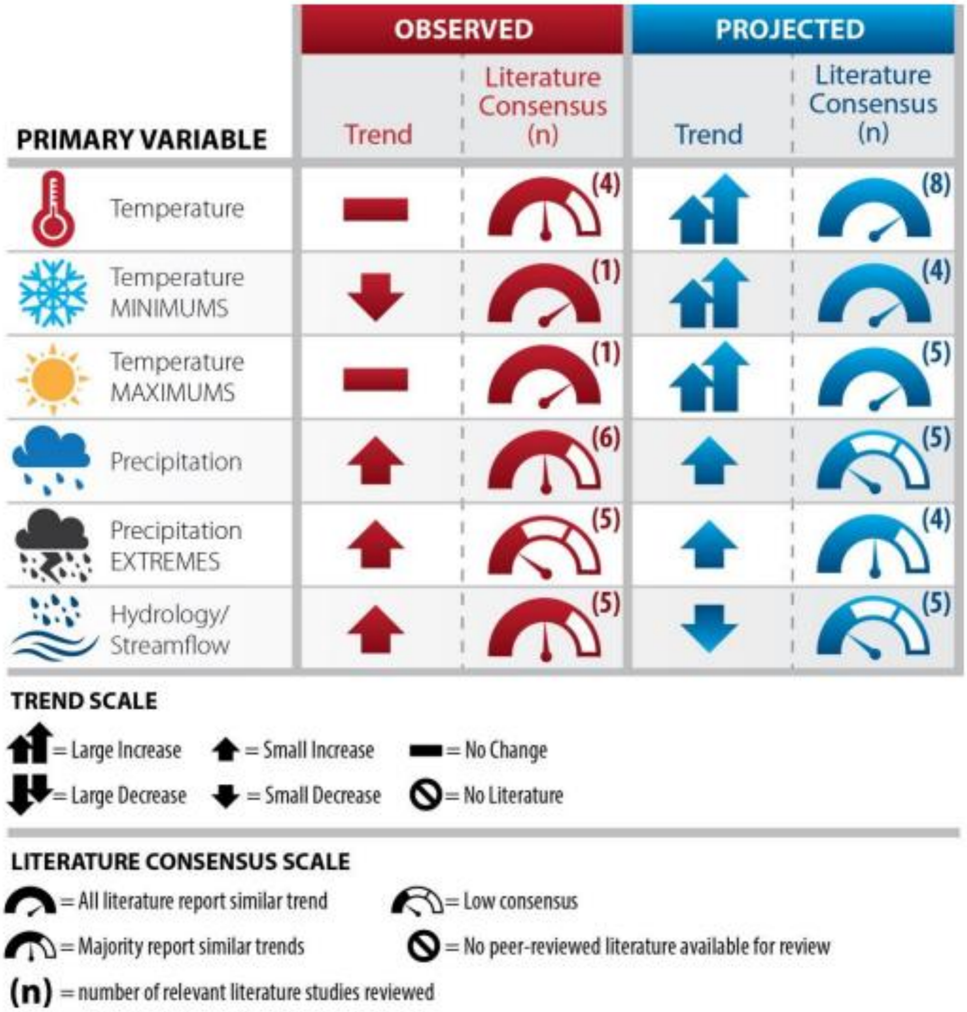


Figure I: 1-6. Summary Matrix of Observed and Projected Climate Trends and Literary Consensus for Region 08 Source: U.S. Army Corps of Engineers (USACE 2015)

Figure I: 1-7 represents a matrix of the results from the “Recent US Climate Change and Hydrology Literature Applicable to U.S. Army Corps of Engineers Missions – South Atlantic-Gulf Region 03” representing observed and projected trends. Unlike Region 08, Region 03 results indicate a moderate increase to observed air temperatures in the study area for the South Atlantic-Gulf region, and air temperatures are projected to exhibit a strong increase in the future. Observed precipitation is increasing for Region 03, along with precipitation extremes. Precipitation trends are predicted to remain constant; however, extreme precipitation events are expected to exhibit a small increase. Additionally, there is a decreasing trend in observed hydrology/streamflow without a strong consensus (less than half), and this trend is projected to not change in the near future.

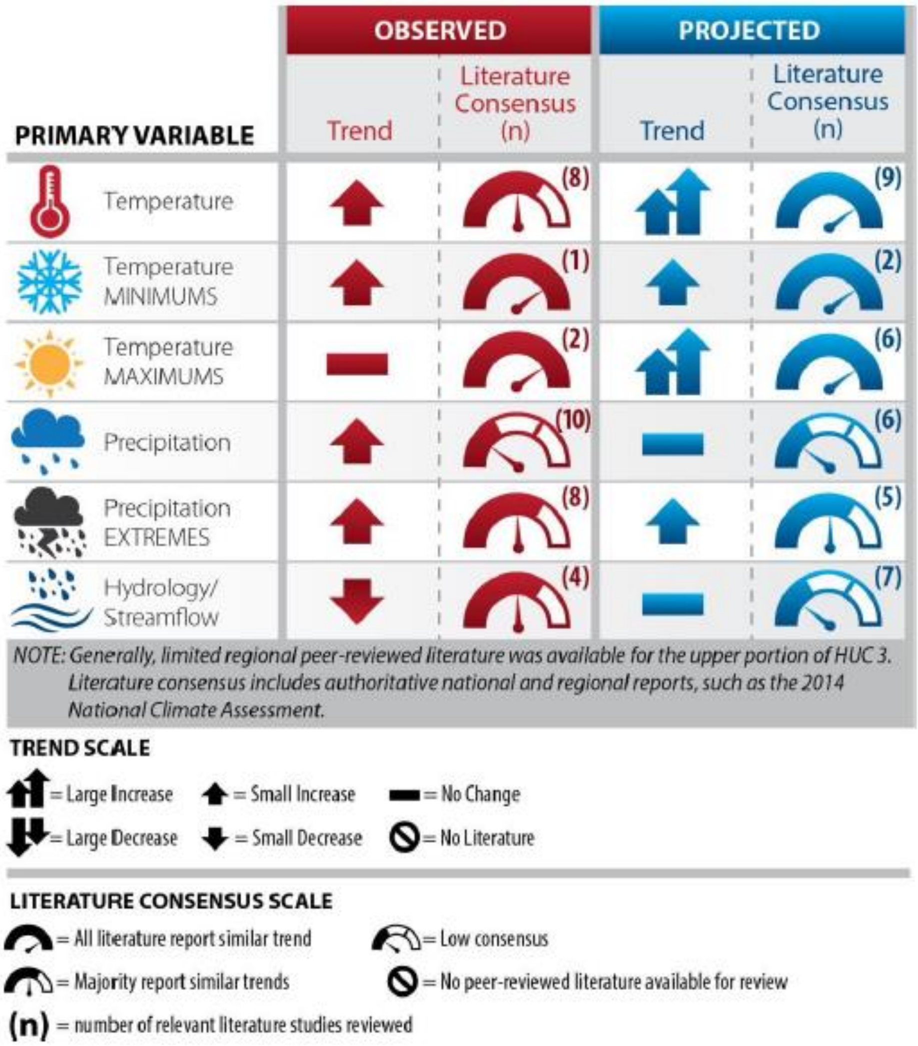


Figure I: 1-7. Summary Matrix of Observed and Projected Climate Trends and Literary Consensus for Region 03 Source: U.S. Army Corps of Engineers (USACE 2015)

Additionally, the TST was utilized to evaluate nonstationarity detections (NSDs) in the three gages used for calibration of the hydrologic and hydraulic models which are listed in Appendix B Table 3-3. Of the three calibration gages utilized for this study, two gages have nonstationarities detected. USGS Gage 07376500 – Natalbany River at Baptists, LA has nonstationarities detected at years 1944, 1945, 1946 using the Smooth Lombard Wilcoxon Statistical Method and at year 1984 using the Energy Divisive Method. USGS Gage 07375500 – Tangipahoa River at Robert, LA has nonstationarities detected at year 1971 using the Energy Divisive Method. It should be noted that the sole use of the gage data in this study was for calibration of the Hydraulic model. The nonstationarities detected in these two gages do not impact the study as the years they are detected do not overlap with the selected events used for model calibration. Therefore, the presence of these nonstationarities is non-consequential for analyses conducted in this study.

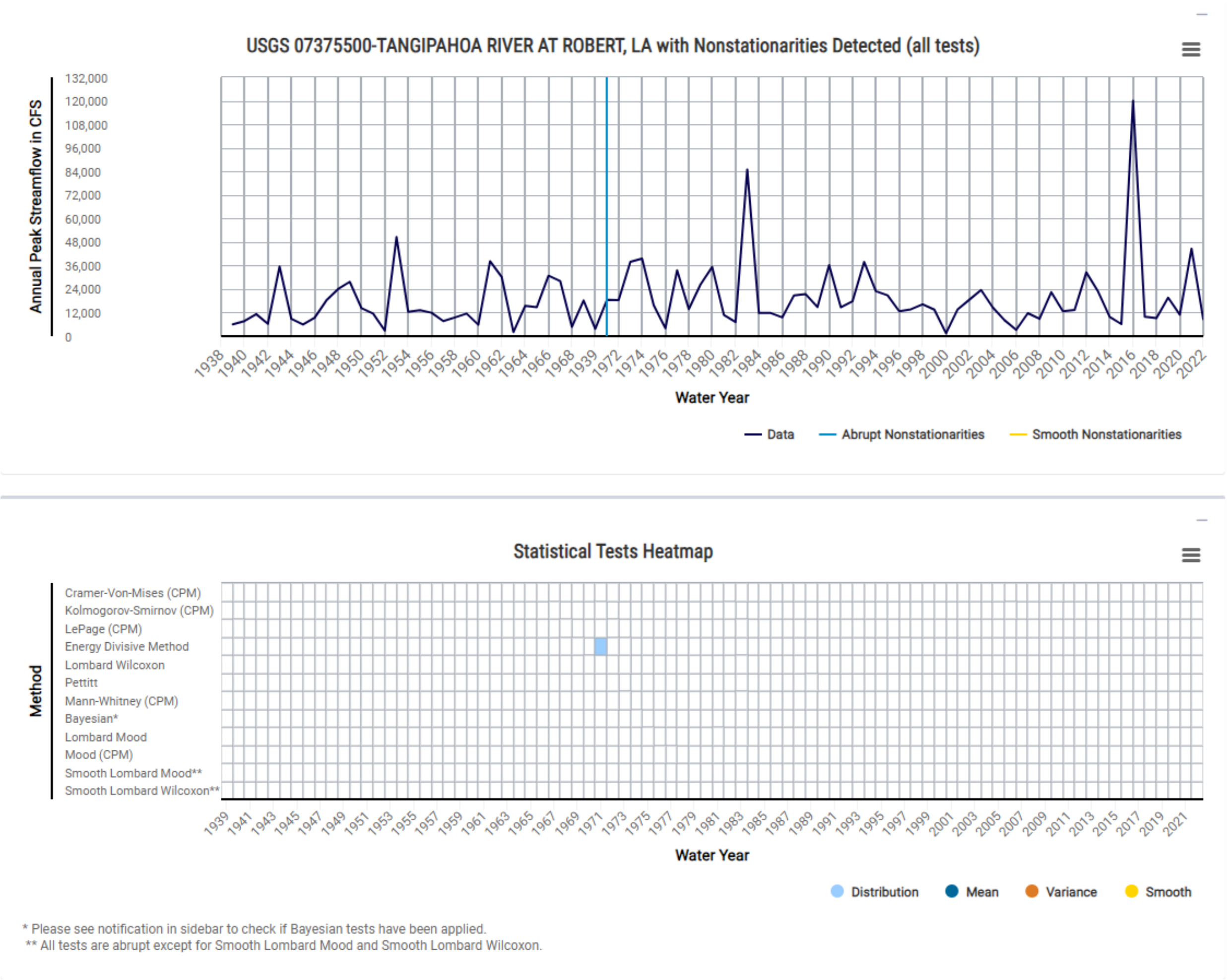


Figure I: 1-2. Lower Mississippi River Region 08 nonstationarity results for the Tangipahoa River at Robert, LA

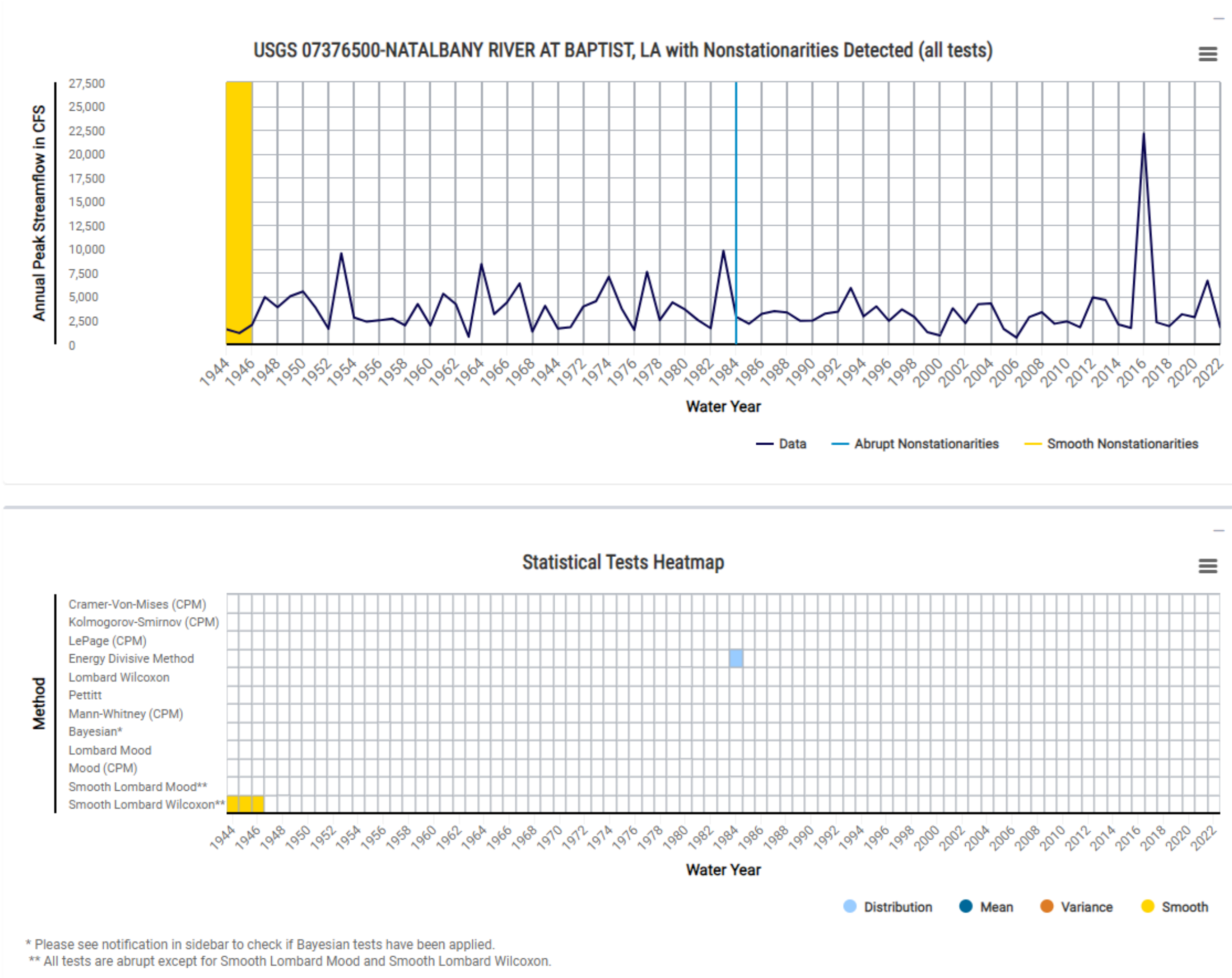


Figure I: 1-9. Lower Mississippi River Region 08 nonstationarity results for the Natalbany River at Baptist, LA

1.5 CLIMATE HYDROLOGY ASSESSMENT TOOL (CHAT)

CHAT displays simulated historical and projected future climate-changed hydrology (annual maximum of average monthly streamflow) for individual stream segments associated with each HUC-8 watershed. The association between segment and HUC-8 watershed is performed by selecting the terminal or outlet stream segment for the watershed. Figure I: 1-10 depicts CHAT results for the Lower Mississippi HUC-4 basin, Tangipahoa HUC-8 Basin and Figure I: 1-11 depicts CHAT results for the Lower Mississippi HUC-4 Basin, Tickfaw River HUC-8 Basin. Both figures illustrate the annual-maximum of mean streamflow, annual-maximum 1-day precipitation, and annual-maximum temperature based on historical and projected data from 1950 until 2100 for their respective regions.

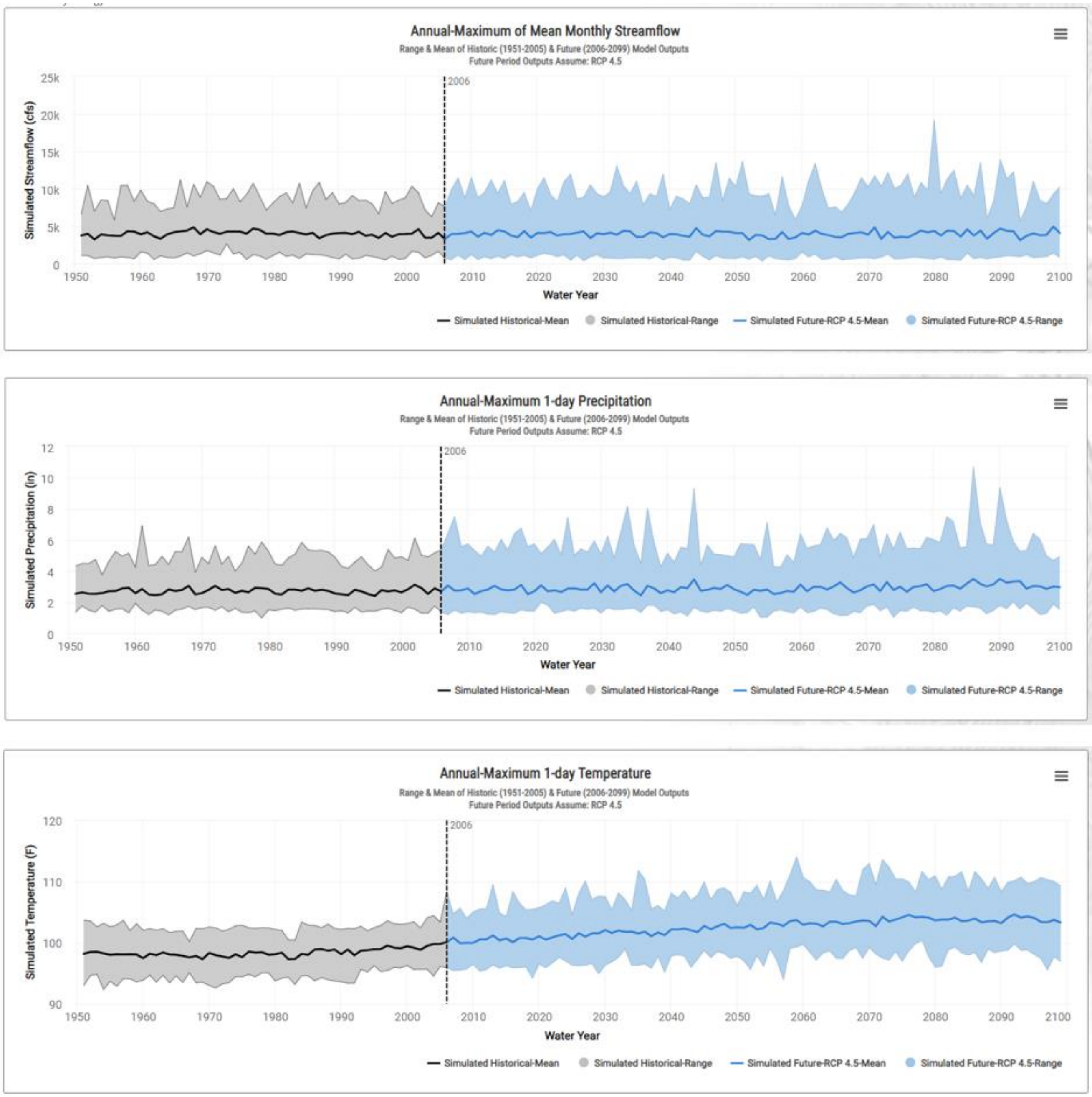


Figure I: 1-10. Lower Mississippi River Region 08 CHAT results depicting annual-maximum of mean streamflow, annual-maximum 1-day precipitation, and annual-maximum temperature for the Lower Mississippi HUC-4 basin, Tangipahoa River HUC-8 Basin

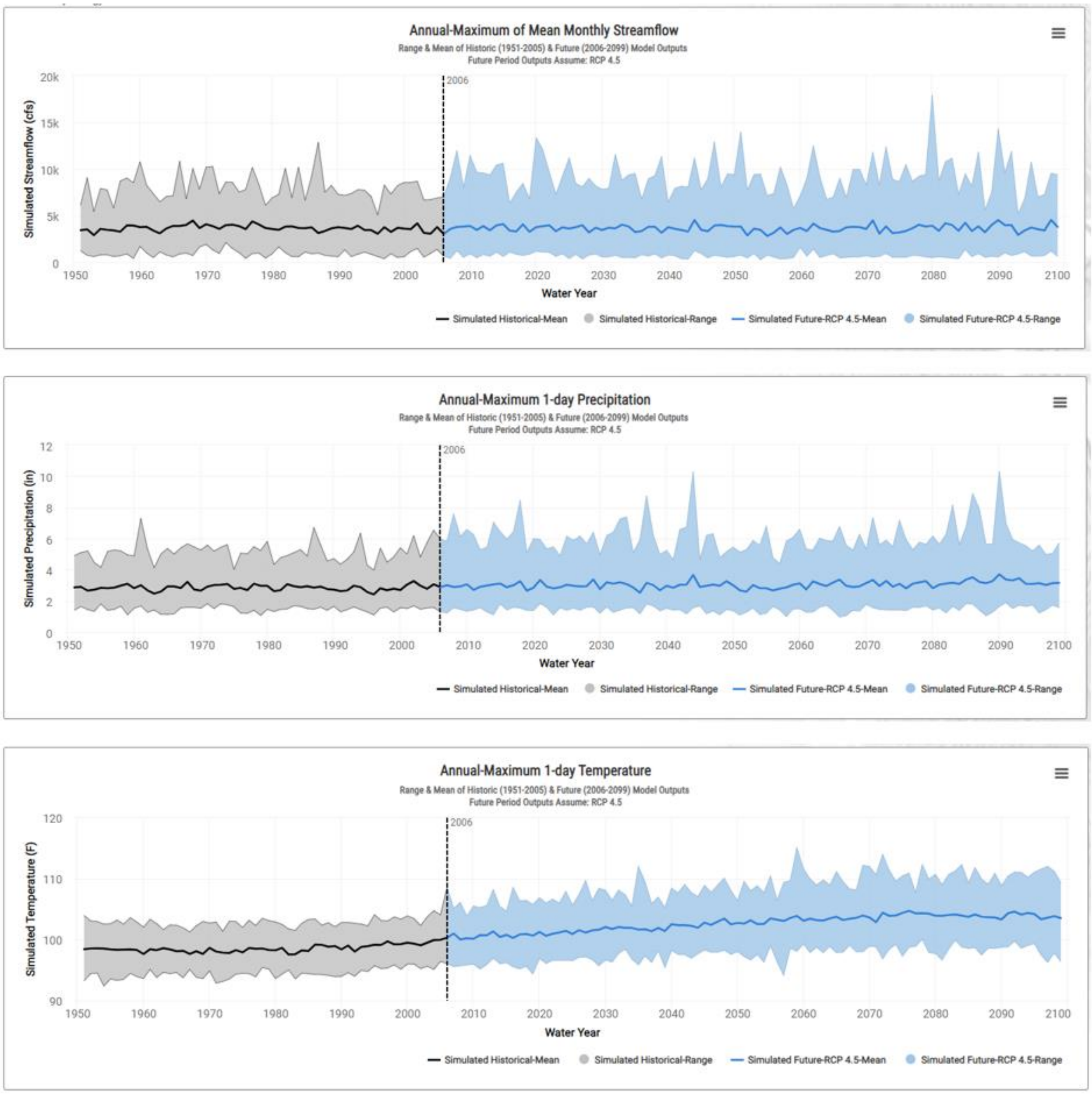


Figure I: 1-11. Lower Mississippi River Region 08 CHAT results depicting annual-maximum of mean streamflow, annual-maximum 1-day precipitation, and annual-maximum temperature for the Lower Mississippi HUC-4 basin, Tickfaw River HUC-8 Basin

According to the CHAT output for the simulated future mean for both regions, annual-maximum temperature is predicted to trend upwards through year 2100. Simulated future streamflow and annual-maximum 1-day precipitation for both regions fluctuate mildly over time. Neither streamflow nor precipitation are predicted to trend higher at the same rate as annual-maximum temperatures through the year 2100. For both the Lower Mississippi region, HUC-8 Basin Tangipahoa River and the Lower Mississippi region, HUC-8 Basin Tickfaw River, the annual maximum temperature is simulated to reach between 96°F and 110°F by the year 2100.

For the selected project baseline year of 2033, temperatures are predicted to have a future simulated range of 66.05°F-71.39°F and 66.37°F-71.72°F for the Lower Mississippi Tangipahoa and Tickfaw HUC-8 regions, respectively. For the selected project future year of 2083, temperatures are predicted to be 68.95°F-75.66°F and 69.3°F-75.95°F for the Lower Mississippi Tangipahoa and Tickfaw HUC-8 regions, respectively. The Lower Mississippi, Tangipahoa and Tickfaw HUC-8 basins have a future simulated range in precipitation of 1.53in-6.56in and 1.41in-7.27in in the year 2033, and 1.64in-7.19in and 1.66in-8.16in the year 2083, respectively. The simulated future mean annual-maximum monthly streamflow for the Tangipahoa HUC-8 region is 4,407 cfs for year 2033 and 4,362 cfs for year 2083. The simulated future mean annual-maximum monthly streamflow for the Tickfaw HUC-8 region is 4,030 cfs for year 2033, and 3,989 cfs for year 2083.

1.6 VULNERABILITY ASSESSMENT (VA) TOOL

The USACE VA tool provides a nationwide, screening-level assessment of climate change vulnerability relating to the USACE mission, operations, programs, and projects. A weighted order weighted average (WOWA) method is used to combine vulnerability indicators and their associated data sets into a vulnerability score for each HUC4 watershed, the WOWA score. The WOWA score combines indicators using a weighting technique to control how much an indicator with a small value can average out an indicator with a large value, thereby affecting perceived vulnerability.

For the TPFS, the MVD HUC-4 watersheds of interest include the Lower Mississippi Basin HUC4-0807.

VA tool assesses three areas of interest: (1) Flood Risk Reduction, (2) Ecosystem Restoration, and (3) Emergency Management. The results for each area of interest are described below for 2050 and 2080 projections and wet or dry projected trends. Projections with total runoff values above the median value for the set are grouped as "wet" and ones with total runoff values below the median as "dry". In general, a lower WOWA score indicates a basin is less vulnerable, and a larger WOWA score indicates a basin is more vulnerable.

1.6.1 Flood Risk Reduction

Figure I: 1-12 depicts the VA tool’s summary of WOWA results for the flood risk reduction business line for HUC-0807. WOWA scores for the Lower Mississippi HUC-0807 projections are dry 2050-46.59, wet 2050-50.93, dry 2085-46.66, and wet 2085-51.44. The Lower Mississippi HUC-0807 Basin is not identified as vulnerable under Flood Risk Reduction for any of the analyzed projections.

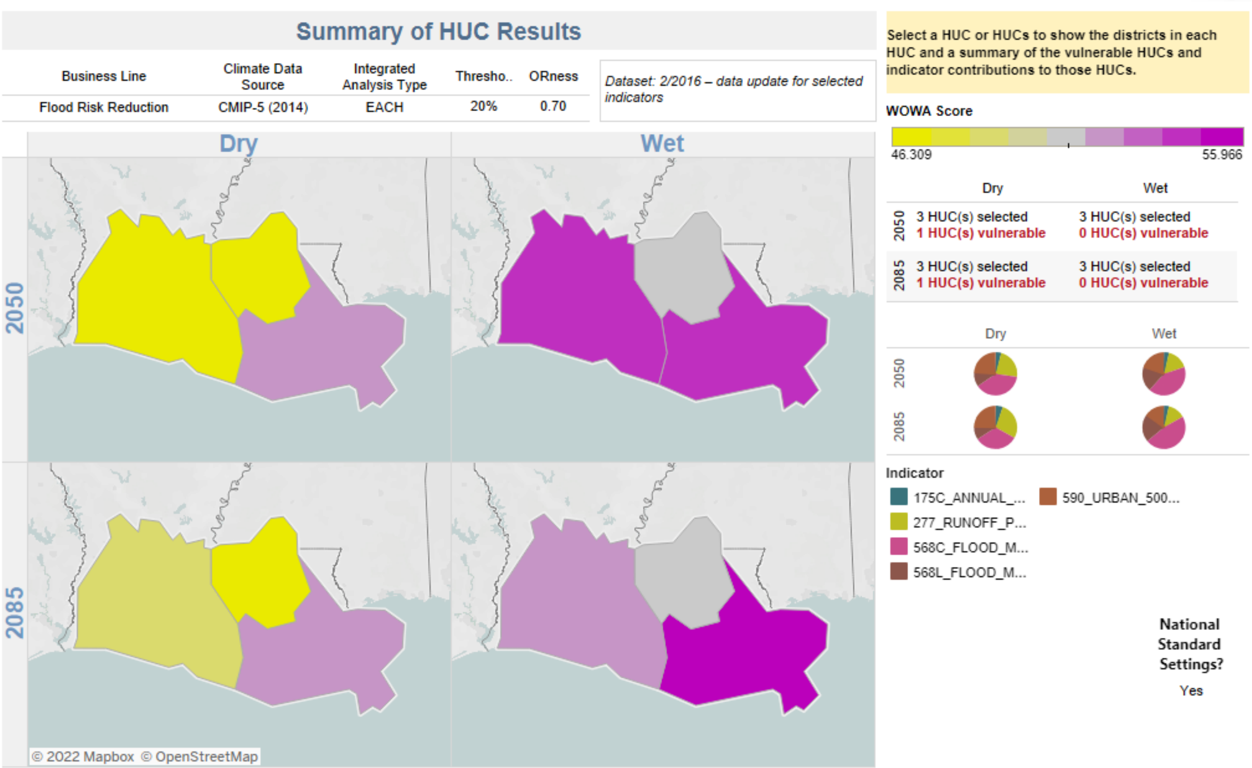


Figure I: 1-12. Lower Mississippi HUC-0807 summary for flood risk reduction

1.6.2 Ecosystem Restoration

Figure 3 depicts the VA tool's summary of WOWA results for the ecosystem restoration business line of HUC-0807. WOWA scores for the Lower Mississippi HUC-0807 projections are dry 2050-69.52, wet 2050-70.01, dry 2085-69.20, and wet 2085-70.52. The Lower Mississippi HUC-0807 Basin is not identified as vulnerable under Flood Risk Reduction for any of the analyzed projections.

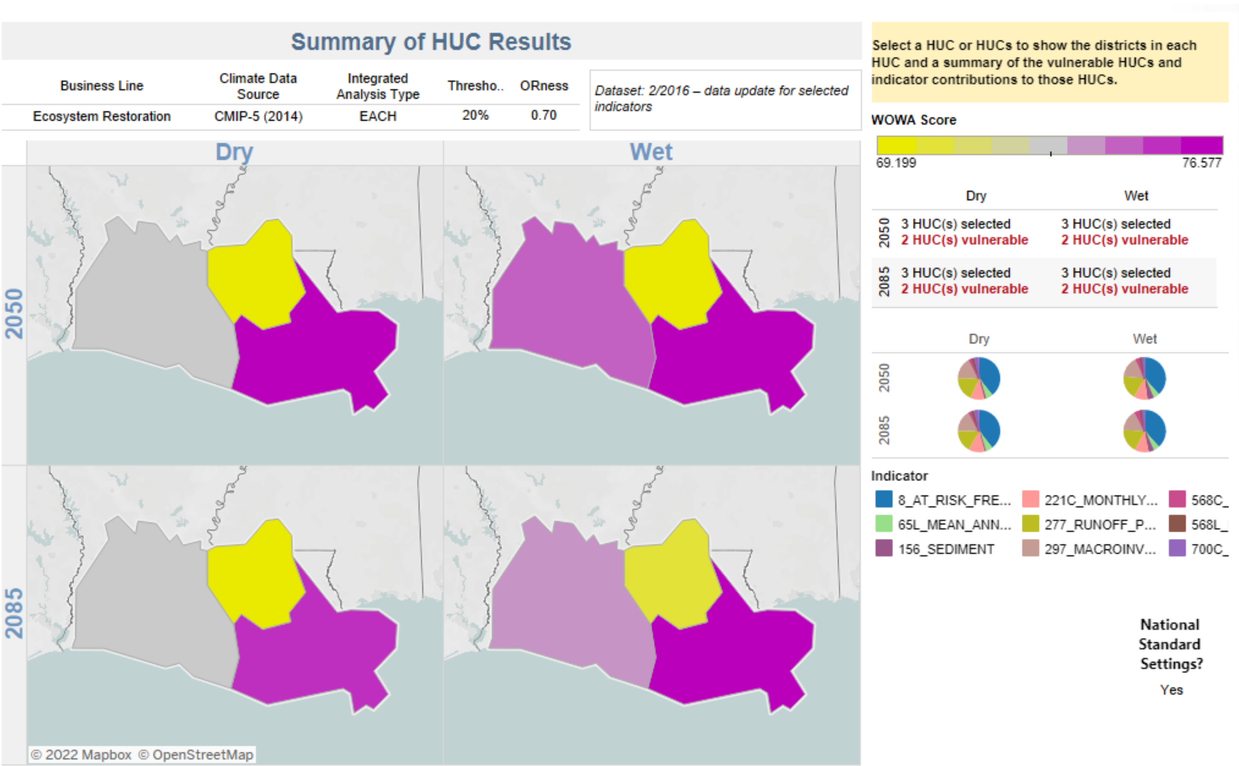


Figure I: 1-13. Lower Mississippi HUC-0807 summary for ecosystem restoration

1.6.3 Emergency Management

Figure *I:* 1-4 depicts the VA tool's summary of WOWA results for the emergency management business line of HUC-0807. WOWA scores for the Lower Mississippi HUC-0807 projections are dry 2050-67.70, wet 2050-65.81, dry 2085-69.79, and wet 2085-66.81. The Lower Mississippi HUC-0807 Basin is not identified as vulnerable under emergency management for the any of the analyzed projections.

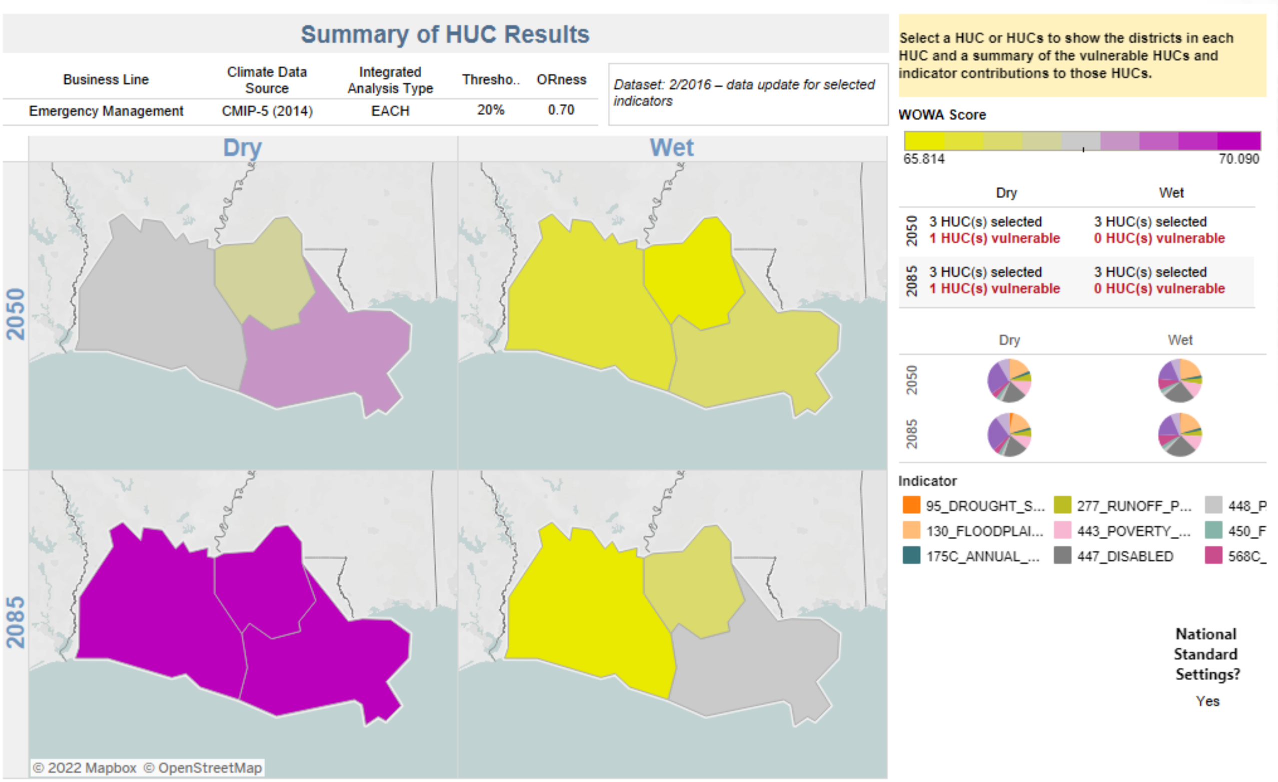


Figure I: 1-14. Lower Mississippi HUC-0809 summary for emergency management.

1.7 SUMMARY

Based on the guidance from USACE and data from the available tools, the TPFS can identify climate change risks based on specific project features. Table I: 1-1 summarizes how a specific project feature in the focused array of alternatives may be triggered by a climate change variable, which then produces a hazardous and harmful impact to the community.

Table I: 1-1. Climate Risks Features and Outcomes

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood
Levee	Increased precipitation from larger, slower-moving storms Increased likelihood of tropical storm events Increased likelihood of larger storm surge elevations during tropical storm events Land subsidence	Future flood volumes may be larger than present Large flood volumes may occur more frequently Extent and duration of coastal inundation may be greater than present Land loss rates in southern Louisiana may increase	Flood waters (caused by riverine flooding and surge) may load the levee for longer durations, and more frequently, potentially compromising integrity of the flood control feature With increasing land loss rates and coastlines receding, location of the flood control feature may be more exposed to coastal surge and wave events	High Likelihood
Road Raise	Increased precipitation from larger, slower-moving storms Increased frequency of hurricanes and tropical storms	Future flood volumes and durations may be larger than present Increased likelihood of tropical storm events	Designed roadway elevation be sufficient to accommodate increased volumetric runoff caused by larger precipitation event; this may in turn cause increased flooding to the road	Likely
Channel Clearing and Snagging	Increased likelihood of tropical storm events Land subsidence	Surge may travel further inland as land loss rates in southern Louisiana increase	With increasing land loss rates and coastlines receding, surge may travel further inland and impact the proposed cleared and snagged channel; a cleared and snagged channel may support sustaining surge height because surge and wave energy will not be dampened by the once present vegetative growth	Low Likelihood
Nonstructural Plan	Increased precipitation from larger, slower-moving storms Increased riverine flooding caused by upstream watersheds	Future flood volumes may be larger than present Large flood volumes may occur more frequently	With increased flood volumes and higher frequency of larger floods, current day projections of the necessary height to raise structures to combat these more frequent and larger storms may not be adequate	Likely

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood
	Increased likelihood of larger storm surge elevations during tropical storm events Land Subsidence	Extent and duration of coastal inundation may be greater than present Land loss rates in southern Louisiana may increase	With increasing land loss rates and coastlines receding, surge may travel further inland and impact structures further inland not initially identified in the Non-Structural Plan	

It should be noted two features in Table I: 1-1, which summarizes the climate risk features and outcomes, will warrant an adaptive management (AM) plan to be formulated during PED. These features have been designated a High Likelihood qualitative rating and include the levee and floodwall features encompassed in this study. With an AM plan in place, the uncertainty of how these project features will perform following construction regarding climate resiliency can be reduced.

1.8 CONCLUSION

The study seeks to improve flood risk in the parish. However, based on climate shifts, aspects of the study area are at risk of experiencing climate change impacts. USACE requires projects to evaluate and consider climate change impacts early in the project development process. The information gathered in this assessment produced a summary of climate risk identifiers that may be impacted by climate change to varying degrees, thus impacting communities.

SECTION 2

References and Resources

Project References:

Louisiana's Comprehensive Master Plan for a Sustainable Coast; Louisiana Coastal Protection and Restoration Authority (2017). https://coastal.la.gov/our-plan/2017-coastal-master-plan/

Sea Level Calculator for Non-NOAA Long-Term Tide Gauges Version 2020.88; USACE (2020). https://cwbi-app.sec.usace.army.mil/rccslc/slcc_nn_calc.html

Software:

Hydrologic Engineering Center – Hydrologic Modeling Software (HEC-HMS) 4.11

Hydrologic Engineering Center – River Analysis System (HEC-RAS) 6.3.1

Advanced Circulation (ADCIRC) Model

SECTION 3
List of Acronyms and Abbreviations

USACE	United States Army Corps of Engineers
ER	Engineer Regulations
RSL	Relative Sea Level
TPFS	Tangipahoa Parish Feasibility Study
SLR	Sea Level Rise
ECB	Engineering and Construction Bulletin
FRM	Flood Risk Management
CSRM	Coastal Storm Risk Management
USGS	United States Geological Survey
VA	Vulnerability Assessment
HUC	Hydrologic Unit Code
CHAT	Climate Hydrology Assessment Tool
TST	Time Series Toolbox
NCA	National Climate Assessment
CWTS	Civil Works Technical Report
NOAA	National Oceanic and Atmospheric Administration
USGCRP	United States Global Change Research Program
GCMs	Global Climate Models
RCPs	Representative Concentration Pathways
NRC	National Research Council
IPCC	Intergovernmental Panel on Climate Change
NSDs	Nonstationarity Detections
WOWA	Weighted Order Weighted Average
cfs	Cubic Feet per Second
MVD	Mississippi Valley Division
AM	Adaptive Management
PED	Pre-Construction Engineering and Design