Mississippi Valley Division
Regional Planning and Environmental Division South

St. Tammany Parish, Louisiana Feasibility Study

Appendix E– Hydrologic & Hydraulics

December 2023

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Section 1
General Description of Work

The U.S. Army Corps of Engineers (USACE), Mississippi Valley Division (MVD), New Orleans District (MVN), Hydrology, Hydraulics, and Coastal Engineering Branch (HH&C) performed hydrologic and hydraulic modeling for the St. Tammany Parish, Louisiana Feasibility Study (study). The purpose of this hydrologic and hydraulic modeling effort is to evaluate various design alternatives for flood risk management (FRM) and coastal storm risk management (CSRM) within the 1,124 square miles of St. Tammany Parish.

Riverine modeling was performed for the 2, 5, 10, 25, 50, 100, 200, and 500-year rainfall events for existing conditions and with-project base (year 2032) and future conditions (year 2082). Coastal storm surge and wave modeling was completed for the without-project condition and statistical analysis determined the 10, 20, 50, 100, 200, 500, 1000-year base (year 2032) and future conditions (year 2082). Water surface elevation (WSE) results for each frequency were extracted and provided to the project delivery team (PDT) for use in economic, environmental, and engineering analyses. With-project model runs and analyses were performed for the structural FRM measures. Analysis of with-project benefits and impacts was completed for the structural CSRM measures.

The Final Array of alternatives includes the no action alternative (Alternative 1), a nonstructural alternative (Alternative 2), and six structural alternatives (numbered Alternatives 4 through 9), for a total of eight alternatives and 26 measures evaluated for both FRM and CSRM structural projects (see Table E:1-1 for a summary of the structural measures in the Final Array of alternatives that underwent hydrologic and hydraulic modeling and analysis). (Note: There is no Alternative 3 as it was screened out earlier in the planning process and is not contained in the Final Array of alternatives.) Many of the proposed measures have no influence on other measures, making them independent or “separable and combinable” in planning terminology. The alternatives may be more clearly understood as regions of potential projects. FRM alternative analysis was completed through Hydrologic Engineering Center-River Analysis System (HEC-RAS) modeling. CSRM alternative analysis was completed through estimation of storm surge water level changes. With-project analyses are in Section 6 of this appendix.

Table E:1-1. Summary of Final Array Structural Alternatives Evaluated Prior to Tentatively Selected Plan (TSP) Milestone

	Alternative Name	Measure	Project Type
Alternative 4	Lacombe	4a Lacombe Levee	CSRM
		4a.1 Lacombe Levee Short	CSRM
		4.b Lacombe Levee Combined with West Slidell Levee	CSRM
Alternative 5	Bayou Liberty/ Bayou Vincent/ Bayou Bonfouca	Bayou Liberty Channel Improvements	FRM
		Bayou Patassat Channel Improvements	FRM
		Bayou Bonfouca Detention Pond	FRM
Alternative 6	South Slidell Storm Surge	Eden Isle Levee	CSRM
		Slidell Levee	CSRM
Alternative 7	Eastern Slidell	Doubloon Bayou Channel Improvements	FRM
		Poor Boy Canal Channel Improvements	FRM
		Pearl River Levee	FRM
		Gum Bayou Diversion	FRM
Alternative 8	Upper Tchefuncte/Covington	Mile Branch Channel Improvements	FRM
		Mile Branch Lateral A Channel Improvements	FRM
Alternative 9	Mandeville Lakefront	Mandeville Seawall Replacement	CSRM
		Ravine aux Coquilles Passive Barrier	CSRM
		Little Bayou Castine Passive Barrier	CSRM
		Pump Stations	CSRM

Section 2
Software and Model Development

2.1 HYDRAULIC ENGINEERING CENTER-HYDROLOGIC MODELING SYSTEM 4.4.1

The latest version of the USACE HEC-Hydrologic Modeling System (HMS) available at the time of model development was used for the hydrologic modeling. The Southeast Louisiana Master Model (SLaMM) HEC-HMS model, developed by MVN' s HH&C branch, was used as a starting point for application on the study. The existing model domain of the SLaMM was trimmed down to the extents of St. Tammany Parish. Further discussion on the HEC-HMS model used for this study may be found in Section 3.3 of this appendix.

2.2 HEC-RAS 5.0.7

The HEC- RAS modeling took place in the spring of 2020. The model used the SLaMM as a starting point, which was developed by MVN's HH&C branch. The model was trimmed down to only include hydraulic subbasins within St. Tammany Parish. In addition to the SLaMM, various other hydraulic models were used during model development to create one single HEC-RAS model. For the model domain, elements from MVN's SLaMM, a separate model focused on the Tchefuncte River Basin, and USACE Vicksburg District's (MVK's) Pearl River model were combined into a single model domain. St. Tammany Parish officials also provided the PDT with various HEC-RAS models developed for waterways and previous studies that took place in the parish. Elements from two models provided to the PDT by the parish were used in this study for stream bathymetry. Further discussion on the HEC-RAS model used for this study is presented in Section 4 of this appendix.

2.3 ADVANCED CIRCULATION (ADCIRC) MODEL

Coastal models ADCIRC+ Simulating WAves Nearshore (SWAN) were used to simulate storm surge and waves, respectively. Results from the 2017 Coastal Protection and Restoration Authority (CPRA) ADCIRC+SWAN study (Roberts and Cobell, 2017) were used for the study. No ADCIRC model runs were completed specifically for this study. MVN's HH&C branch completed a statistical analysis on results generated for current and future conditions from a suite of storm simulations that were previously run for the study area.

Section 3

Hydrology, Climate Change, and Storm Surge

St. Tammany Parish is comprised of 10 major watersheds, which include the Pearl River, Gum Bayou, W-14/W-15 basin, Bayou Bonfouca, Bayou Lacombe, Bayou Cane, Bayou Castine, Little Bayou Castine, Bayou Chinchuba and the Tchefuncte River. Figure E:3-1 depicts these 10 major watersheds. The study area experiences flood risk from three primary sources: coastal storm surge and waves, local rainfall on and around the study area, and the Pearl River basin that outlets to the Gulf of Mexico along the eastern boundary of St. Tammany Parish. Assessment of the parish waterways and drainage basins began with review of various flood studies performed for the St. Tammany Parish Government dating from 1986 to present-day. Following the analysis of existing documentation from previous studies, the PDT was able to accurately assess the hydrology and hydraulics of the study area.

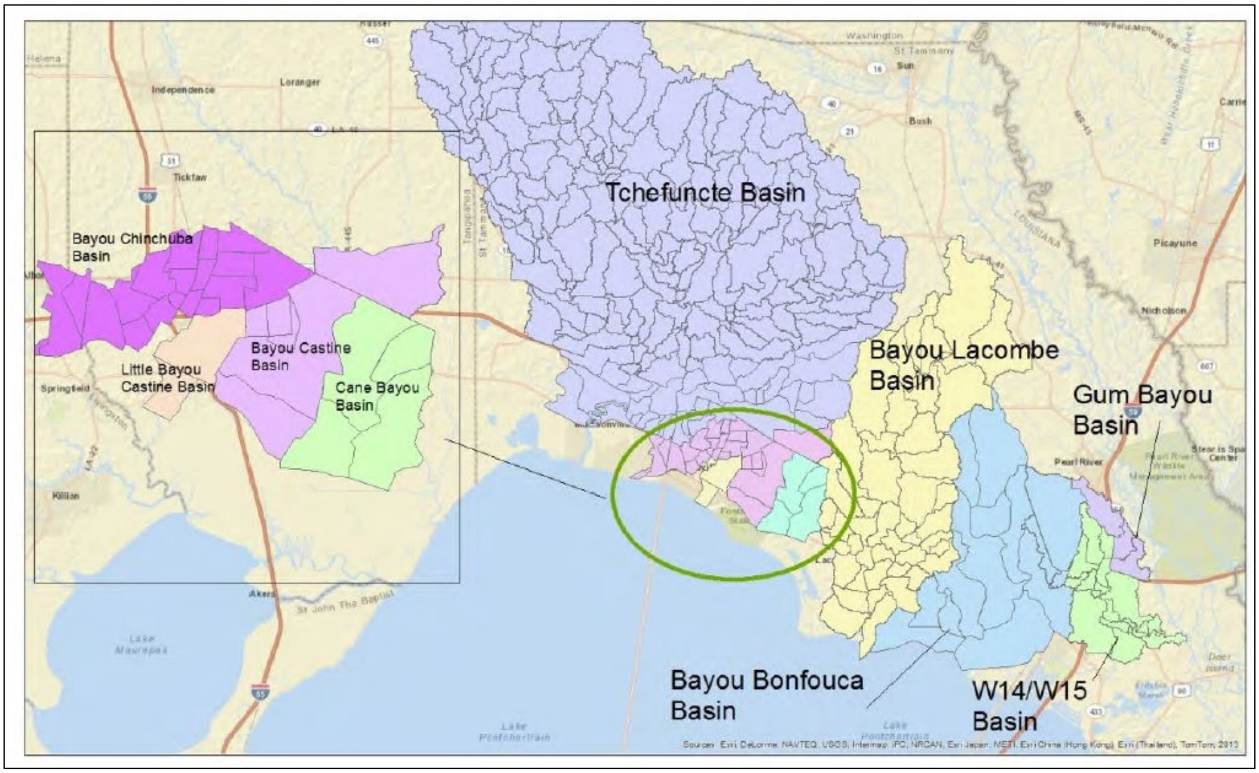


Figure E:3-1. CPRA St. Tammany Parish Watershed Study Drainage Basin Map

3.1 BASIN HYDROLOGY

As noted previously, St. Tammany Parish consists of 10 major watersheds. Hydrologic unit codes (HUC) 12 basins were chosen for hydrologic analysis for a more detailed analysis of the hydrology in the study area. The St. Tammany Parish boundary extents cover 30 HUC 12 basins. A comprehensive list is provided in Table E:3-1. and Figure E:3-2.

Table E:3-1. List of St. Tammany Parish HUC-12 Basins

St. Tammany Parish HUC-12 Basins	
1	Bull Branch-Tchefuncte River
2	Upper Bogue Falaya River
3	Berrys Creek-Bogue Chitto
4	Talleys Creek-Bogue Chitto
5	Pearl River Canal - Pearl River
6	Savannah Branch-Tchefuncte River
7	Simalusa Creek
8	Little Bogue Falaya River
9	Talisheek Creek
10	Wilson Slough-Pearl River
11	Bedico Creek
12	Soap and Tallow Branch-Tchefuncte River
13	Lower Bogue Falaya River
14	Black River
15	Ponchitalawa Creek-Tchefuncte River
16	Abita River
17	Bayou Chinchuba
18	Bayou Castine-Cane Bayou
19	English Branch
20	West Pearl River- Pearl River
21	Lacombe Bayou
22	Old Channel-Pearl River
23	Big Branch Bayou-Lacombe Bayou
24	Liberty Bayou-Bayou Bonfouca
25	Middle River-Pearl River
26	Pearlington-Pearl River
27	Salt Bayou
28	Rigolets-Pearl River
29	Lake Pontchartrain
30	Second Alligator Branch-Pearl River

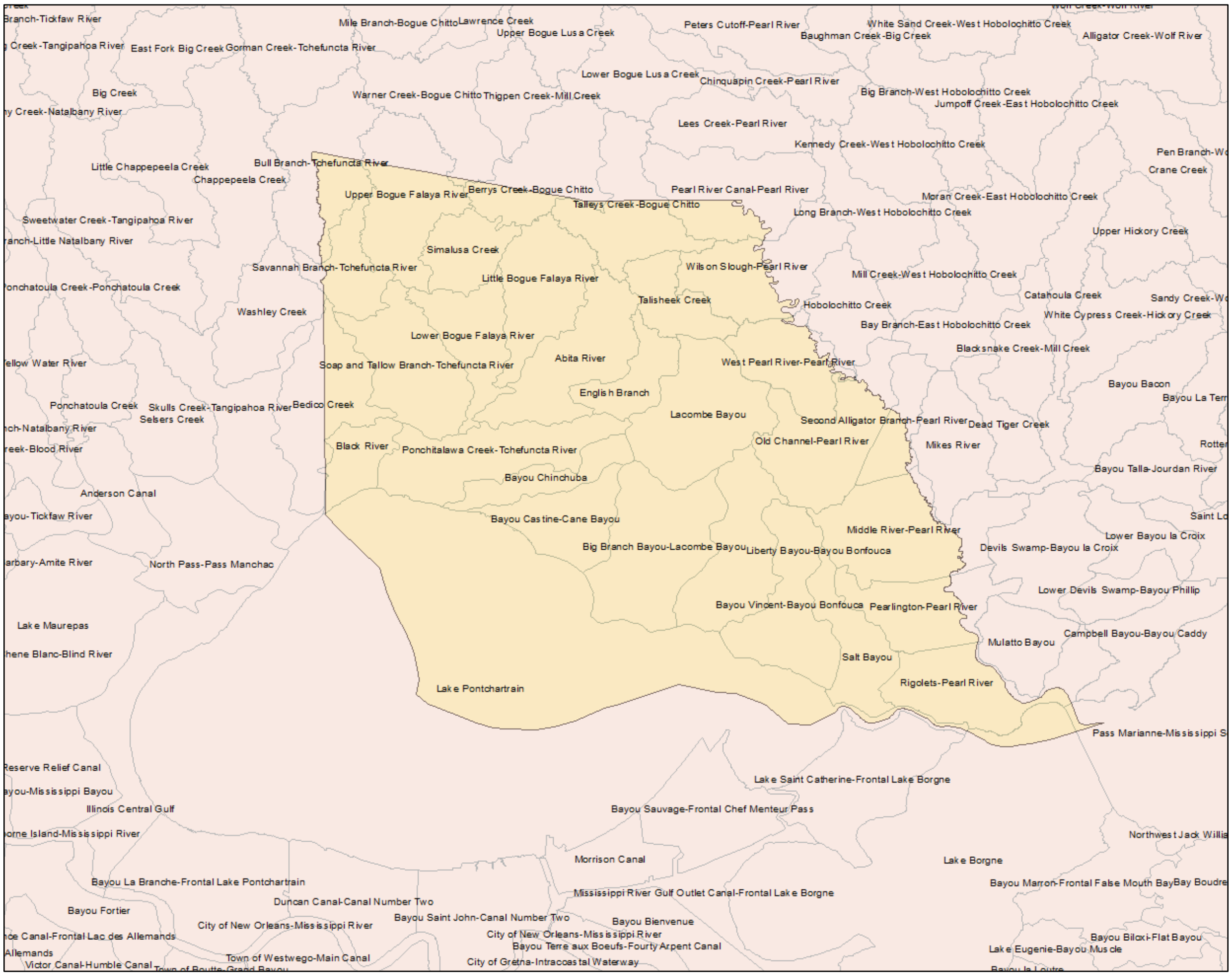


Figure E:3-2. St. Tammany Parish HUC 12 Basins

3.2 PRECIPITATION AND RUNOFF

Eight precipitation events were evaluated: the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year, and 500-year recurrence interval 24-hour duration events. Frequency storm precipitation hyetographs were developed for each of those events, based on rainfall intensities from the National Oceanic and Atmospheric Administration’s (NOAA) Atlas 14 Volume 9 Point Precipitation Frequency Estimates. Figure E:3-3 and Figure E:3-4 depict NOAA Atlas 14 Precipitation frequency depth-duration and depth-frequency, respectively. Annual Maximum Series data was used for a site near the center of St. Tammany Parish. Aerial reduction was applied using the TP-40 method.

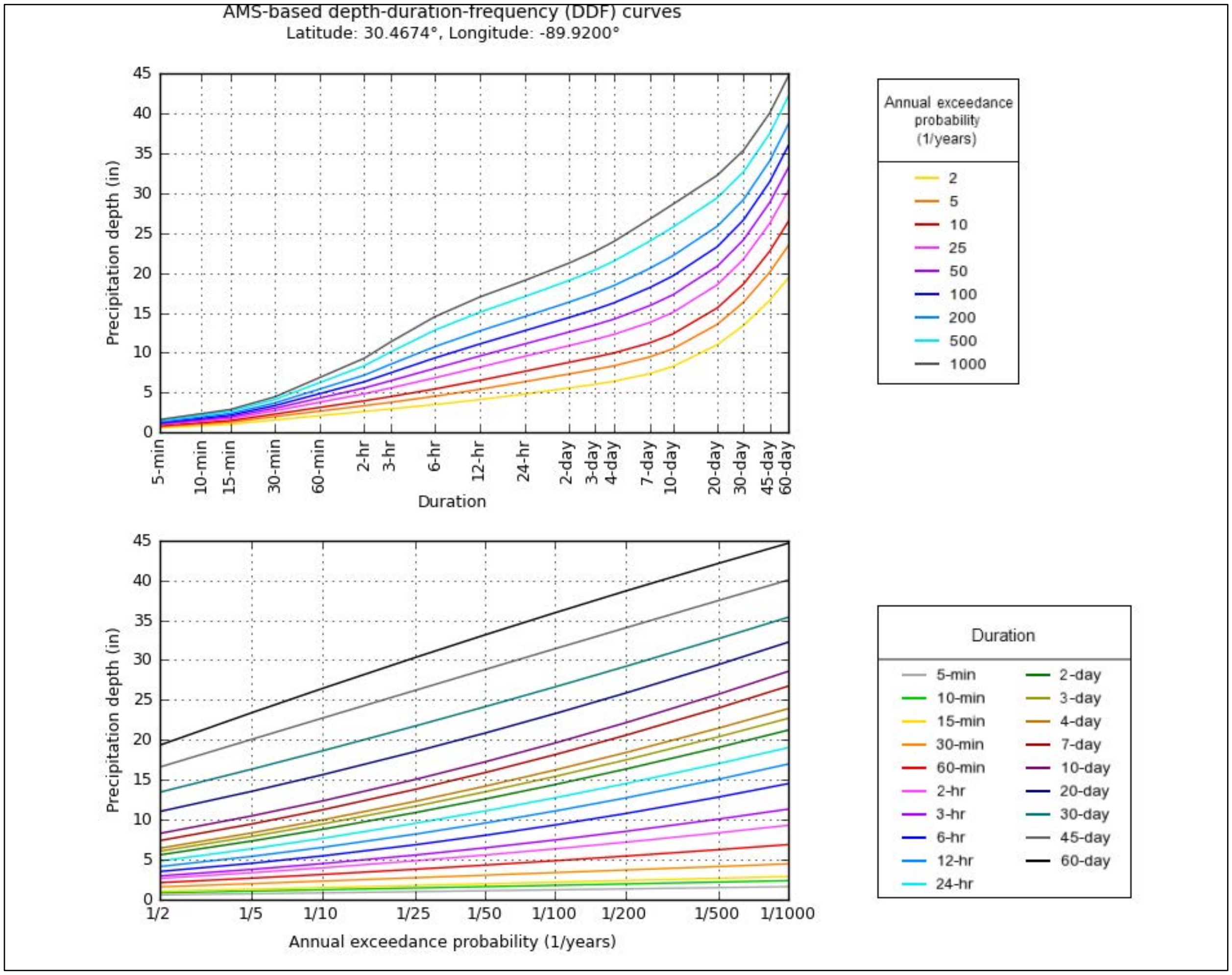
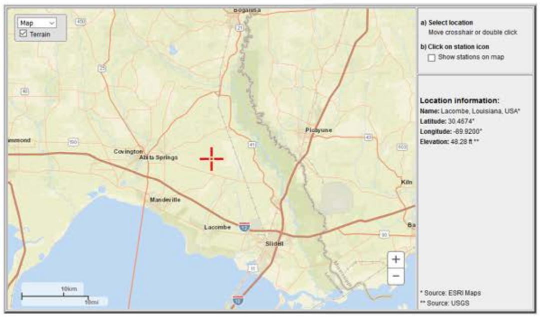


Figure E:3-3. NOAA Atlas 14 Precipitation Data by Annual Exceedance and Duration



AMS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Annual exceedance probability (1/years)								
	1/2	1/5	1/10	1/25	1/50	1/100	1/200	1/500	1/1000
5-min	**0.584** (0.471-0.721)	**0.729** (0.587-0.902)	**0.841** (0.673-1.04)	**0.991** (0.769-1.25)	**1.11** (0.841-1.42)	**1.22** (0.901-1.59)	**1.34** (0.953-1.78)	**1.50** (1.03-2.03)	**1.62** (1.09-2.22)
10-min	**0.855** (0.690-1.06)	**1.07** (0.859-1.32)	**1.23** (0.985-1.53)	**1.45** (1.13-1.84)	**1.62** (1.23-2.07)	**1.79** (1.32-2.33)	**1.96** (1.40-2.60)	**2.19** (1.51-2.97)	**2.37** (1.59-3.24)
15-min	**1.04** (0.841-1.29)	**1.30** (1.05-1.61)	**1.50** (1.20-1.86)	**1.77** (1.37-2.24)	**1.97** (1.50-2.53)	**2.18** (1.61-2.84)	**2.39** (1.70-3.18)	**2.67** (1.84-3.62)	**2.89** (1.94-3.96)
30-min	**1.59** (1.28-1.96)	**2.00** (1.61-2.47)	**2.31** (1.85-2.87)	**2.73** (2.12-3.46)	**3.06** (2.32-3.91)	**3.38** (2.49-4.40)	**3.70** (2.63-4.92)	**4.14** (2.84-5.60)	**4.47** (3.00-6.12)
60-min	**2.12** (1.71-2.61)	**2.68** (2.16-3.32)	**3.14** (2.52-3.90)	**3.79** (2.96-4.84)	**4.32** (3.30-5.56)	**4.87** (3.60-6.37)	**5.44** (3.88-7.27)	**6.25** (4.30-8.50)	**6.89** (4.62-9.43)
2-hr	**2.65** (2.15-3.24)	**3.37** (2.73-4.13)	**3.97** (3.20-4.89)	**4.85** (3.83-6.18)	**5.58** (4.30-7.16)	**6.36** (4.74-8.29)	**7.18** (5.17-9.55)	**8.36** (5.81-11.3)	**9.30** (6.29-12.7)
3-hr	**2.95** (2.41-3.60)	**3.78** (3.07-4.62)	**4.50** (3.64-5.51)	**5.57** (4.43-7.11)	**6.48** (5.02-8.31)	**7.47** (5.61-9.74)	**8.54** (6.18-11.3)	**10.1** (7.04-13.6)	**11.3** (7.69-15.4)
6-hr	**3.51** (2.88-4.25)	**4.55** (3.72-5.51)	**5.46** (4.45-6.65)	**6.86** (5.49-8.71)	**8.05** (6.29-10.3)	**9.35** (7.08-12.1)	**10.8** (7.86-14.2)	**12.8** (9.03-17.3)	**14.5** (9.92-19.6)
12-hr	**4.12** (3.41-4.96)	**5.41** (4.46-6.52)	**6.53** (5.35-7.89)	**8.19** (6.59-10.3)	**9.58** (7.52-12.1)	**11.1** (8.44-14.3)	**12.7** (9.33-16.7)	**15.1** (10.7-20.1)	**17.0** (11.7-22.7)
24-hr	**4.82** (4.01-5.74)	**6.36** (5.28-7.60)	**7.66** (6.32-9.18)	**9.54** (7.70-11.9)	**11.1** (8.75-13.9)	**12.7** (9.75-16.2)	**14.5** (10.7-18.9)	**17.0** (12.1-22.5)	**19.0** (13.2-25.3)
2-day	**5.58** (4.68-6.61)	**7.34** (6.13-8.70)	**8.79** (7.31-10.5)	**10.9** (8.84-13.4)	**12.6** (10.00-15.6)	**14.4** (11.1-18.2)	**16.3** (12.1-21.0)	**19.0** (13.6-25.0)	**21.2** (14.8-28.0)
3-day	**6.05** (5.08-7.13)	**7.91** (6.63-9.34)	**9.45** (7.88-11.2)	**11.7** (9.52-14.3)	**13.5** (10.8-16.7)	**15.4** (11.9-19.4)	**17.5** (13.0-22.4)	**20.4** (14.7-26.7)	**22.7** (15.9-29.9)
4-day	**6.42** (5.41-7.54)	**8.35** (7.02-9.83)	**9.96** (8.33-11.8)	**12.3** (10.1-15.0)	**14.2** (11.4-17.5)	**16.2** (12.6-20.4)	**18.4** (13.8-23.6)	**21.5** (15.5-28.0)	**23.9** (16.8-31.4)
7-day	**7.37** (6.25-8.61)	**9.47** (8.01-11.1)	**11.2** (9.45-13.2)	**13.8** (11.4-16.8)	**15.9** (12.8-19.5)	**18.2** (14.2-22.6)	**20.6** (15.5-26.2)	**24.0** (17.4-31.1)	**26.7** (18.9-34.9)
10-day	**8.27** (7.04-9.61)	**10.5** (8.90-12.2)	**12.3** (10.4-14.4)	**15.0** (12.4-18.2)	**17.2** (13.9-21.0)	**19.6** (15.3-24.4)	**22.1** (16.7-28.1)	**25.7** (18.7-33.2)	**28.6** (20.3-37.2)
20-day	**11.0** (9.44-12.7)	**13.6** (11.6-15.7)	**15.6** (13.3-18.1)	**18.5** (15.4-22.1)	**20.9** (16.9-25.2)	**23.3** (18.3-28.6)	**25.9** (19.6-32.4)	**29.4** (21.5-37.7)	**32.2** (23.0-41.6)
30-day	**13.4** (11.6-15.4)	**16.3** (14.0-18.8)	**18.6** (15.9-21.5)	**21.7** (18.0-25.7)	**24.2** (19.6-28.9)	**26.6** (21.0-32.5)	**29.2** (22.2-36.4)	**32.7** (24.0-41.6)	**35.4** (25.3-45.5)
45-day	**16.6** (14.3-18.9)	**20.1** (17.3-23.0)	**22.7** (19.5-26.1)	**26.2** (21.8-30.7)	**28.8** (23.5-34.2)	**31.4** (24.8-38.0)	**34.0** (25.9-42.1)	**37.5** (27.6-47.3)	**40.0** (28.8-51.3)
60-day	**19.3** (16.7-22.0)	**23.4** (20.2-26.7)	**26.4** (22.7-30.3)	**30.3** (25.2-35.3)	**33.2** (27.1-39.1)	**35.9** (28.4-43.2)	**38.6** (29.5-47.5)	**42.1** (31.0-52.9)	**44.6** (32.2-57.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of annual maxima series (AMS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and annual exceedance probability) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Figure E:3-2. Precipitation Frequency for Lacombe, LA (Central Location of the Parish)

3.3 HYDROLOGIC MODELING

HEC-HMS was used to model the hydrology. A subsection of the SLaMM HEC-HMS model was adapted by removing subbasins that are not included within the parish. Hydrology for frequency storms 2, 5, 10, 25, 50, 100, 200, and 500 years were computed based on subbasin square mileage, canopy and loss calculations, and the model was run for a time period of three days. The SLaMM has been calibrated for the March 2016 rain event, and no additional calibration of the HEC-HMS model was done for the study.

Hydrologic losses, or infiltration, were calculated in the HEC-HMS model using the deficit and constant loss method. The deficit and constant loss method uses a single soil layer to account for continuous changes in moisture content. The deficit is the amount of water required at any point in time to bring the soil layer to saturation. Four parameters must be estimated using the deficit and constant loss method. The first parameter, initial deficit, specifies the amount of available water storage capacity in the soil layer at the beginning of the simulation. An initial deficit of 0.08 inches was used for all subbasins in the model domain. The second parameter, maximum deficit, specifies the maximum amount of water that can be held in the soil layer. A maximum deficit of 2 inches was used for all subbasins. The constant rate defines how quickly water enters the soil while it is saturated and precipitation is occurring. A constant rate of 0.05 inches/hour was used for each subbasin in the model domain. Impervious area was not explicitly defined. Loss and deficit values came from a combination of published resources, including the HEC-HMS user's manual, in conjunction with using best engineering judgement for final selection.

Of the total precipitation depth at each computation interval, HEC-HMS computes the infiltration and runoff (excess precipitation) depth. This excess precipitation variable was used as the input for the local rainfall on the two-dimensional (2D) areas in the HEC-RAS model.

3.4 SEA LEVEL RISE

To evaluate potential future changes in project performance due to relative sea level change (RSLC), Engineer Regulation (ER) 1100-2-8162 requires planning studies and engineering designs to be formulated and evaluated considering all possible rates of RSLC: low, intermediate, and high. The most recent USACE tool for projecting and analyzing the three rates is the Sea Level Analysis Tool (SLAT). Results can be seen in Figure E:3-5. It should be noted the base year used for the Sea-Level Calculator is the designated base year for the project, year 2032. The tool then extends the RSLC scenarios to the 100-year adaptation time horizon, year 2132. After comparing and evaluating the rates determined by the calculator, the PDT determined that the 'intermediate' rate of sea level rise (SLR) should be used in this study for future conditions model runs in the analysis of alternatives. This topic is discussed further in Section 4.4.2.2.

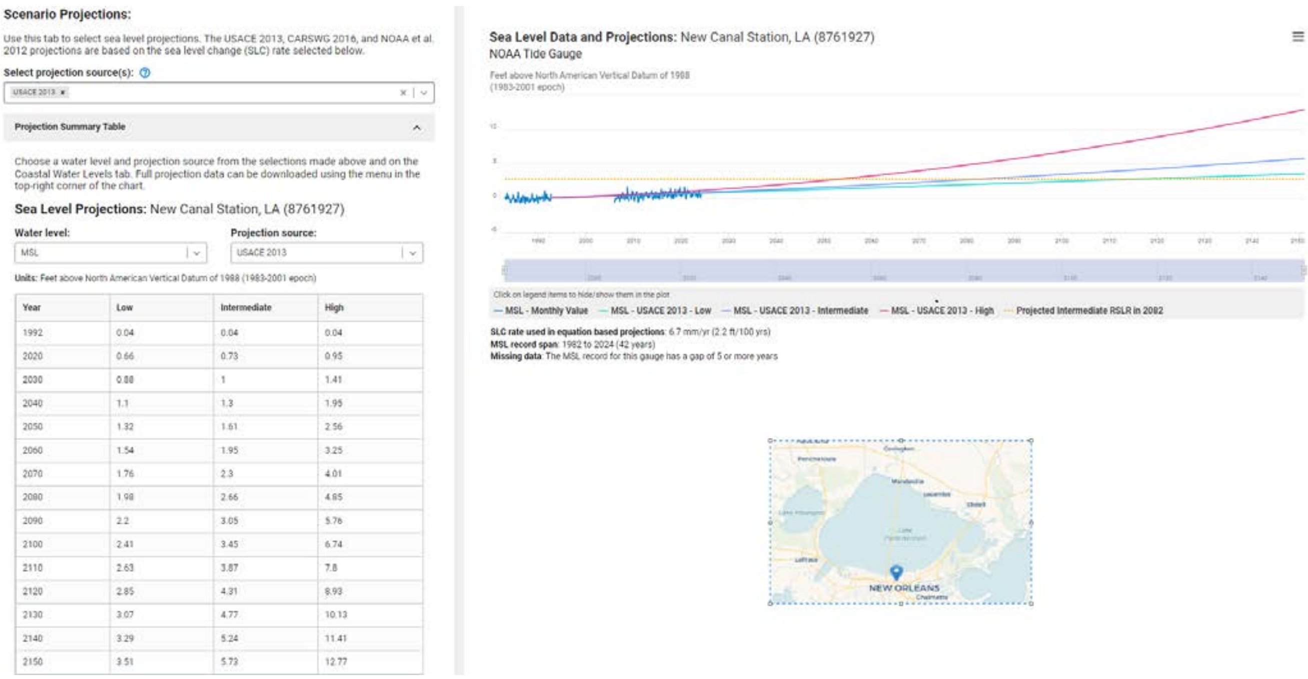


Figure E:3-3. USACE Sea Level Change Curves

Table E3-2 below contains the FWP 1% AEP storm surge still water levels with SLR included at the structural features and segments of the selected plan for this project.

Table E3-2. FWP Still Water Levels with SLR

Segment	Description		2082 Elevation, feet NAVD88	FWP Still Water Level, 1% AEP, ft NAVD88
Western Extension	Additional Western Extension for West Slidell Ring	Levee	17.5	11.4
Western Terminus to Bayou Paquet	West Slidell Ring Levee segment that is located between Western Terminus and the Northwest Tributary of Bayou Paquet	Levee	17.5	11.4
West Doucette Neighborhood Floodwall	350-ft Floodwall going through a group of properties	Floodwall	17.5	11.4
Western Terminus to Bayou Paquet	West Slidell Ring Levee segment that is located between Western Terminus and the Northwest Tributary of Bayou Paquet	Levee	17.5	11.5
Western Terminus to Bayou Paquet @ NW Tributary Sluice Gate	West Slidell Ring Levee segment that is located between Western Terminus and the Northwest Tributary of Bayou Paquet	Levee	17.5	11.5
Bayou Paquet to Bayou Liberty	West Slidell Ring Levee segment that is located between in the Bayou Paquet Watershed, starting at the Bayou Paquet Northwest Tributary and extending south and east to Bayou Liberty	Levee	17.5	11.4
Northside of Bayou Paquet Drive Floodwall	250-ft Floodwall located on north side of Bayou Paquet	Floodwall	16.5	11.4
Bayou Paquet to Bayou Liberty @ Bayou Paquet Road Floodgate #2	West Slidell Ring Levee segment that is located between in the Bayou Paquet Watershed, starting at the Bayou Paquet Northwest Tributary and extending south and east to Bayou Liberty	Levee	17.5	11.3
Bayou Paquet to Bayou Liberty @ Bayou Paquet NE Tributary Sluice Gate	West Slidell Ring Levee segment that is located between in the Bayou Paquet Watershed, starting at the Bayou Paquet Northwest Tributary and extending south and east to Bayou Liberty	Levee	17.5	11.3
Bayou Paquet to Bayou Liberty	West Slidell Ring Levee segment that is located between in the Bayou Paquet Watershed, starting at the Bayou Paquet Northwest Tributary and extending south and east to Bayou Liberty	Levee	17.5	11.3

Bayou Paquet/Mayer Drive Floodwall	1400-ft floodwall between east bank of Bayou Paquet and residences along Mayer Drive	Floodwall	16	11.3
Bayou Paquet to Bayou Liberty @Bayou Liberty	West Slidell Ring Levee segment that is located between in the Bayou Paquet Watershed, starting at the Bayou Paquet Northwest Tributary and extending south and east to Bayou Liberty	Levee	17.5	11.3
Bayou Liberty to Bayou Bonfouca @Bayou Liberty	West Slidell Ring Levee segment that is located between Bayou Liberty Pump Station Complex and Bayou Bonfouca Pump Station Complex	Levee	17.5	11.3
Bayou Liberty to Bayou Bonfouca @Bayou	West Slidell Ring Levee segment that is located between Bayou Liberty Pump Station Complex and Bayou Bonfouca Pump Station Complex	Levee	17.5	11.3
Levee on south bank of Bayou Bonfouca	Redigitized alignment on the south bank of Bayou Bonfouca to fall within the spoil bank easement (300 ft from south bank line)	Levee	17.5	11.3
Levee on south bank of Bayou Bonfouca @Big Branch Marsh NWR	Redigitized alignment on the south bank of Bayou Bonfouca to fall within the spoil bank easement (300 ft from south bank line)	Levee	17.5	11.3
Front Street/Railraod Floodwall	1375 Linear feet of T-WALL along Railroad between Delwood Pump Station and Baptist Church	Floodwall	16.5	11.3
Slidell-Oak Harbor Segment	Slidell Ring Levee in Oak Harbor neighborhood between Delwood Pump Station and 1-10 Cross-over	Levee	17.5	11.9
Slidell-Oak Harbor Segment	Slidell Ring Levee in Oak Harbor neighborhood between Delwood Pump Station and 1-10 Cross-over	Levee	17.5	11.9
Floodwall near Schneider Canal Pump Station	100-foot floodwall at Schneider Canal outflow canal	Floodwall	16.5	11.9
Slidell-Oak Harbor Segment to Mariner's Cove	Slidell Ring Levee in Oak Harbor neighborhood between Delwood Pump Station and 1-10 Cross-over	Levee	17.5	11.5
Mariner's Cove Floodwall and Vehicular Gate	500 Linear feet of floodwall for narrow section of Oak Harbor levee at Mariners Cove Blvd	Floodwall	16.5	11.5

Slidell-Oak Harbor Segment to Oak Harbor Vehicular Gate	Slidell Ring Levee in Oak Harbor neighborhood between Delwood Pump Station and 1-10 Cross-over	Levee	17.5	11.5
Slidell-Oak Harbor Segment to Slidell I-10	Slidell Ring Levee in Oak Harbor neighborhood between Delwood Pump Station and 1-10 Cross-over	Levee	17.5	12.4
Slidell I-10 to Hwy 433	Slidell Ring Levee between the I-10 road ramp and Old Spanish Trail	Levee	18.5	13.3
Slidell-Old Spanish Trail Extension	Slidell Ring Levee short section near Old Spanish Trail	Levee	18.5	13.3
Slidell-Old Spanish Trail Extension @Hwy 433	Slidell Ring Levee short section near Old Spanish Trail	Levee	18.5	13.6
Floodwall behind Esprit du Lac Street	450 Linear feet of T-WALL behind Esprit du Lac Street	Floodwall	18.5	13.6
Slidell I-10 to Hwy 433	Slidell Ring Levee between the I-10 road ramp and Old Spanish Trail	Levee	20	13.6
Slidell-Old Spanish Trail Extension	Slidell Ring Levee short section near Old Spanish Trail	Levee	18.5	13.6
Slidell Hwy 433 to Kings Point	Slidell Ring Levee between Old Spanish Trail and Kings Point Levees	Levee	20	13.6
Kings Point to Hwy 190B	Slidell Ring Levee between Kings Point Levees and Hwy 190B	Levee	20	13.6
Substation Enclosure near Hwy 190B	Slidell Ring expansion to enclose the power substation that is located south of Hwy 190B on the east side of the alignment	Levee	20	13.6
Substation Floodwall (south of Hwy 190B)	1950 Linear feet of floodwall to enclose power substation south of Hwy 190-B on east side of alignment.	Floodwall	18.5	13.6
Hwy 190B Floodwall	430 Linear feet of T-WALL at Hwy 190 Business (East Side)	Floodwall	18.5	13.6
Hwy 190B to Eastern Terminus	Slidell Ring Levee between Hwy 190B floodgate and the TSP Eastern Terminus. This segment includes the Utility Corridor floodwall and the floodwall along Yaupon Drive.	Levee	20	13.4
Utility Corridor Floodwall	3530 Linear feet of floodwall on western edge of utility corridor	Floodwall	18.8	13.4

Holiday Drive to Yaupon Drive Floodwall	3700 Linear feet of floodwall for northeast extension of alignment along utility corridor and along east side of Yaupon Street	Floodwall	18.5	13.4
Eastern Extension	Additional Eastern Extension of Slidell Ring to cross Gause Blvd and tie into high ground at 18.5 feet floodwall and 20 foot levee design (2082).	Levee	20	13.4
Manzella Drive to Gause Blvd	650 Linear feet of floodwall from TSP Eastern Terminus north to Gause Blvd, where alignment switches to short levee and road ramps	Floodwall	18.5	13.4

While the Mandeville gauge is the gauge in Lake Pontchartrain closest to the project area, it is not a NOAA gauge. The New Canal Station gauge, near the south shore of Lake Pontchartrain, is a NOAA gauge, and further analysis of RSLR can be performed on it using USACE Sea Level Analysis Tool (SLAT). The rate of sea level change for the two gauges, for the low SLR scenario, is 6.7 mm/year at New Canal and 6.6 mm/year at Mandeville. Figure E:3-4 shows datums and water levels for the New Canal Gauge.

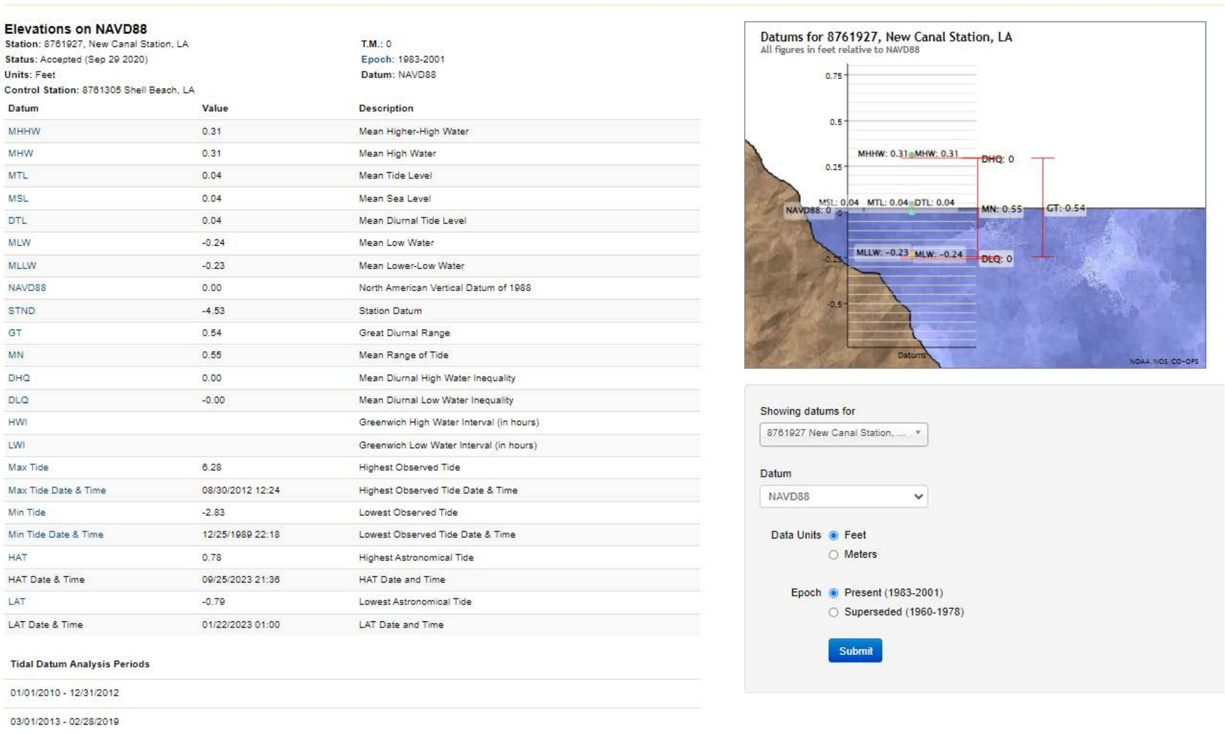


Figure E:3-4. Datums and Water Levels for New Canal Station

The SLAT allows for the plotting of critical thresholds against the SLR curves. Levee heights differ from reach to reach in the system proposed in the RP, as do the still water levels for the 1% AEP storms modeled to analyze coastal flooding risk (see Table E: 3-2). Nevertheless, a general idea of the proposed system can be had by averaging the various levee heights and plotting them against SLR. Figure E: 3-5 also uses the average 2082 1% AEP still water level of 13.2 feet NAVD88, subtracts from it the 2.7 feet of sea level rise that occurs in the Intermediate scenario to obtain a 1992 comparison level of surge of 10.5 feet, and reprojects RSLR from that 10.5 feet forward to 1982.

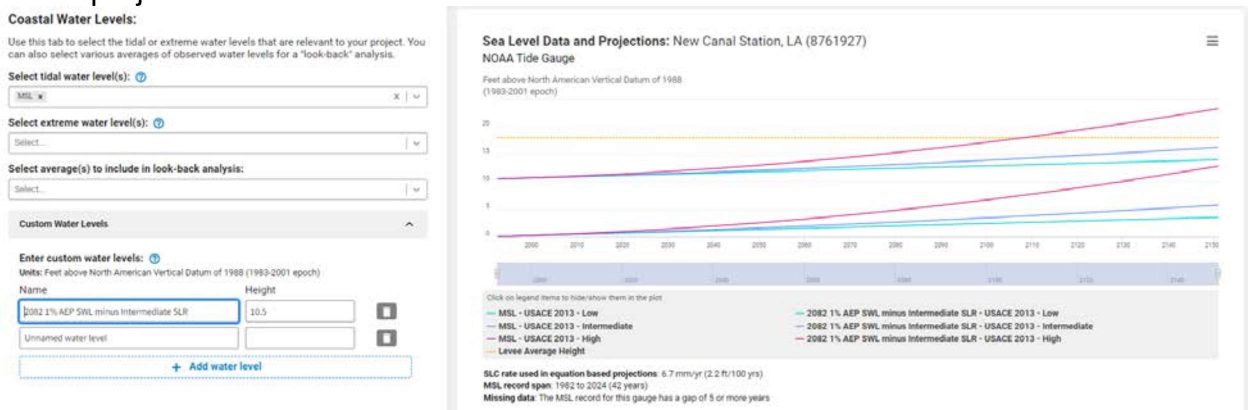


Figure E:3-5. USACE Sea Level Change Curves with Zero = 0 Feet and Zero = 10.5 Feet

The RP depends on the Intermediate SLR scenario, which sees 2.7 feet of SLR projected for 2082. Figure E:3-6 sets this 2.7 feet of rise as a critical threshold in order to assess the temporal performance of the RP against the other two SLR scenarios.

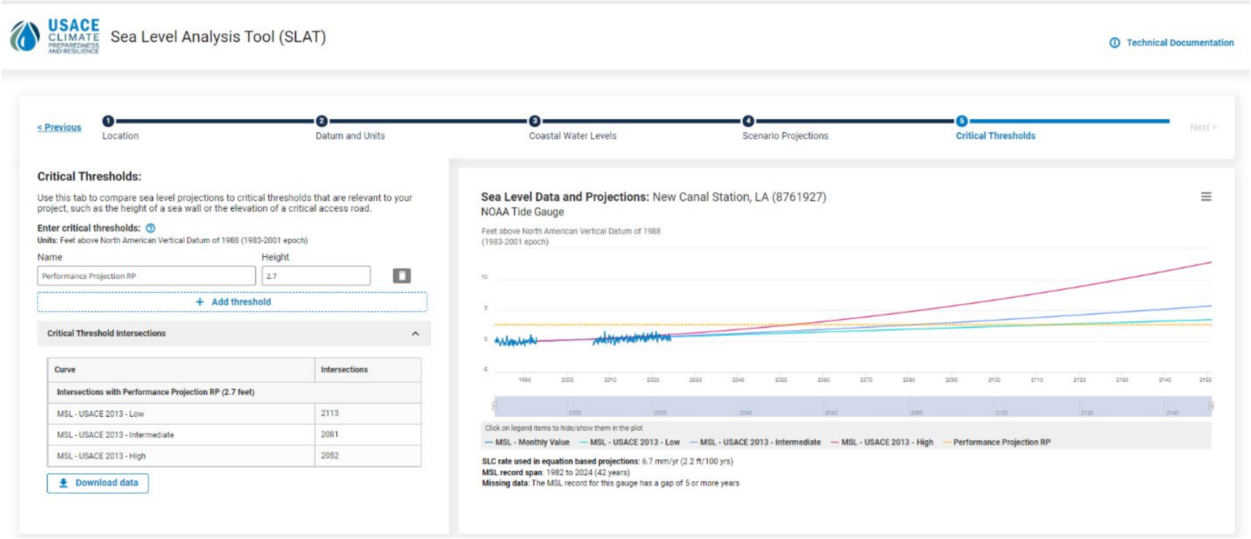


Figure E:3-6. Dates When USACE Sea Level Change Curves Project 2.7 Feet Change

In order to assess the sensitivity of St. Tammany Parish to RSLR, the region was split into four coastal aggregate areas and the mean elevation of the developed land in each aggregate computed. The mean elevation of each aggregate was then used as a critical threshold and compared to the three different SLR scenarios. The results for the Slidell, Madisonville, Mandeville and Lacombe coastal aggregates are below.

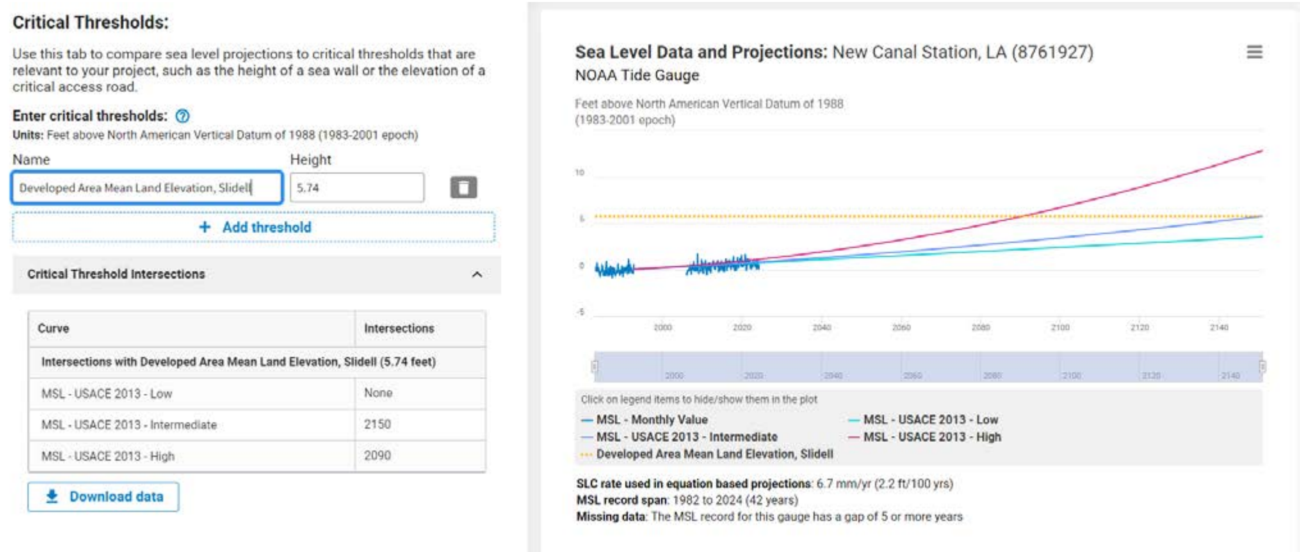


Figure E:3-7. Developed Coastal Slidell Mean Elevation and SLR Projections

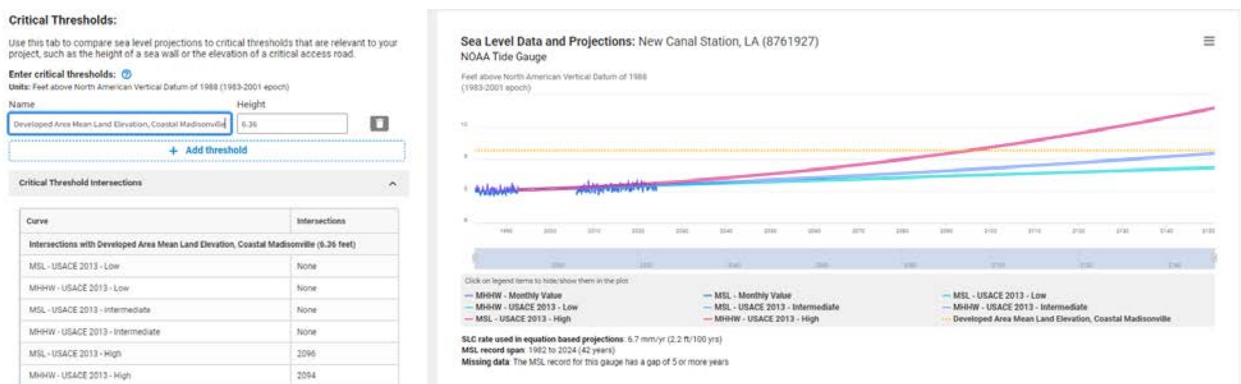


Figure E:3-8. Developed Coastal Madisonville Mean Elevation and SLR Projections

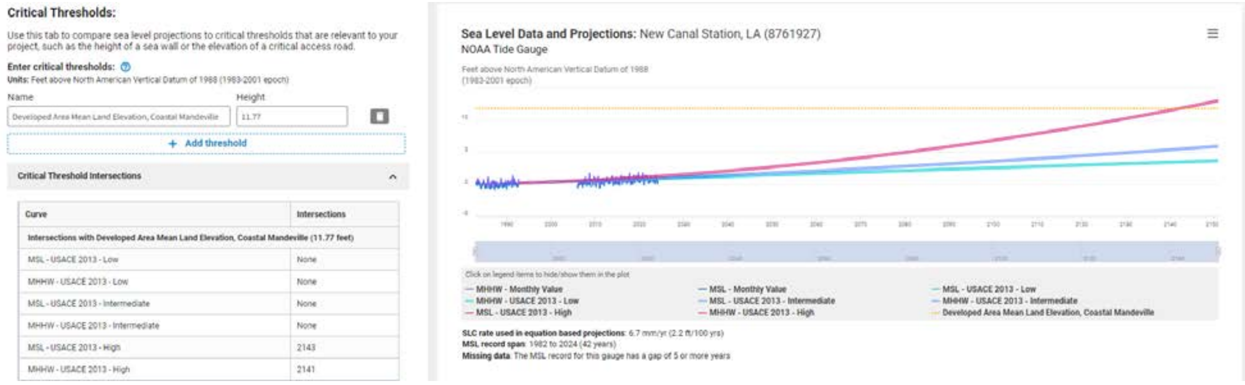


Figure E:3-9. Developed Coastal Mandeville Mean Elevation and SLR Projections

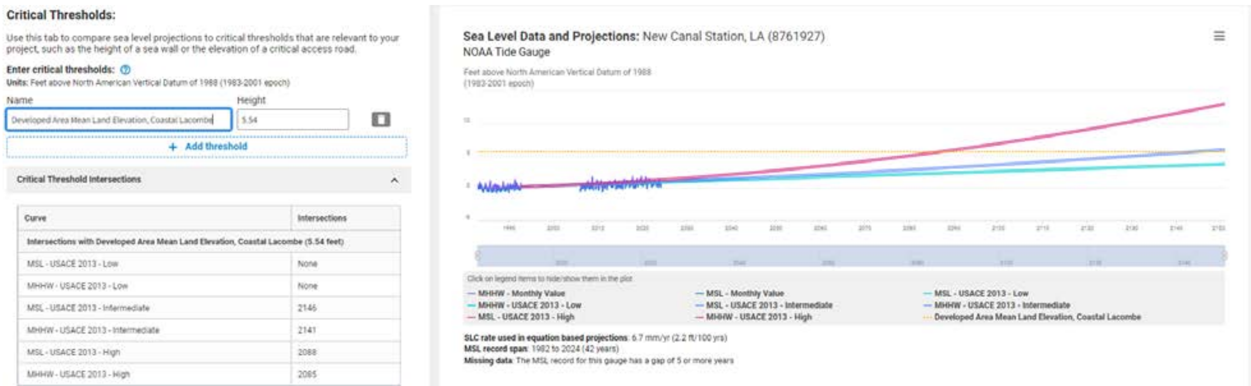
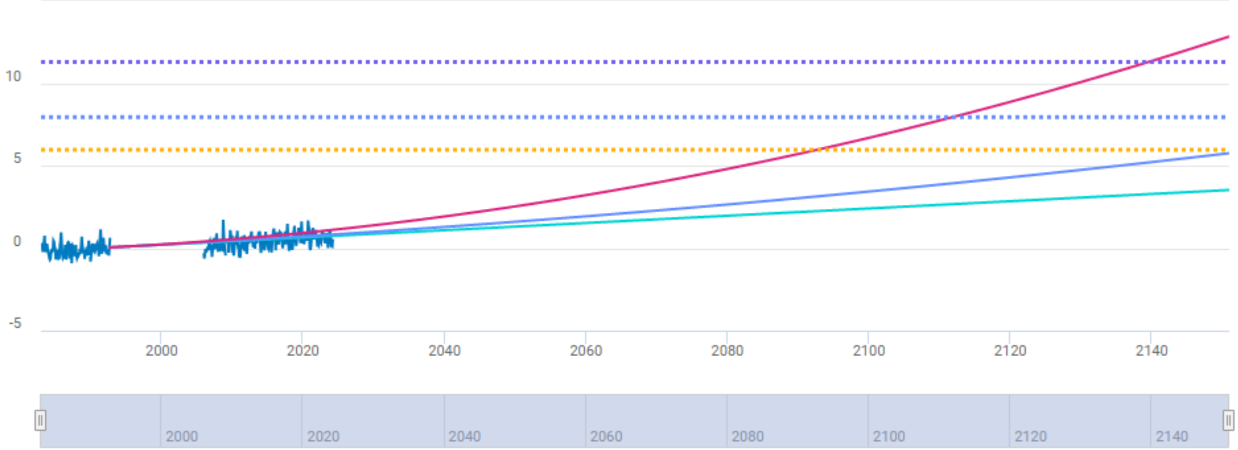


Figure E:3-10. Developed Coastal Lacombe Mean Elevation and SLR Projections

The sensitivity of the transportation infrastructure of each of the four coastal aggregates was also evaluated. Major roadways were converted to points, with at least one point every 1000 feet, and those points assigned an elevation. Critical thresholds were assigned to elevations at which 25%, 50%, and 75% of the roadway points were inundated under high tide in each of the SLR scenarios. The results for each of the four aggregate areas are below.

Sea Level Data and Projections: New Canal Station, LA (8761927)
NOAA Tide Gauge

Feet above North American Vertical Datum of 1988
(1983-2001 epoch)



Click on legend items to hide/show them in the plot

- **MSL - Monthly Value**
- **MSL - USACE 2013 - Low**
- **MSL - USACE 2013 - Intermediate**
- **MSL - USACE 2013 - High**
- **Inundation of 25% Critical Roadways, Slidell**
- **Inundation of 50% Critical Roadways, Slidell**
- **Inundation of 75% Critical Roadways, Slidell**

SLC rate used in equation based projections: 6.7 mm/yr (2.2 ft/100 yrs)
MSL record span: 1982 to 2024 (42 years)
Missing data: The MSL record for this gauge has a gap of 5 or more years

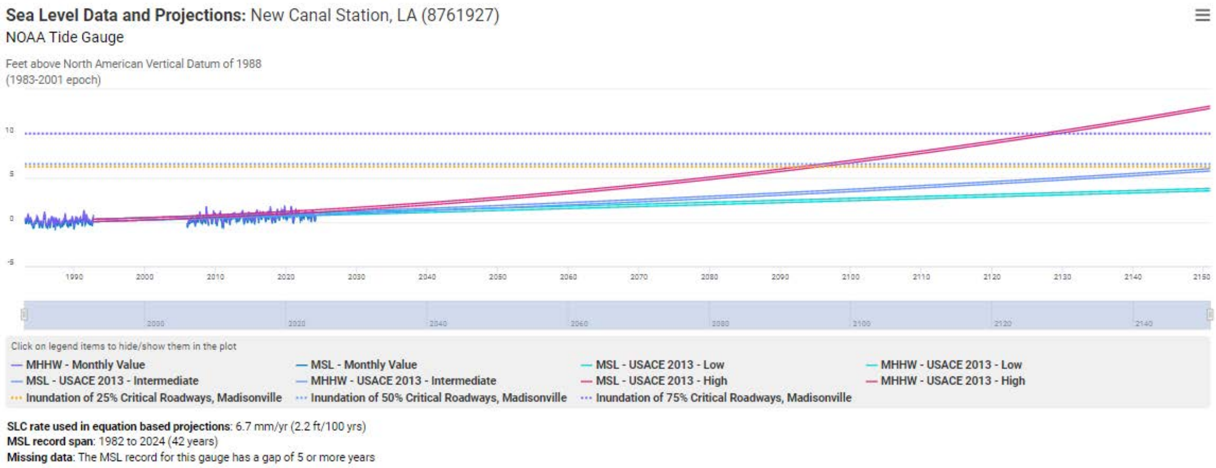
Inundation of 25% Critical Roadways, Slidell	5.97
Inundation of 50% Critical Roadways, Slidell	7.94
Inundation of 75% Critical Roadways, Slidell	11.28

+ Add threshold

Critical Threshold Intersections

Curve	Intersections
Intersections with Inundation of 25% Critical Roadways, Slidell (5.97 feet)	
MSL - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2092
Intersections with Inundation of 50% Critical Roadways, Slidell (7.94 feet)	
MSL - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2111
Intersections with Inundation of 75% Critical Roadways, Slidell (11.28 feet)	
MSL - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2139

Figure E:3-11. Inundation of Madisonville Critical Roadways Under SLR Projections


Sea Level Data and Projections: New Canal Station, LA (8761927)
NOAA Tide Gauge
Feet above North American Vertical Datum of 1988
(1983-2001 epoch)
10
5
0
-5
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
2120
2130
2140
2150
Click on legend items to hide/show them in the plot
MHHW - Monthly Value
MSL - Monthly Value
MSL - USACE 2013 - Low
MHHW - USACE 2013 - Low
MSL - USACE 2013 - Intermediate
MHHW - USACE 2013 - Intermediate
MSL - USACE 2013 - High
MHHW - USACE 2013 - High
Inundation of 25% Critical Roadways, Madisonville
Inundation of 50% Critical Roadways, Madisonville
Inundation of 75% Critical Roadways, Madisonville
SLC rate used in equation based projections: 6.7 mm/yr (2.2 ft/100 yrs)
MSL record span: 1982 to 2024 (42 years)
Missing data: The MSL record for this gauge has a gap of 5 or more years

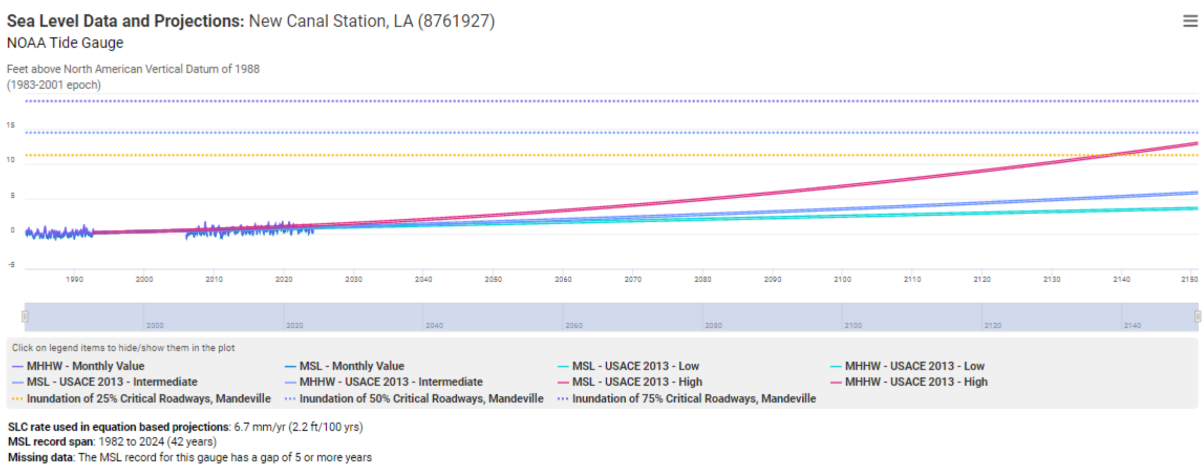
Name	Height
Inundation of 25% Critical Roadways, Madisonville	6.25
Inundation of 50% Critical Roadways, Madisonville	6.53
Inundation of 75% Critical Roadways, Madisonville	10

+ Add threshold

Critical Threshold Intersections

Curve	Intersections
Intersections with Inundation of 25% Critical Roadways, Madisonville (6.25 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2095
MHHW - USACE 2013 - High	2092
Intersections with Inundation of 50% Critical Roadways, Madisonville (6.53 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2098
MHHW - USACE 2013 - High	2095
Intersections with Inundation of 75% Critical Roadways, Madisonville (10 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2129
MHHW - USACE 2013 - High	2127

Figure E:3-12. Inundation of Madisonville Critical Roadways Under SLR Projections


Sea Level Data and Projections: New Canal Station, LA (8761927)
NOAA Tide Gauge
Feet above North American Vertical Datum of 1988
(1983-2001 epoch)
15
10
5
0
-5
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
2120
2130
2140
2150
Click on legend items to hide/show them in the plot
MHHW - Monthly Value
MSL - Monthly Value
MSL - USACE 2013 - Low
MHHW - USACE 2013 - Low
MSL - USACE 2013 - Intermediate
MHHW - USACE 2013 - Intermediate
MSL - USACE 2013 - High
MHHW - USACE 2013 - High
Inundation of 25% Critical Roadways, Mandeville
Inundation of 50% Critical Roadways, Mandeville
Inundation of 75% Critical Roadways, Mandeville
SLC rate used in equation based projections: 6.7 mm/yr (2.2 ft/100 yrs)
MSL record span: 1982 to 2024 (42 years)
Missing data: The MSL record for this gauge has a gap of 5 or more years

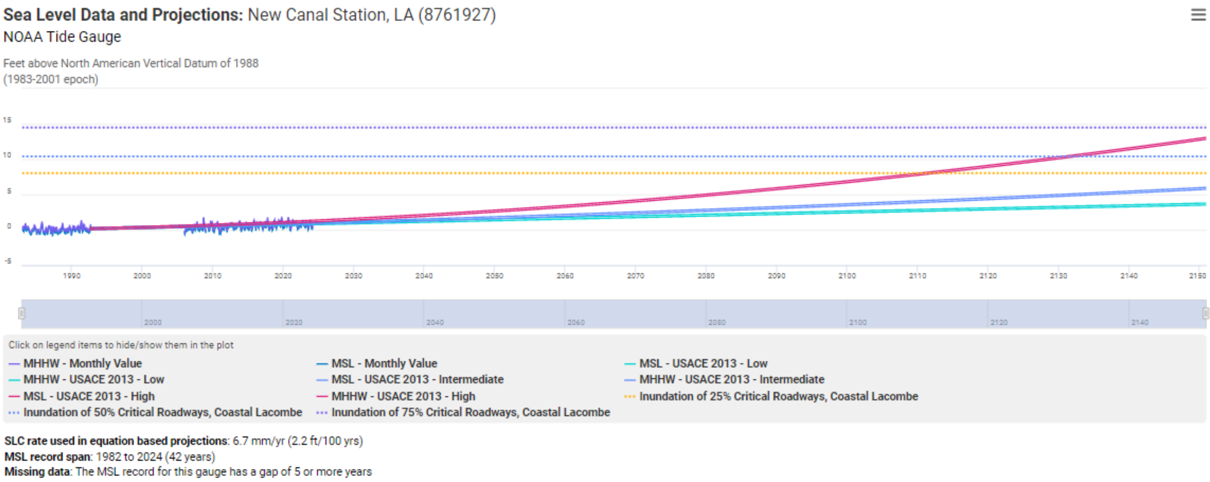
Name	Height
Inundation of 25% Critical Roadways, Mandeville	11.25
Inundation of 50% Critical Roadways, Mandeville	14.5
Inundation of 75% Critical Roadways, Mandeville	18.97

+ Add threshold

Critical Threshold Intersections

Curve	Intersections
Intersections with Inundation of 25% Critical Roadways, Mandeville (11.25 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2139
MHHW - USACE 2013 - High	2137
Intersections with Inundation of 50% Critical Roadways, Mandeville (14.5 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	None
MHHW - USACE 2013 - High	None
Intersections with Inundation of 75% Critical Roadways, Mandeville (18.97 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	None
MHHW - USACE 2013 - High	None

Figure E:3-13. Inundation of Mandeville Critical Roadways Under SLR Projections


Sea Level Data and Projections: New Canal Station, LA (8761927)
NOAA Tide Gauge
Feet above North American Vertical Datum of 1988
(1983-2001 epoch)
15
10
5
0
-5
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
2120
2130
2140
2150
Click on legend items to hide/show them in the plot
MHHW - Monthly Value
MSL - Monthly Value
MSL - USACE 2013 - Low
MHHW - USACE 2013 - Low
MSL - USACE 2013 - Intermediate
MHHW - USACE 2013 - Intermediate
MSL - USACE 2013 - High
MHHW - USACE 2013 - High
Inundation of 25% Critical Roadways, Coastal Lacombe
Inundation of 50% Critical Roadways, Coastal Lacombe
Inundation of 75% Critical Roadways, Coastal Lacombe
SLC rate used in equation based projections: 6.7 mm/yr (2.2 ft/100 yrs)
MSL record span: 1982 to 2024 (42 years)
Missing data: The MSL record for this gauge has a gap of 5 or more years

Enter critical thresholds:
Units: Feet above North American Vertical Datum of 1988 (1983-2001 epoch)

Name	Height
Inundation of 25% Critical Roadways, Coastal Lacombe	8.03
Inundation of 50% Critical Roadways, Coastal Lacombe	10.41
Inundation of 75% Critical Roadways, Coastal Lacombe	14.47

+ Add threshold

Critical Threshold Intersections

Curve	Intersections
Intersections with Inundation of 25% Critical Roadways, Coastal Lacombe (8.03 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2112
MHHW - USACE 2013 - High	2110
Intersections with Inundation of 50% Critical Roadways, Coastal Lacombe (10.41 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	2132
MHHW - USACE 2013 - High	2130
Intersections with Inundation of 75% Critical Roadways, Coastal Lacombe (14.47 feet)	
MSL - USACE 2013 - Low	None
MHHW - USACE 2013 - Low	None
MSL - USACE 2013 - Intermediate	None
MHHW - USACE 2013 - Intermediate	None
MSL - USACE 2013 - High	None
MHHW - USACE 2013 - High	None

Figure E:3-14. Inundation of Lacombe Critical Roadways Under SLR Projections

Section 4
Hydraulic Modeling

4.1 OVERVIEW

Hydraulic modeling was performed using 2D unsteady flow capabilities of HEC-RAS. The model covers the extents of St. Tammany Parish, all within the Lake Pontchartrain watershed, and features five connected 2D areas. The vertical datum of elevations in the model is NAVD 88 (Geoid 12B). Detailed discussion of model development and parameter selection is included in this section.

4.2 MODEL GEOMETRY

Two versions of model geometry were used in this modeling effort. One model geometry represents the parish baseline, or without-project, conditions. Three different HEC-RAS models were combined to develop this geometry. Elements of stream bathymetry were integrated into the terrain for this model from two individual watershed models provided by St. Tammany Parish. The second model geometry represents the alternative analysis and incorporates the separate measures investigated in this study, as described in Section 6.1. Figure E:4-1 depicts the existing conditions model domain.

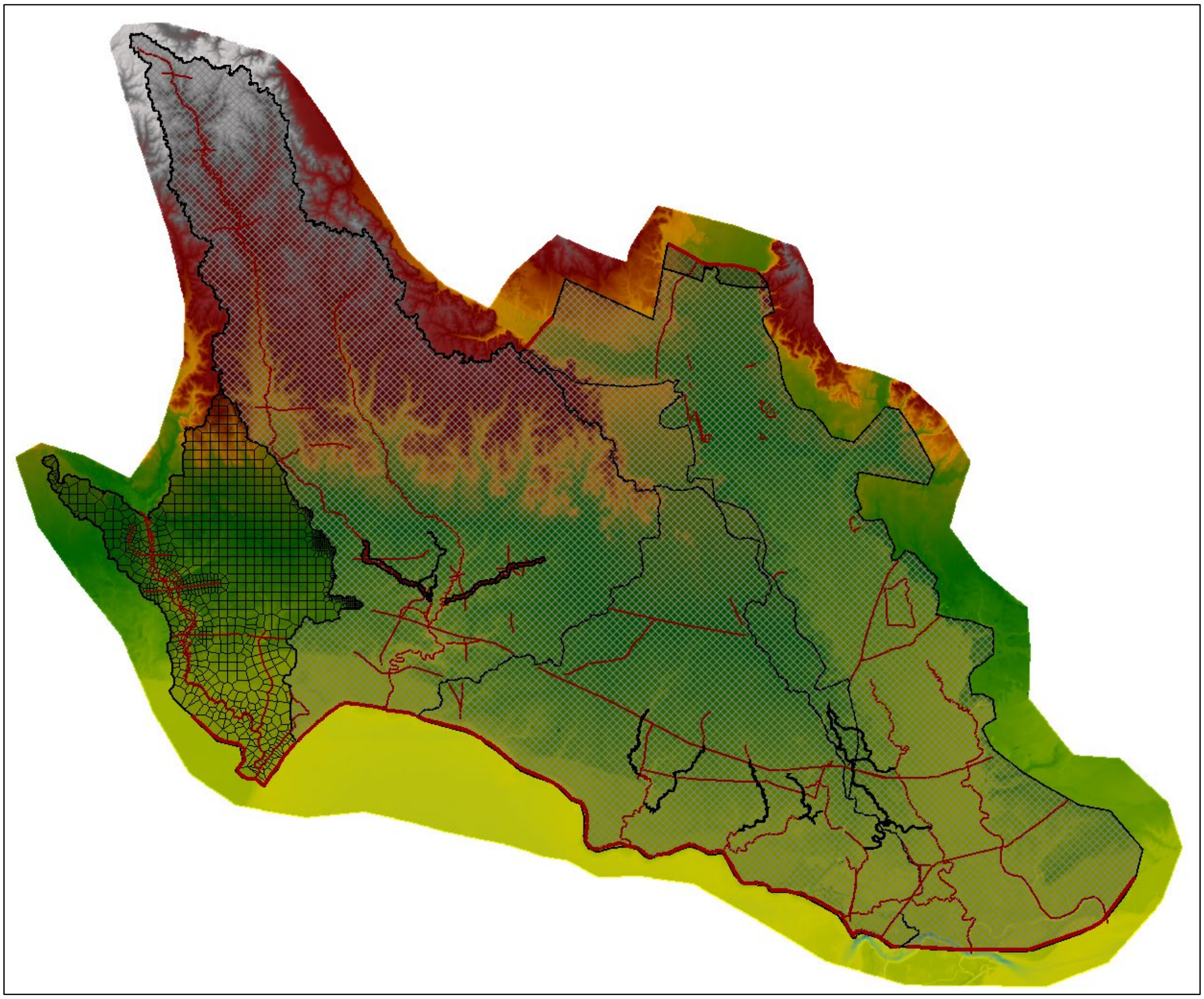


Figure E:4-1. Existing Conditions Model Domain

Both the existing conditions and with-project geometries use the 2D unsteady flow equations in HEC-RAS. The 2D areas encompass the spatial extent of the study area, including all rivers and streams. The 2D cell sizes in the geometry mesh varied. Waterways that intersect a potential alternative or measure being investigated in the study have finer resolution cells of 25x25 feet. Outside of these waterways and in areas the PDT was less interested in investigating in-depth, the cell definition increases with a range between 100x100 up to 2000x2000 feet cells. Also, for near model features such as culverts, lateral structures, 2D area connections, and 2D inflow points, smaller cells were used to allow better model stability and accuracy.

As discussed previously, this model integrates the domain of three separate models. Figure E:4-2 depicts the boundaries of each. From the SLaMM two 2D areas, basin 748 and basin 726, were integrated into the final geometry. A separate model of the Tchefuncte River Basin that had been refined on the Tchefuncte and Bogue Falaya Rivers was used. A 2D model of the Pearl River Basin, used by MVK for flood forecasting, was also integrated into the model. Finally, a gap existed between the Pearl River Basin model and eastern extents of basin 726 and the Tchefuncte River Basin model. A 2D area labeled as Gap was created with the appropriate connections to the adjacent 2D areas.

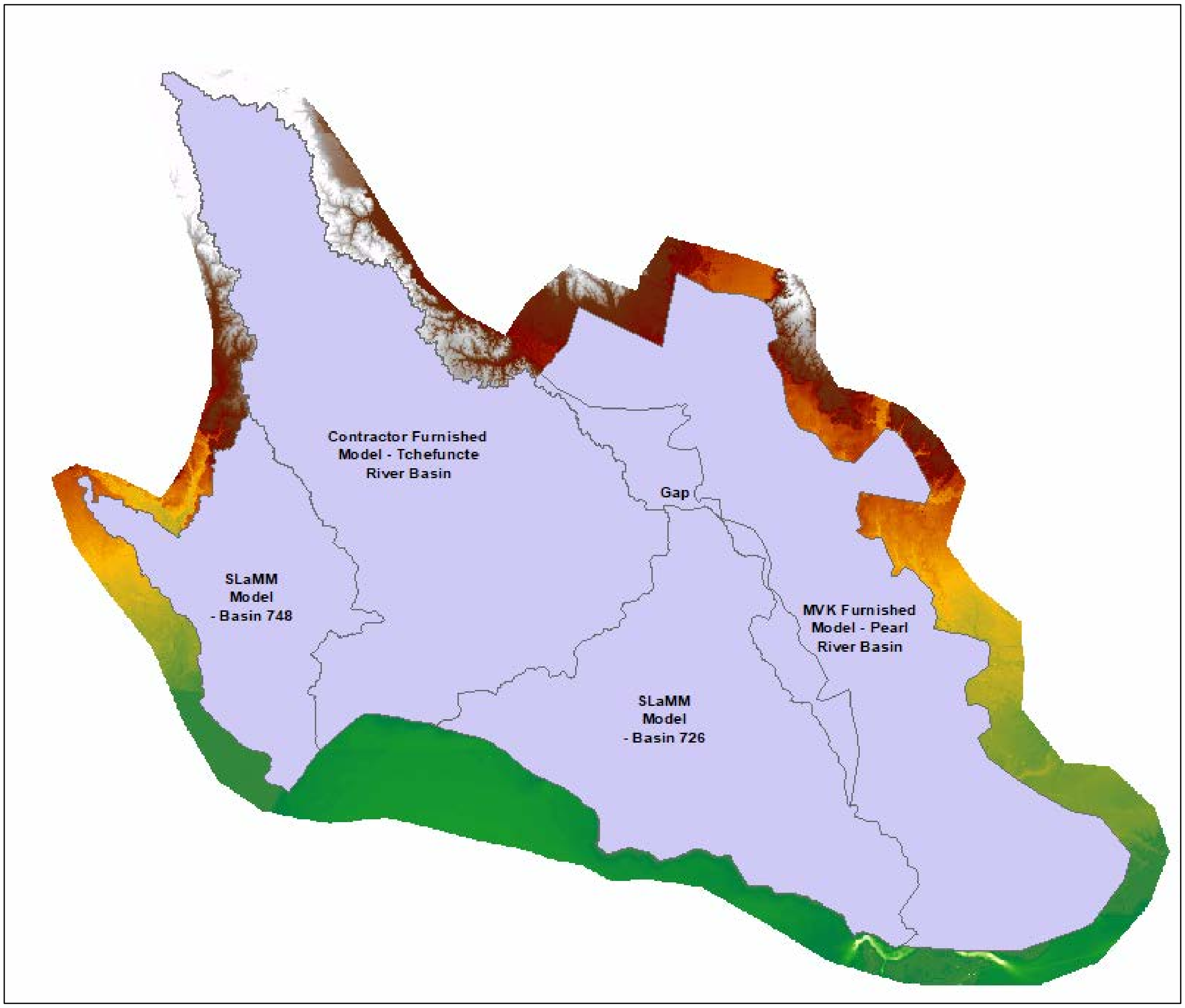


Figure E:4-2. Depiction of 2D Areas Pulled from Various HEC-RAS Models

4.3 TERRAIN AND LAND COVER

Elevation data is used by 2D flow areas to calculate storage within and flow between 2D cells. Topography data came from various sources. Pixel resolution, layer order, descriptions and the source of each raster file can be seen in Table E:4-1. The layer order used for the final terrain is numbered as one being the top-most and six being the bottom layer in Table E:4-1. DEM 23, DEM 22, NG20ft, and United States Geological Survey (USGS) National Elevation DEMs cover the entirety of the domain of the study area. CE-Hyd and MVK Pearl TIFs were layered on top of the DEMs because they have higher resolution. Figure E:4-3. Depicts the final model terrain and Table E:4-2. Tabulates the 17 waterways that have bathymetry burned into the terrain along with the estimation method or source used to estimate bathymetry.

Table E:4-1. Raster Resolution Sizes, Layer Order, Description, and Source Information

Raster File	**Resolution Scale**	**Resolution Cell Size (ft)**	**Layer Order: Top (1) to Bottom (6)**	Description	**Source**
CE-Hyd	1:55.810	4.79	1	The geographic extents of this file include the entirety of the Tchefuncte and Bogue Falaya River Basin. It is a combination of LiDAR and channel elevations in the Tchefuncte and Bogue Falaya Rivers.	Contractor furnished topography
MVK Pearl	1:38.192	7	2	The geographic extents of this file include the Pearl River Basin within the St. Tammany Parish Boundary	USACE MVK
DEM 23	1:27.179	9.83	3	The geographic extents of this file include the Bayou Lacombe, Bayou Bonfouca, and Bayou Liberty River Basin. Includes topographic and some bathymetric elevations.	USGS Topobathymetric Elevation Model of Northern Gulf of Mexico
DEM 22	1:27.167	9.84	4	The geographic extents of this file include the Tchefuncte River from the intersection of Hwy 1077 and 1078 westward to the St. Tammany Parish Boundary. Includes topographic and some bathymetric elevations.	USGS Topobathymetric Elevation Model of Northern Gulf of Mexico
NG20ft	1:13.367	20	5	The geographic extents of this file include the North Eastern extents of the Parish, West of the Pearl River Basin	USGS Northern Gulf of Mexico Topobathymetric Dataset
USGS National Elevation Dataset 11ft	1:2.805	95.30	6	The geographic extents of this file include the Bogue Falaya and Tchefuncte River from Folsom, Louisiana north to the St. Tammany Parish Boundary	USGS National Elevation Dataset topography

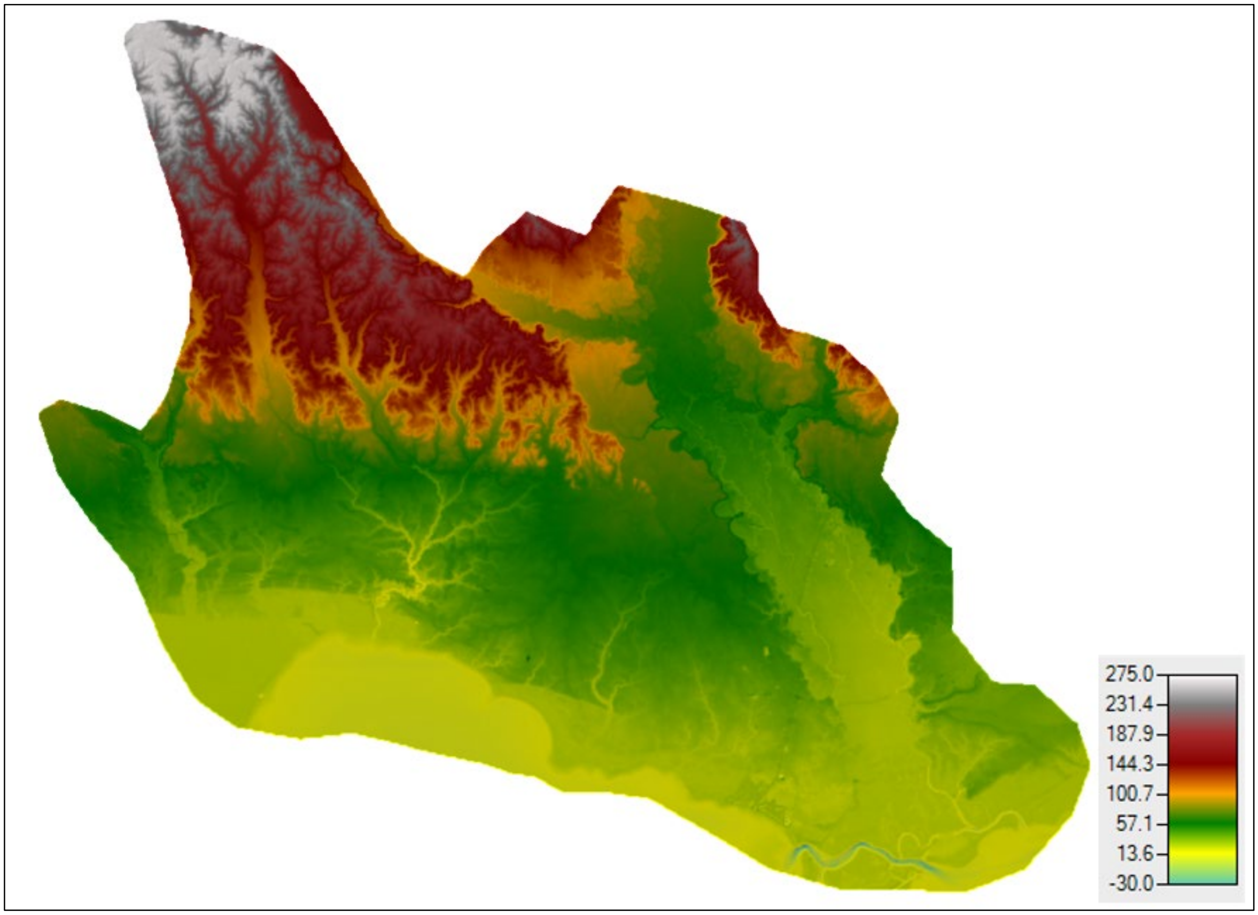


Figure E:4-3. Combined LiDAR Dataset

Table E:4-2. Bathymetry Estimation Methodology for Each Reach

Burned-in Bathymetry		
	Waterway Name	**Estimation Method**
1	Bayou Liberty	Parish-Furnished Bayou Liberty Model cross sections utilized
2	Bayou Patassat	Parish-Furnished W-14 Model cross sections utilized
3	Poor Boy Canal	Parish-Furnished W-14 Model cross sections utilized
4	Doubloon Bayou	Parish-Furnished W-14 Model cross sections utilized
5	Gum Bayou	Parish-Furnished W-14 Model cross sections utilized
6	W-14	Parish-Furnished W-14 Model cross sections utilized
7	W-15 French Branch	Parish-Furnished W-14 Model cross sections utilized
8	Salt Water Bayou	Parish-Furnished W-14 Model cross sections utilized
9	West Diversion Canal	Parish-Furnished W-14 Model cross sections utilized
10	Bayou Bonfouca	Estimated based on channel slope and prior study bathymetry
11	West Pearl River	Estimated based on channel slope and prior study bathymetry
12	Pearl River	Estimated based on channel slope and prior study bathymetry
13	Bayou Lacombe	Estimated based on channel slope and prior study bathymetry
14	Cypress Bayou	Estimated based on channel slope and prior study bathymetry
15	Tchefuncte River	Estimated based on channel slope and prior study bathymetry
16	Mile Branch	LiDAR capture of waterway was spotty. No bathymetry estimated but cross sections cut from existing terrain to ensure a continuous channel exists
17	Mile Branch Lateral A	LiDAR capture of waterway was spotty. No bathymetry estimated but cross sections cut from existing terrain to ensure a continuous channel exists

Land cover data is used to spatially vary the Manning's n roughness coefficients throughout the 2D flow areas. Manning's roughness coefficients are used in the calculation of flow between 2D cells. Land cover data came from the 2016 National Land Cover Database (NLCD). An appropriate Manning's roughness coefficient was selected for each land cover type that is found in the study area. The literature source used to apply land cover values is from the Journal of Spatial Hydrology. Figure E:4-4. displays the tabulation of land cover coefficients from the Journal of Spatial Hydrology Article: Land use-based surface roughness on hydrologic model output.

Table 2 Manning's n values used for NLCD map

Land Cover	Description	Manning's n
21	Developed, open space	0.0404
22	Developed, low intensity	0.0678
23	Developed, medium intensity	0.0678
24	Developed, high intensity	0.0404
31	Barren land	0.0113
41	Deciduous forest	0.36
42	Evergreen forest	0.32
43	Mixed forest	0.40
52	Shrub/scrub	0.40
71	Grassland/herbaceous	0.368
81	Pasture/Hay	0.325
90	Woody wetlands	0.086
95	Emergent herbaceous wetlands	0.1825

Figure E:4-4. Table 2 from the Journal of Spatial Hydrology Article: Land Use-based Surface Roughness on Hydrologic Model Output

4.4 BOUNDARY CONDITIONS

Inflow and precipitation boundary conditions to the hydraulic model were calculated for each return period. The precipitation boundary conditions use HEC-HMS output to apply the calculated excess precipitation directly on the 2D areas. The inflow boundary conditions in this model are 2D inflow hydrographs that represent the Bogue Chitto and Pearl Rivers. The downstream boundary conditions in this model are stage hydrographs applied to each 2D area representing Lake Pontchartrain.

4.4.1 2D Inflow Hydrographs

Inflow hydrographs are applied to the 2D portions of the model at 2D boundary condition lines. At the northern and northwestern boundary of the Pearl River 2D area, the model has two inflow Boundary Condition lines: one is for the Bogue Chitto River and the other is for the Pearl River. Inflow for return periods 2-500 years were applied for both the Bogue Chitto and Pearl Rivers. The inflow boundary condition line extends the entire length of the 500-year floodplain for each river.

Flows for selected key frequencies were available from the most-recent flood insurance studies (FIS) of the area. The 2009 Washington Parish FIS was used for the Bogue Chitto

River flows of 10, 50, 100, and 500-year return periods. The 2019 Pearl River, Mississippi FIS was used for the Pearl River flows of 10, 25, 50, 100, and 500-year return periods. Regression equations were developed to calculate flows for additional frequencies that were needed (1, 5, 200-year return period).

Figure E:4-5 depicts the return periods annual exceedance calculations graphically. Table E:4-3 depicts the calculated inflow for return periods 2-500 years. Figure E:4-6 shows the locations of the 2D inflow hydrograph for the Bogue Chitto and Pearl River.

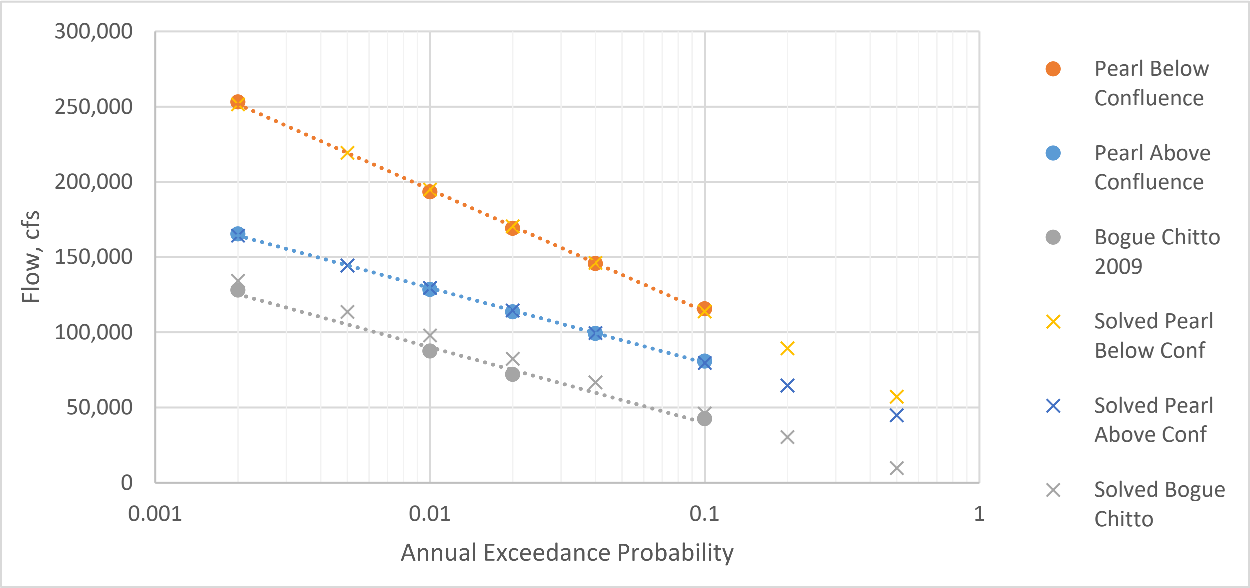


Figure E:4-5. Depiction of Return Periods Annual Exceedance Calculations

Table E:4-3. Tabulation of Return Period Calculations for Inflow Boundary Condition Lines at the Pearl and Bogue Chitto Rivers

Return Period	Annual Exceedance Probability	Pearl Above Confluence	Bogue Chitto
2	0.5	44,855	9,757
5	0.2	64,671	30,418
10	0.1	79,661	46,047
25	0.04	99,476	66,707
50	0.02	114,466	82,336
100	0.01	129,456	97,965
200	0.005	144,446	113,594
500	0.002	164,262	134,255

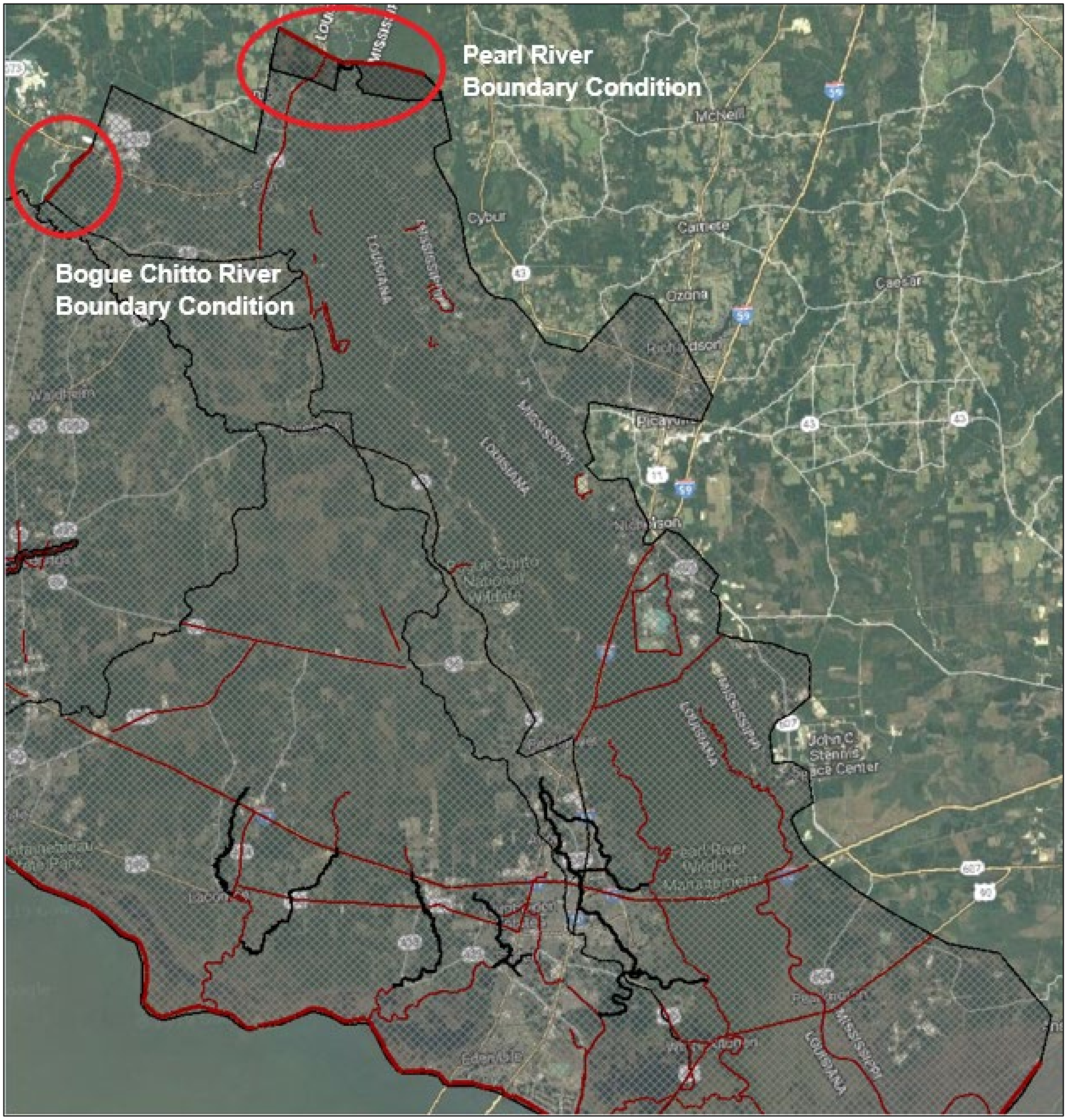


Figure E:4-6. 2D Boundary Condition Line for the Bogue Chitto and Pearl Rivers

4.4.2 Stage Hydrographs

4.4.2.1 Coincidence of Rainfall and Surge

Given the multiple sources of flood risk that threaten St. Tammany Parish, coincidence and joint probability of two sources is an issue that complicates any flood risk analysis. Flooding is experienced by people and property as a total water level, regardless of the source (rain, storm surge, or river flooding). Coastal flooding damage was analyzed separately from the rainfall and river-based flood damage. Rainfall associated with tropical cyclones is not modeled within ADCIRC, which may result in underestimated flood levels and damages by some amount. The uncertainty associated with degree of coincidence between local rainfall, regional river flooding and coastal storm surges, is consistent across all the study alternative areas. For this analysis, it was assumed that local rainfall with regional river flooding is independent of, or non-coincident with coastal storm surges.

With coastal storm damage being modeled and analyzed separately, the rainfall and river-based flooding was modeled without a coastal storm surge influence present. The average daily stage from each gage’s period of record was used for the Lake Pontchartrain boundary conditions. This represents a mean water level expected in the lake.

Local excess precipitation and Pearl River flooding were modeled together in HEC-RAS, though the timing of the peaks was not coincident. This approach enabled the identification of flooding from each source. The rainfall boundary conditions are applied to the model domain starting at the beginning of the simulation, with the peak of the rainfall at 12 hours into the simulation. The Pearl River is rising to its peak at this time. The peak flow for the Pearl and Bogue Falaya Rivers takes 24-48 hours to propagate to the downstream end of the model domain, which results in peaks that are not coincident.

Results provided for economic damage analysis show the maximum WSE throughout an entire simulation. Thus, in areas that experience flooding from both local rainfall and the Pearl River, the higher of the two peaks is counted in the maximum water surface output.

4.4.2.2 Relative Sea Level Change

Global, or eustatic, RSLC and regional subsidence have affected the study area and are projected to continue affecting the area. Together, these two processes are referred to as “relative sea level change” in USACE guidance (USACE ER 1100-2-8162; EP 1100-2-1). River basins in St. Tammany Parish eventually drain to Lake Pontchartrain. Higher sea levels in the future reduce the hydraulic gradient, which somewhat slows the drainage of storm runoff, increasing flooding levels from the same amount of rain. USACE guidance provides a low, intermediate, and high rate to use for project evaluation. The intermediate rate was selected for use in the alternative evaluation phase. The intermediate rate of RSLC was selected for the Alternative Analysis phase because it was determined that each measure was geographically in a similar influence zone with respect to varying rates of RSLC from the Lake Pontchartrain coastline. The decision to select the intermediate rate was made using best engineering judgement to yield more consistent flood risk reduction performance between the CSRM and FRM projects. For planning purposes, this study assumed a project completion, or base, year of 2032. The end of the 50-year period of analysis (planning horizon) is 2082. Calculated changes in relative sea level by the year 2032 are 0.5 feet for the Mandeville gage and 0.4 feet for the Rigolets gage. Calculated changes in relative sea level by the year 2082 are 2.2 feet for the Mandeville gage and 1.7 feet for the Rigolets gage. These values were added on to the established downstream boundary conditions.

4.4.2.3 Boundary Conditions

The downstream boundaries of the hydraulic model are stage boundaries that represent the water level of Lake Pontchartrain. Stage boundaries are used along the entire extents of the southern boundary of the model domain where the 2D domain interacts with Lake Pontchartrain. There are two long-term water level gages on the north shore of Lake Pontchartrain that were used to determine downstream boundary conditions: Lake Pontchartrain at Mandeville and Rigolets near Lake Pontchartrain. Downstream boundary conditions vary along the model extents. For downstream boundary conditions B3, B4, and B5-West, a stage of 1.31 feet and 3.01 feet was used for the 2032 and 2082 events, respectively levels that represent the mean daily stage for the Lake Pontchartrain at Mandeville gage. For downstream boundary condition B5-East, a stage of 0.97 feet and 2.27 feet was used for the 2032 and 2082 events, respectively, levels that represent the mean daily stage for the Rigolets near Lake Pontchartrain gage. For downstream boundary condition B6, a stage of 1.50 feet and 2.80 feet was used for the 2032 and 2082 events respectively. For boundary condition B6, an approximation was made for the appropriate stages based on the Rigolets gage mean value and the model performance with the Pearl River flood wave at the downstream end of the mesh. These values are tabulated in Table E:4-4. Figure E:4-7. Depicts the locations of the five total downstream boundary condition lines.

Table E:4-4. Downstream Boundary Condition Stages along the Extents where the Model Domain Interacts with Lake Pontchartrain

	Boundaries B3, B4, B5-West	Boundary B5-East	Boundary B6
Mean Daily Stage	0.81ft	0.57ft	-
Existing Conditions – 2032	1.31ft	0.97ft	1.50ft
Future Conditions – 2082	3.01ft	2.27ft	2.80ft

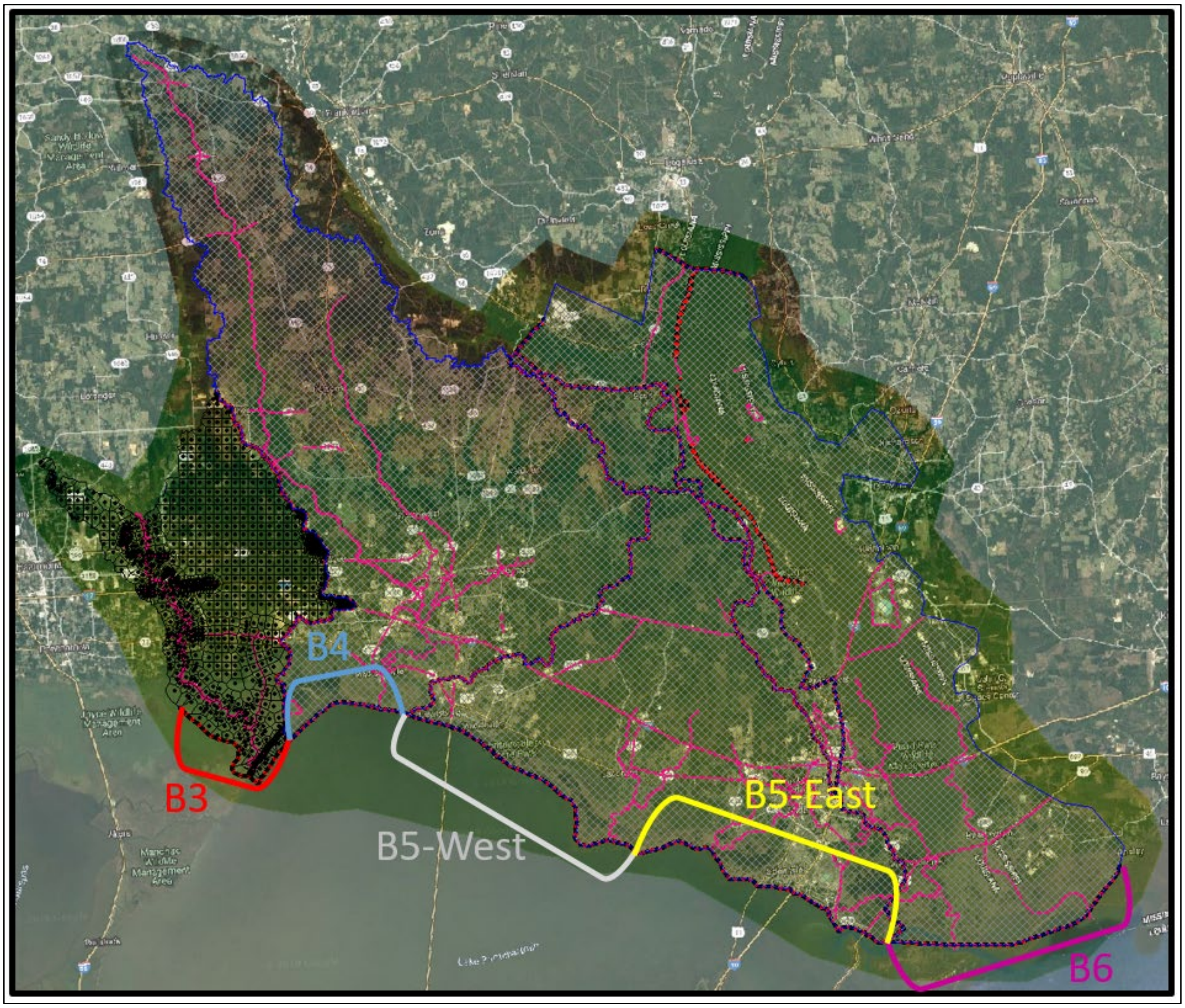


Figure E:4-7. Locations of Downstream Boundary Conditions B3, B4, B5-West, B5-East, and B6

4.5 CLIMATE CHANGE VULNERABILITY

Regional-scale climate change and hydrology trends for the study area are documented in the report "Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Lower Mississippi River Region 08" (USACE, 2015). Vulnerability to climate change is the degree to which a system is susceptible to and unable to cope with adverse effects of climate change including climate variability and extremes. There are six climate variables that are impacted due to climate change, including increased ambient temperatures, increased maximum temperatures, increased annual precipitation, increased storm intensity and frequency, streamflow variability, and SLR. According to the Climate Change Assessment for Water Resources Region 08 (Lower Mississippi River

Region) these climate variables will create countless vulnerabilities on business lines within the region.

Air temperatures within region 08 are expected to increase by 3-6 degrees Celsius in the latter half of the 21st century, especially in the summer months. This is expected to create increased water temperatures leading to water quality concerns, particularly for dissolved oxygen levels, growth of nuisance algal blooms, and influence wildlife and supporting food supplies. Additionally, periods of prolonged drought and reduced stream flows should be expected. Drought and reduced stream flows will lead to the killing of diverse vegetation throughout the region, then impacting sediment stabilization in the watershed. Loss of non-drought resistant vegetation may result in an increase in sediment loading potentially causing geomorphic changes in the tributaries to the river system.

By the middle of the 21st century, annual precipitation is expected to increase in the region. Increased precipitation is expected to increase flows and runoff within the watershed. Increased runoff caries more pollutants to receiving water bodies, therefore depreciating water quality health. Increased erosion with subsequent changes in sediment accumulation is also anticipated. Flooding will also increase and have a negative consequence on infrastructure, habitats, and human life.

Extreme storm events are expected to become more frequent and intense over time. Higher intensity and more frequent storms will inherently increase flows and runoff, cause erosion with subsequent changes in sediment accumulation, increase groundwater recharge rates, as residence times are shortened within areas where evapotranspiration takes place during high intensity events, and increase flooding, which has a negative impact on infrastructure, habitats, and human life. Additionally, increased sea level exacerbates saltwater intrusion into fresh water supplies which directly impacts numerous Southern Louisiana fishery industries.

In addition, a comprehensive assessment of climate trends in the study area will be completed in subsequent documentation and further evaluation of project performance under a range of possible RSLC scenarios will be completed.

4.6 HYDRAULIC MODEL CALIBRATION

Some calibration was completed on the previous models independently, prior to combining them into a single working model domain. Model calibration of the new combined HEC-RAS model was completed to benchmark and improve the performance of the model. Two events were chosen to calibrate the model. For the central portion of the parish, the March 2016 rain event was chosen as there was heavy flooding that this event caused in that portion of the parish. For the southeastern portion of the parish, an event that occurred in December 2009 that impacted Slidell, Louisiana, was chosen.

Existing USACE and USGS gages were used to evaluate the calibration runs of the novel model geometry and terrain. A complete list of gages used for each calibration event may be seen in Table E:4-5 and locations of the gages may be seen in Figure E:4-8. Calibration plots depicting the March 2016 and December 2009 events at the gage locations listed in

Table E:4-5. compared with flows in the final calibrated model may be seen in Annex 2 of this appendix.

Table E:4-5. Calibration Gages for St. Tammany Parish

Gage Name	Gage ID	Gage Link
Lake Pontchartrain at Mandeville, LA	USACE 85575	https://rivergages.mvr.usace.army.mil/WaterControl/stationinfo2.cfm?sid=85575&fid=&dt=S
Tangipahoa River at Robert, LA	USGS 07375500	https://nwis.waterdata.usgs.gov/la/nwis/uv?cb_00065=on&format=html&site_no=07375500&period=&begin_date=2016-03-01&end_date=2016-03-31
Tchefuncte River at Madisonville, LA	USGS 07375230	https://nwis.waterdata.usgs.gov/usa/nwis/uv/?cb_00065=on&format=html&site_no=07375230&period=&begin_date=2016-03-01&end_date=2016-03-31
Bayou Liberty near Slidell, LA	USGS 07374581	https://nwis.waterdata.usgs.gov/usa/nwis/uv/?cb_00065=on&format=html&site_no=07374581&period=&begin_date=2016-03-01&end_date=2016-03-31
Rigolets at Hwy 90 near Slidell, LA	USGS 301001089442600	https://nwis.waterdata.usgs.gov/la/nwis/uv/?cb_00065=on&format=html&site_no=301001089442600&period=&begin_date=2016-03-01&end_date=2016-03-31
Bogue Chitto River near Bush, LA	USGS 02492000	https://nwis.waterdata.usgs.gov/nwis/uv?cb_00060=on&format=html&site_no=02492000&period=&begin_date=2016-03-01&end_date=2016-03-31
Pearl River near Bogalusa, LA	USGS 02489500	https://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=html&site_no=02489500&referred_module=sw&period=&begin_date=2016-03-01&end_date=2016-03-31
Tchefuncte at Covington	USGS 07375050	http://waterdata.usgs.gov/usa/nwis/uv?site_no=07375050
Bogue Falaya at Boston St at Covington	USGS 07375175	http://waterdata.usgs.gov/usa/nwis/uv?site_no=07375175
Pearl River at Real River, LA	USGS 02492600	http://waterdata.usgs.gov/usa/nwis/uv?site_no=02492600
Bogue Falaya River near Camp Covington	USGS 07375105	http://waterdata.usgs.gov/usa/nwis/uv?site_no=07375105
Abita River at Abita Springs	USGS 7375222	https://waterdata.usgs.gov/la/nwis/uv/?site_no=07375222&PARAmeter_cd=00065,72020,63160,00060

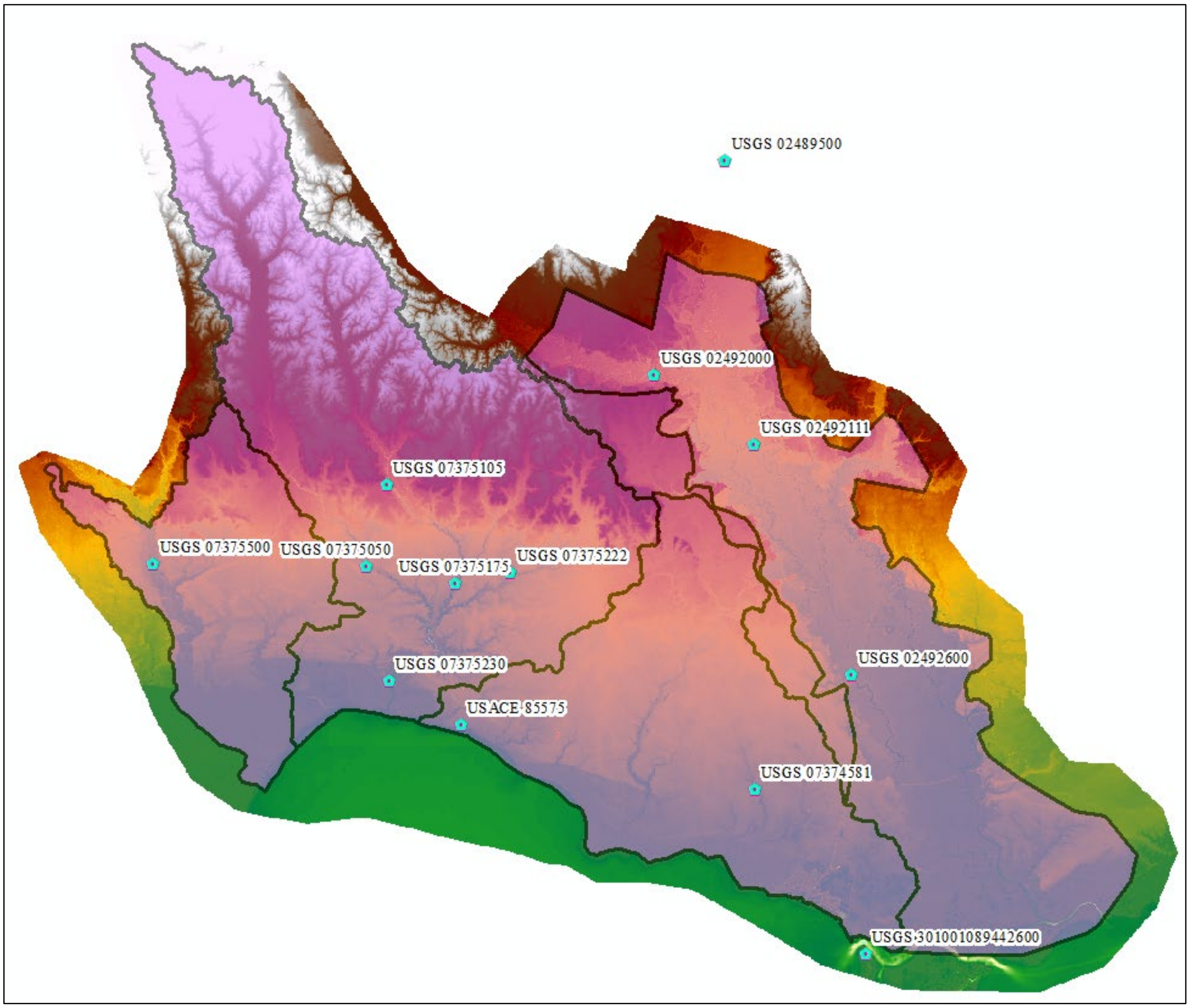


Figure E:4-8. Calibration Gage Locations for March 2016 and December 2009 Events

In HEC-HMS, precipitation was generated using Next Generation Weather Radar (NEXRAD) hourly precipitation estimates and the simulation was run for 30 days to ensure precipitation data for each event was accessible. Centroids were determined for each 2D area and precipitation was pulled from the NEXRAD grid based on those coordinate locations. Precipitation pulled from each centroid was applied uniformly over each of the five corresponding 2D areas.

To ensure the model produces credible results, a few adjustments were required to adequately align the model and gages with the actualized December 2009 and March 2016 events. A warm-up period on the Pearl River 2D area of 24 hours was applied to both the 2016 and 2009 events to ensure flow was established at the beginning of the simulation. The inflow boundary condition for the Bogue Chitto is linked to the Bogue Chitto gage near Bush, Louisiana (USGS 02492000). The inflow boundary condition for the Pearl River inflow is linked to the Pearl River gage near Bogalusa, Louisiana (USGS 02489500). Downstream boundary conditions for B3, B4, and B5-West were linked to the Mandeville gage (USACE 85575). Downstream boundary conditions for B5-East and B6 were linked to the Rigolets gage (USGS 301001089442600). For both the March 2016 and December 2009 calibration events, the HEC-RAS simulation was run for 5 days to ensure a peak was reached for the entire model domain. A 15 second computation interval was used for both events. Additional enforcement of a few hydraulic barriers was applied in the Slidell region with breaklines.

Revisions were also made to the roughness coefficients that represent the channel and floodplain areas. Manning's n override regions were applied to 13 waterways to supersede the default landcover-based Manning's n value, which achieved a more accurate calibration to observed gage records. Tabulation of the Manning's n override regions may be seen in Table E:4-6. Additionally, the Journal of Spatial Hydrology Article: Land use-based surface roughness on hydrologic model output cited a roughness coefficient of 0.086 and 0.001 for woody wetlands and open water, respectively. Following analysis of the first few calibration runs, it was determined that woody wetlands landcover type should be decreased to a Manning's n value of 0.075 and open water should be changed to 0.03 throughout the entire model domain to represent the roughness coefficient of those landcover categories more accurately.

Table E:4-6. Manning's n Override Region Values for Waterways related to the Proposed Final Array FRM measures

Manning's n Override Region Values	
Waterway Name	**n**
Abita River	0.03
Tchefuncte River	0.07
Bayou Liberty	0.04
Mile Branch	0.04
Mile Branch Lateral A	0.04
Bayou Lacombe	0.04
Cypress Bayou	0.04
Bayou Bonfouca	0.04
Bayou Patassat	0.04
Doubloon Bayou	0.04
Gum Bayou	0.04
Poor Boy Canal	0.04
W-15 French Branch	0.04

Section 5
ADCIRC Modeling

For the alternative analysis phase of ADCIRC analysis conducted in 2020, the 2017 CPRA dataset – existing conditions – was used to develop storm surge and wave parameters at specific frequencies. Using a Matrix Laboratory (MATLAB) script, storm surge, significant wave height and wave period were extracted from the 2017 CPRA Master Plan ADCIRC dataset. This data set is based on the modeling results of 152 Joint Probability Method-Optimal Sampling (JPM-OS) synthetic storms. The storms cover a range of hypothetical tracks, forward speeds, intensities, and sizes. Figure E:5-1 displays the tracks for all 152 synthetic storms compared against a series of historically significant storms. The JPM-OS synthetic storms are basically an extension of the limited observed record. Figure E:5-2. compares the wind-speeds of the synthetic storms compared against the historically significant storms. The synthetic storms are parametrically similar to actual storms in the record. All 152 storms must be simulated to estimate storm surge statistics.

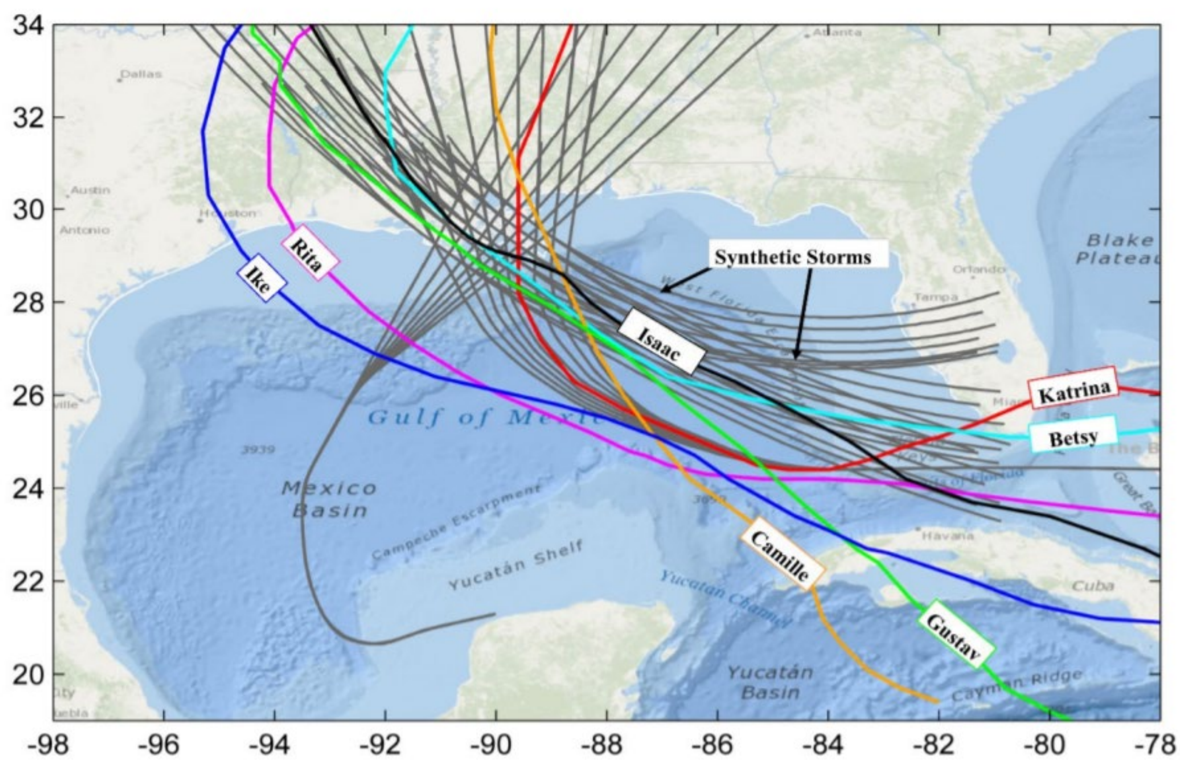


Figure E:5-1. Tracks for all 152 Synthetic Storms Compared against Historically Significant Events

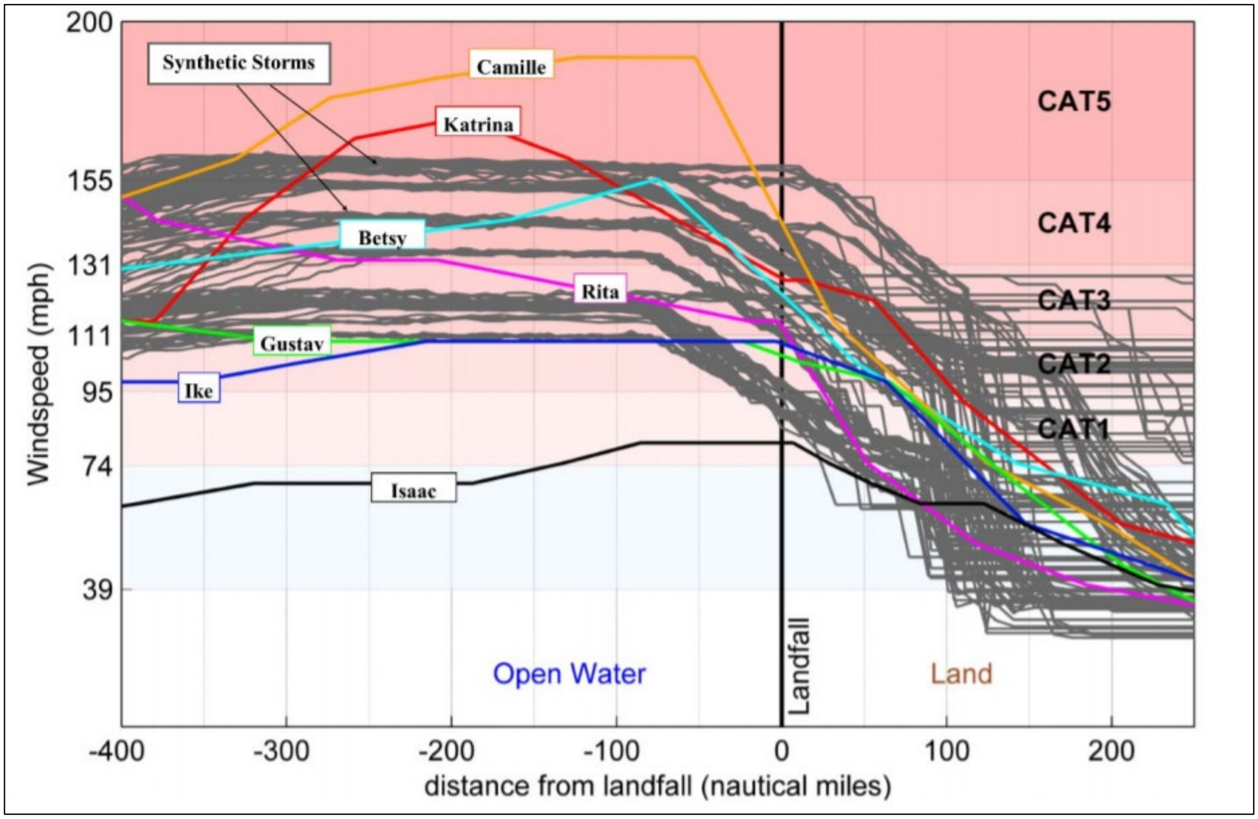


Figure E:5-2. Wind-speeds for all 152 Synthetic Storms Compared against Historically Significant Events

In the coastal and deltaic environment of south Louisiana, future conditions must account for sinking land and rising sea levels – two well-documented processes affecting the area. The 2015 Update to the Tide Gage Atlas of South Louisiana determined long-term trends of relative RSLC at numerous gages in the state, including those at Mandeville and the Rigolets.

CPRA had performed ADCIRC runs for the full suite of 152 storms for the future conditions.

The best estimate of the PDT for the date of project construction completion was 2032 ("base year"). Adding the 50-year window needed for economic analysis results in 2082 ("future year"). At 50+ years out, SLR and regional subsidence are significant. Surge, wave height, and wave period values for 2082 were interpolated or extrapolated for the specified return periods and three rates of SLR specified in USACE guidance (ER 1100-2-8162). The future conditions results based on the intermediate rate of SLR were used for the economic analysis, a PDT decision.

For storm surge inundation, MATLAB code was written to do a 3D interpolation on the CPRA results. The MATLAB function scattered Interpolant develops a 3D surface of the variables return period, SLR, and surge. By inputting return period and SLR, the function returns the surge levels. The code can produce water levels for nodes that are not wet in existing conditions but are wet in future conditions. Because the CPRA future without action simulations used a eustatic SLR of 1.5 feet in 50 years, the low and intermediate rate future conditions were interpolated. Values were extrapolated for the high-rate future condition. This introduces additional error but is a feasible solution at the planning study phase.

Wave periods and significant wave heights were also extracted from the CPRA data set. Results were obtained for Louisiana coastal inundation for storms with rates of return of 10, 20, 50, 100, 200, and 500 years.

5.1 LEVEE DESIGN ELEVATIONS FOR ALTERNATIVE ANALYSIS

The calculations for the design height of levees and floodwalls followed the EurOtop (2018) manual for computing design heights, which uses a slightly different overtopping formulation for levees versus floodwalls. Because a Monte Carlo analysis was used in creating the statistics for values of each variable, the mean value approach equations described in the EurOtop manual were used in the calculation of structure design height. A script was used to calculate the design height for each location allowing an overtopping criterion of 0.1 cubic feet per second (cfs) per linear foot, which is consistent with the USACE's Hurricane and Storm Damage Risk Reduction System (HSDRRS) design criteria. An Excel file contained the inputs at each location for the following parameters: levee/floodwall (uses binary input; floodwall = 0, levee = 1), surface water level (storm surge height) and its standard deviation, significant wave height (Hs) and its standard deviation, wave period and its standard deviation, levee slope (not used for flood wall calculation), berm factor, roughness factor, wave angle factor, and wall factor.

Alternatives in the Final Array included risk reduction systems in Mandeville, Lacombe, and the greater Slidell area. Each alignment was divided into smaller sections based on the geography, topography, or hydrodynamic characteristics (input variables storm surge height, wave height, etc.). A nearby point, or node, was selected for each section and the input variables for that node were used in the design elevation procedure. Some segments were further subdivided to avoid drastic changes in the design elevation. Further subdividing and refinement are recommended for future phases of design.

A levee slope of 3H:1V was assumed and was used by other disciplines for alternative analysis. The storm surge, wave height, and wave period values used for the coastal risk reduction system design elevation procedure were the 1 percent annual exceedance probability (AEP) values, which are commonly referred to as "100-year return period." The selection of the 1 percent AEP parameters was done for consistency across the different areas/alternatives, and not intended to be a recommendation nor optimized solution.

The assumption across all areas/alternatives for this study was that levee design elevations use existing conditions parameters because they can be built up in the future via levee lifts to achieve higher design elevations required by future relative RSLC. Further discussion on levee lifts may be found in Section 5 of Appendix D. Future conditions (2082) design elevations were determined and used by other disciplines to develop quantity and lift schedule estimates. Hard structures (floodwalls and gates) would be designed to future conditions 2082 parameters because increasing their height is not as feasible. Alternative 9-Mandeville Lakefront, was analyzed with a designated elevation of 7.3 feet, based on input from local stakeholders and acceptability considerations.

Final design elevations could include additional considerations beyond the factors discussed here.

Section 6
Alternative Analysis and Results

FRM measures were modeled in HEC-RAS to determine responses during the final alternative analysis and TSP phase. CSRM measures were not specifically modeled in ADCIRC during this phase. Protected area extents, preliminary levee and floodwall elevations, and general estimates of inducements were developed to support the analysis and comparison of alternatives.

6.1 HEC-RAS FRM ALTERNATIVE ANALYSIS

Measures within alternatives were analyzed to determine the response to the specific measure. Measures were modeled together in instances where they were not expected to affect the other. When one measure was expected to influence the hydrology and hydraulics of another measure, they were modeled in distinct model geometries. Table E:6-1. defines how each measure was modeled, either jointly or independently. To gain further efficiencies in model runs, precipitation and inflows were removed over the 2D areas far away from the proposed projects to streamline model run time. These are identified in Table E:6-1. Each model geometry was run for each frequency event, 2 years through 500-years, for both current (2032) and future (2082) conditions. This totaled to 80 model simulations and results to be processed for analysis. Hydraulic model results were provided for analysis of flood damages in the form of GIS Rasters showing the maximum WSE during each frequency storm stimulation.

Table E:6-1. Modeling Plan for HEC-RAS FRM Alternative

Alternatives with FRM Measures	Alternative Name	FRM Measure	Modeling Plan	Simulation Efficiencies
Alternative 5	Bayou Liberty/ Bayou Vincent/ Bayou Bonfouca	Bayou Bonfouca Detention Pond	Each measure was modeled together in one geometry. Hydraulic influence of each measure can be identified under one geometry.	No efficiencies were taken for Alternative 5 simulations. The same precipitation and inflows were applied to each area as the optimized existing conditions model.
		Bayou Liberty Channel Improvements (Clearing and Snagging)		
		Bayou Patassat Channel Improvements (Clearing and Snagging)		
Alternative 7	Eastern Slidell	Doubloon Bayou Channel Improvements (Enlargement)	Doubloon Bayou and Poor Boy Canal were modeled jointly in Channel Improvement model domain.	Precipitation removed from 2D Areas CDHyd and 748 for Alternative 7 simulations.
		Poor Boy Canal Channel Improvements (Enlargement)		
		Pearl River Levee	Modeled Independently	Precipitation removed from 2D Areas CDHyd and 748 for Alternative 7 simulations.
		Gum Bayou Diversion	Modeled Independently	Precipitation removed from 2D Areas CDHyd and 748 for Alternative 7 simulations.
Alternative 8	Upper Tchefuncte/Covington	Mile Branch Channel Improvements (Enlargement)	Mile Branch and Lateral A were modeled in Channel Improvement model geometry	Bogue Chitto and Pearl River Inflows were removed from simulations. Precipitation removed for 2D Areas Pearl and 726.
		Lateral A Channel Improvements (Enlargement)		

6.1.1 Alternative 5 – Bayou Liberty/Bayou Vincent/Bayou Bonfouca

As described previously in Table E:6-1., the Alternative 5 measures were modeled jointly in a single geometry and simulation runs because it was expected that hydraulically, the Bayou Bonfouca Detention Pond, Bayou Liberty channel improvements (clearing and snagging), and Bayou Patassat channel improvements (clearing and snagging) measures in Alternative 5 would not influence each other. Figure E:6-1. depicts locations of all the Alternative 5 measures. Although shown on the figures, the CSRM measures are not discussed in the HEC-RAS modeling section but are described further in Section 6.2.

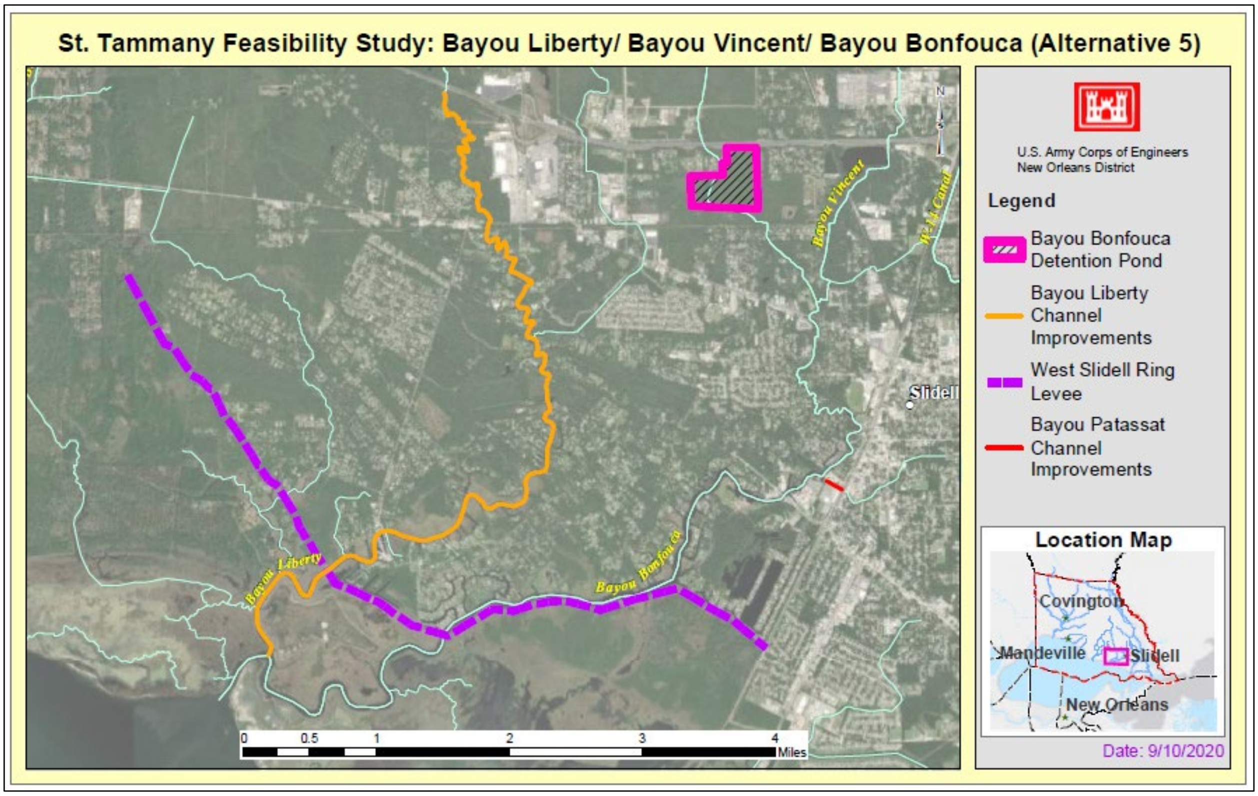


Figure E:6-1. Alternative 5 Final Array Map

The Bayou Bonfouca Detention Pond measure was modeled in HEC-RAS as a terrain modification. The detention pond located south of I-12 has a detention capacity of 1,308 acre-feet. The pond was modeled with 3:1 side slopes, has a footprint of 109 acres, and a depth of 12 feet. Figure E:6-2. depicts the terrain modification for the Alternative 5 simulations.

Figure E:6-2. With and With-out Project Terrain Modification for Bayou Bonfouca Detention Pond (Existing Conditions is on the Left, and With-Project Terrain is on the Right)

The Bayou Liberty Channel Improvements measure was modeled as a modification to the 2D Area by changing the roughness value in the channel. The Manning's n override region feature in HEC-RAS was used. Existing conditions model runs has a 0.04 Manning's n override region over the extents of Bayou Liberty going north of I-12 approximately 1.15 miles. For the with-project simulations, a Manning's n override region of 0.03 was placed over the channel improvement area from I-12 downstream to Lake Pontchartrain to simulate a cleared and snagged channel.

The Bayou Patassat channel improvements measure was modeled as a modification to the geometry mesh Manning's n override regions. Existing conditions model runs has a 0.04 Manning's n override region over the extents of Bayou Patassat. For the with-project simulations, a Manning's n override region of 0.03 was placed over the channel improvement area depicted, previously in Figure E:6-2., to simulate a cleared and snagged channel.

Difference maps that subtract the with-project from the without-project WSE results Rasters were developed for the 10-year and 200-year 2032 events to illustrate the reductions and inducements for each simulation. Each difference map for all alternatives may be seen in Annex 1 of this appendix.

6.1.2 Alternative 7 – Eastern Slidell

The measures in Alternative 7 were broken up in runs based on each measure's hydraulic influence on other nearby measures. The Pearl River levee and Gum Bayou Diversion were both modeled independently. The channel improvements measures for Doubloon Bayou and Poor Boy Canal were modeled jointly because their hydraulic impacts would not overlap. Figure E:6-3. Depicts locations of all Alternative 7 measures.

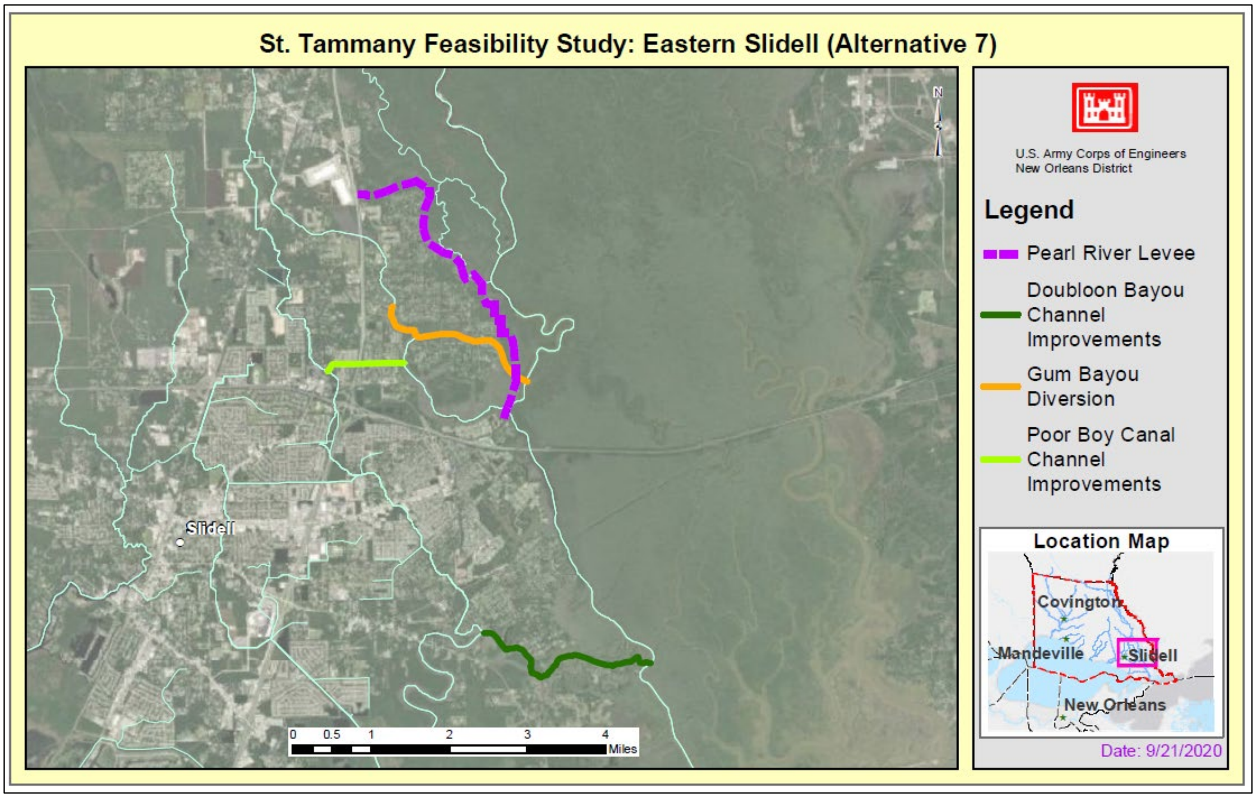


Figure E:6-3. Alternative 7 Map

The Pearl River levee measure of Alternative 7 was modeled as a 2D area connection. The levee was designed to a 200-year flood level of protection plus 2 feet of uncertainty allowance. This measure initially came from the 1986 Pearl River Basin Reconnaissance Study and the alignment has since been adapted due to development. Figure E:6-4 depicts the location in the mesh and 2D connection data editor alignment.

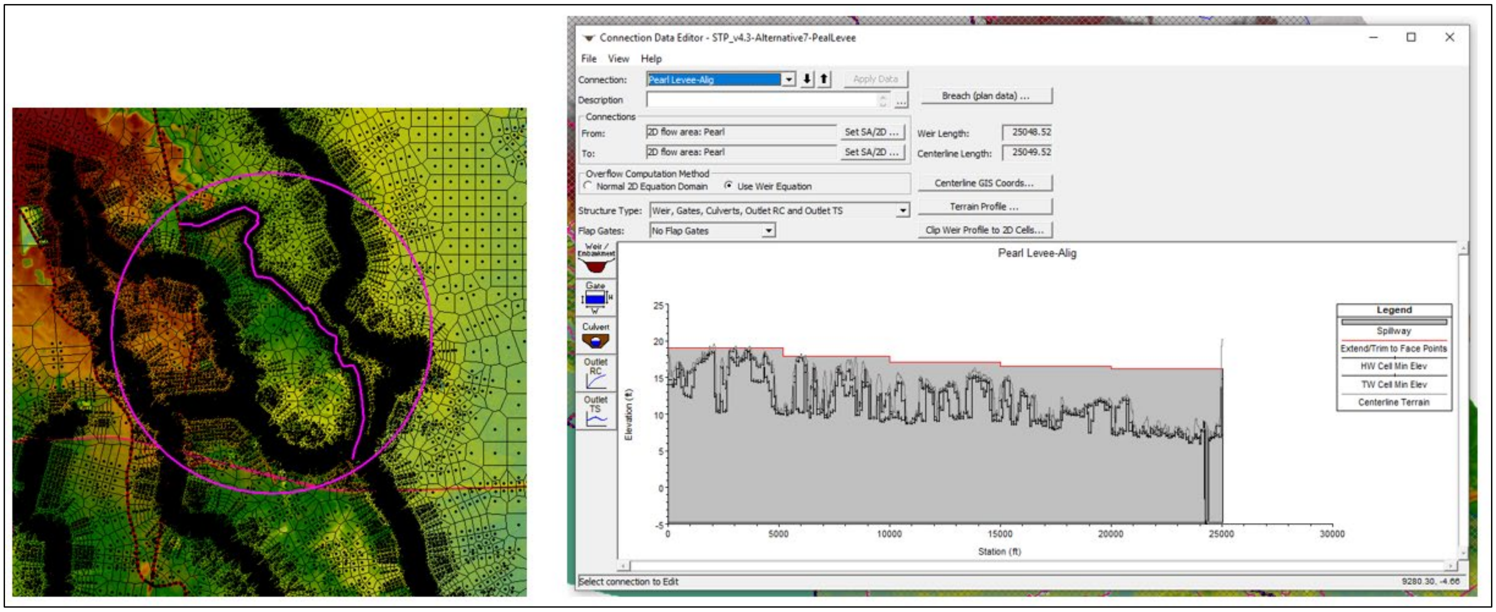


Figure E:6-4. Pearl River Levee 2D Area Connection Location (Left) and Levee Alignment Connection Data Editor

The Gum Bayou Diversion alignment was modeled as a terrain modification. The diversion channel alignment was placed to consider the number of real estate relocations, to follow a remnant past course of a stream that was evident in elevation maps, and to optimize hydraulic efficiency of the diversion. The Gum Bayou Diversion has 3H:1V side slopes and maintains the width beginning at the upstream end where the diversion ties into Gum Bayou. The invert at the upstream end of the diversion matches the invert at the upstream end where the diversion ties into Gum Bayou and the invert drops down 5 feet along the entire length of the alignment until it ties into the West Pearl River. Figure E:6-5. illustrates the Terrain modification for the Gum Bayou Diversion Channel.

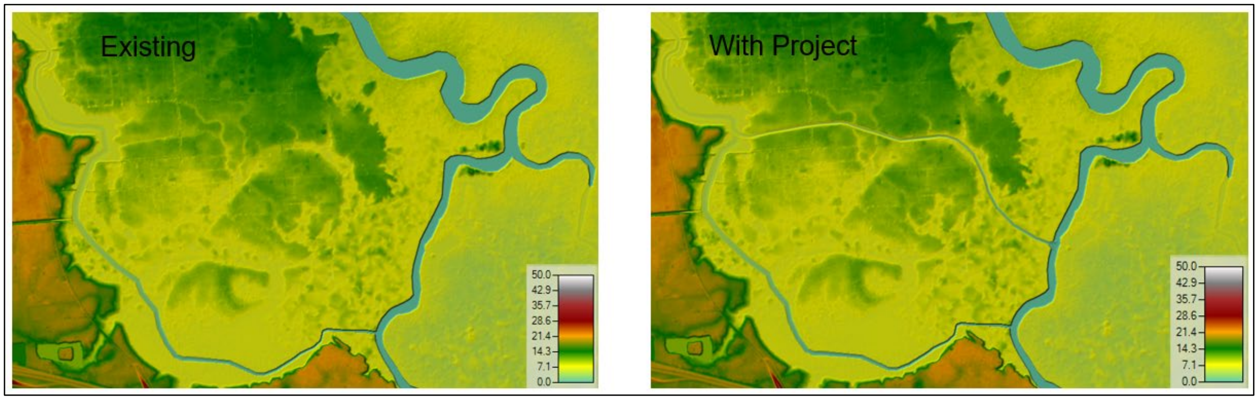


Figure E:6-5. Gum Bayou Diversion Channel Terrain Existing Conditions (Left) and With-

Project (Right)

The Doubloon Bayou and Poor Boy Canal channel improvements dredging measures were modeled jointly in one geometry. These were modeled as a modification to the geometry mesh Manning's n override regions and terrain. Existing conditions model runs have 0.04 Manning's n override region over the extents of Doubloon Bayou and Poor Boy Canal. For the with-project simulations, a Manning's n override region of 0.03 was placed over the channel improvement extents for Doubloon Bayou and Poor Boy Canal to simulate a cleared channel. Additionally, both channels were deepened by 5 feet along the channel improvements extents from the existing invert elevation, maintain 3H:1V side slopes along each reach, maintain a 10 feet bottom width along each channel, and maintain the same channel slope as existing conditions. Figure E:6-6 depicts the channel improvements applied to both Doubloon and Poor Boy Canal.

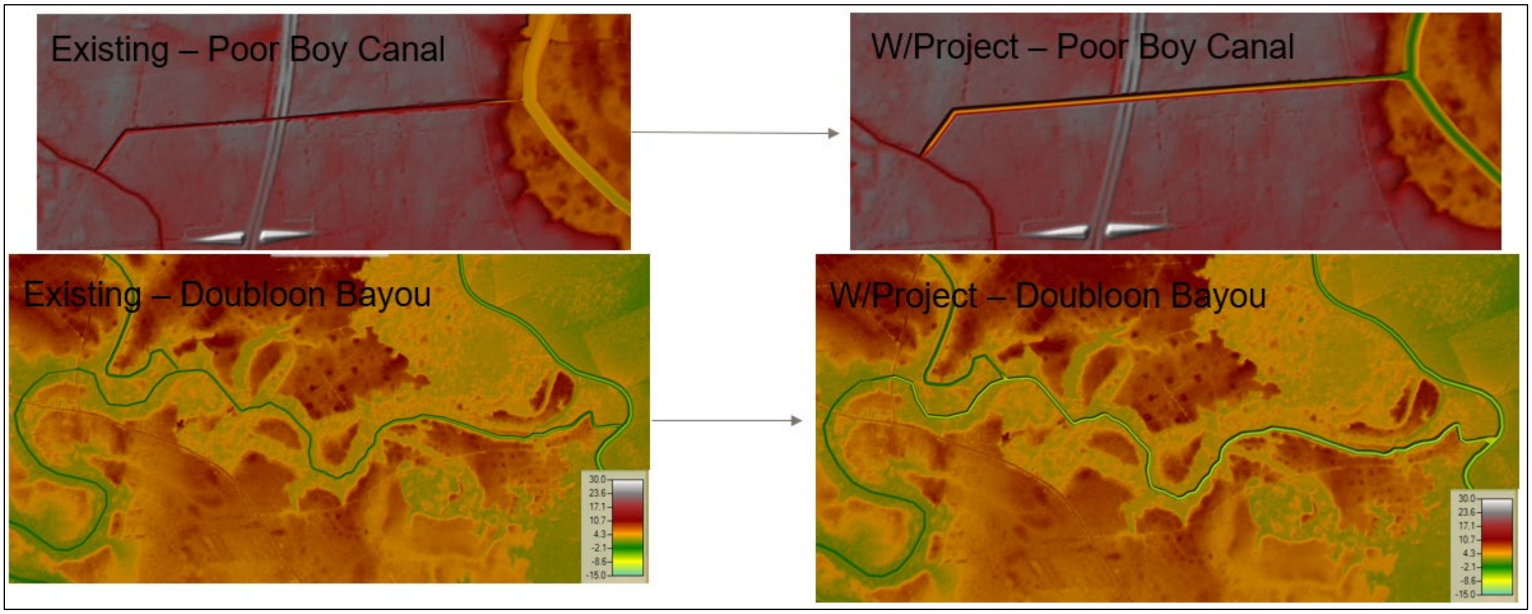


Figure E:6-6. Doubloon Bayou and Poor Boy Canal Existing Conditions (Left) and With-Project Dredging (Right)

Difference maps that subtract the with-project from the without-project WSE results Rasters were developed for the 10-year and 200-year events based on year 2032 to illustrate the reductions and inducements for each simulation. Each difference map for all alternatives may be seen in Annex 1.

6.1.3 Alternative 8 – Upper Tchefuncte/Covington

As described previously in Table E:6-1, it was determined that the Alternative 8 measures could be modeled jointly in a single geometry. Mile Branch and Lateral A were both modeled as a modification to the 2D Area mesh Manning's n override regions and terrain.

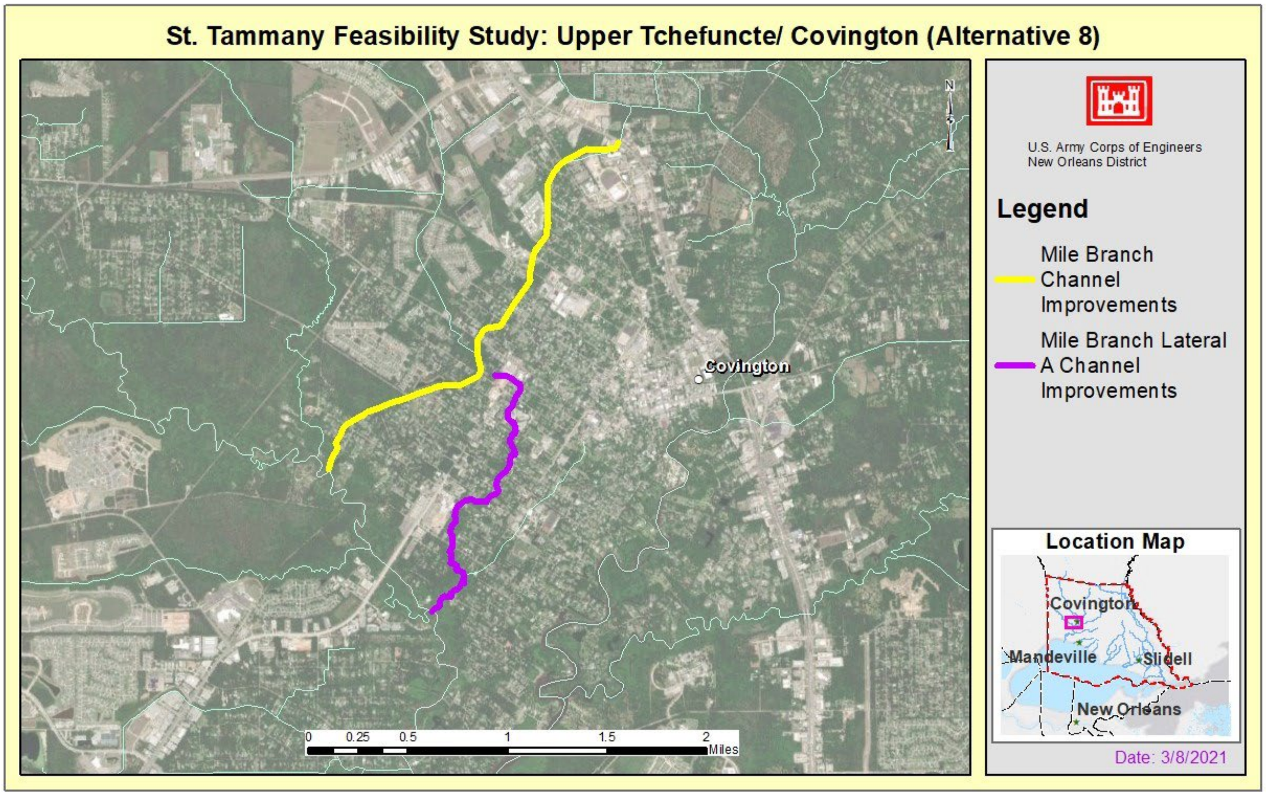


Figure E:6-7. Alternative 8 Upper Tchefuncte/Covington Measures

Existing conditions model runs have 0.04 Manning's n override region over the extents of Mile Branch and Lateral A. For the with-project simulations, a Manning's n override region of 0.03 was placed over the channel improvement extents for Mile Branch and Lateral A to simulate a cleared channel. Figure E:6-8 depicts the channel improvements applied to both Mile Branch and Lateral A. Additionally, both channels were deepened by 5 feet along the channel improvements extents from the existing invert elevation, maintain 3H:1V side slopes along each reach, maintain a 10 feet bottom width along each reach, and maintain the same channel slope as existing conditions.

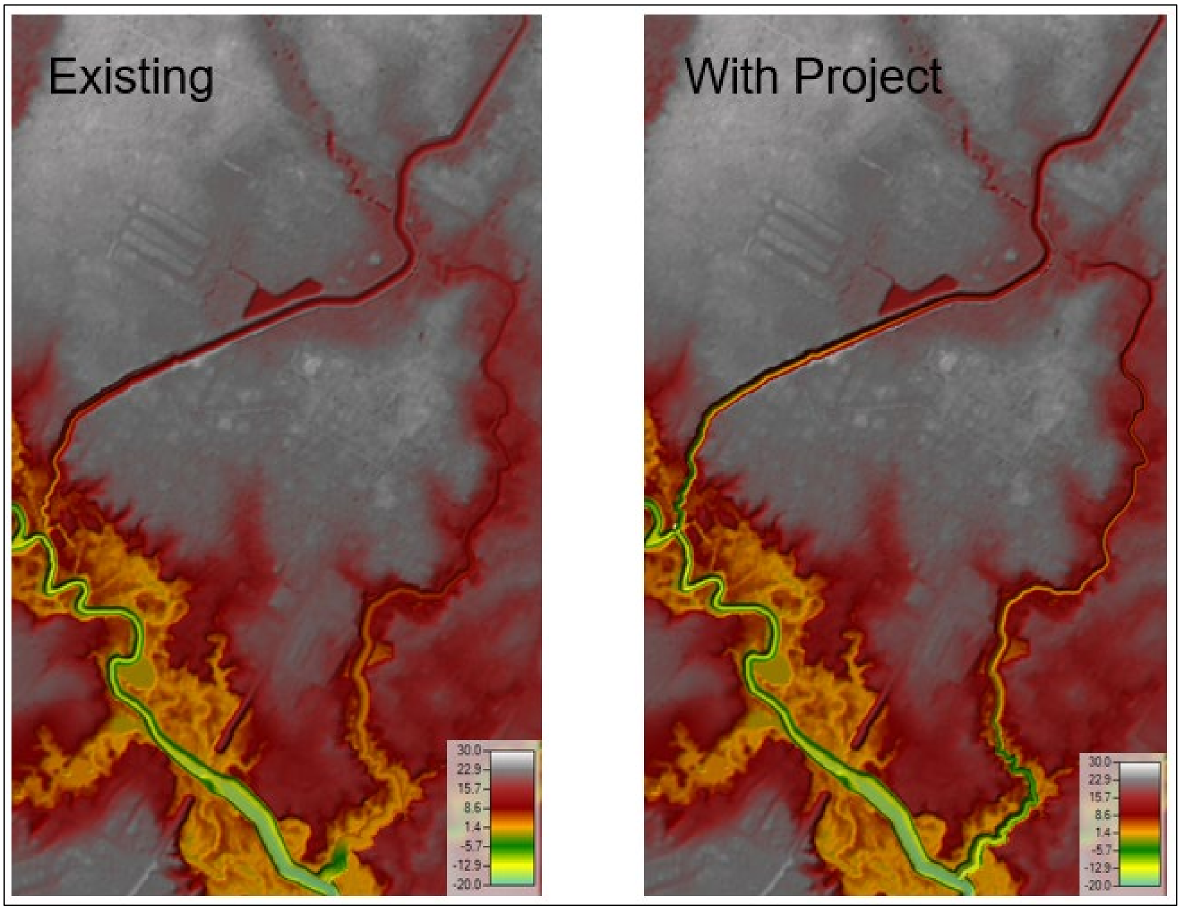


Figure E:6-8. Mile Branch and Lateral A Existing Conditions (Left) and With-Project Dredging (Right

6.2 ADCIRC CSRM ALTERNATIVE ANALYSIS

Alternative analysis of the CSRM alternatives involved delineating areas protected by proposed alternatives, estimating impacts on the exterior of the proposed alternatives, determining preliminary design elevations for alignments, and estimating capacities of interior drainage facilities where proposed alignments cross large waterways.

The measures proposed in the Final Array of alternatives were not directly modeled in ADCIRC. Determining storm surge response to proposed systems, and for a wide range of storms, requires numerous simulations of storms with different characteristics. Future modeling of the RP is required to show detailed responses to the proposed system.

Areas that would be protected by proposed future Federal levees investigated during the Alternative Analysis phase were determined using a Louisiana statewide LiDAR dataset. Design elevations, described in Section 5.1, were continued to meet existing high ground.

Contour lines of that tie-in elevation form the remaining sides of the polygon that represents the area protected by each proposed levee alignment.

6.2.1 Alternative 4 - Lacombe

Figure E:6-9 illustrates the three measures investigated under Alternative 4. Alternative 4a Lacombe levee protects the Lacombe area from flood risk. Alternative 4a.1 Bayou Lacombe Levee Short follows Alternative 4a, but does not include the western extension. Alternative 4b combines the Alternative 4a Lacombe levee alignment with the West Slidell levee (further investigated independently under Alternative 5). Figures E:6-10 and E:6-11 depict the alternative analysis performed for these measures explained previously in Section 6.2. *Furthermore, Section 7 explains the abbreviated interior drainage analysis conducted for the CSRM measure considered to mitigate for interior rainfall within the approximately 20 square mile area of protection for Alternative 4a, approximately 18 square mile area of protection for Alternative 4a1, and approximately 30 square mile area of protection for Alternative 4b.*

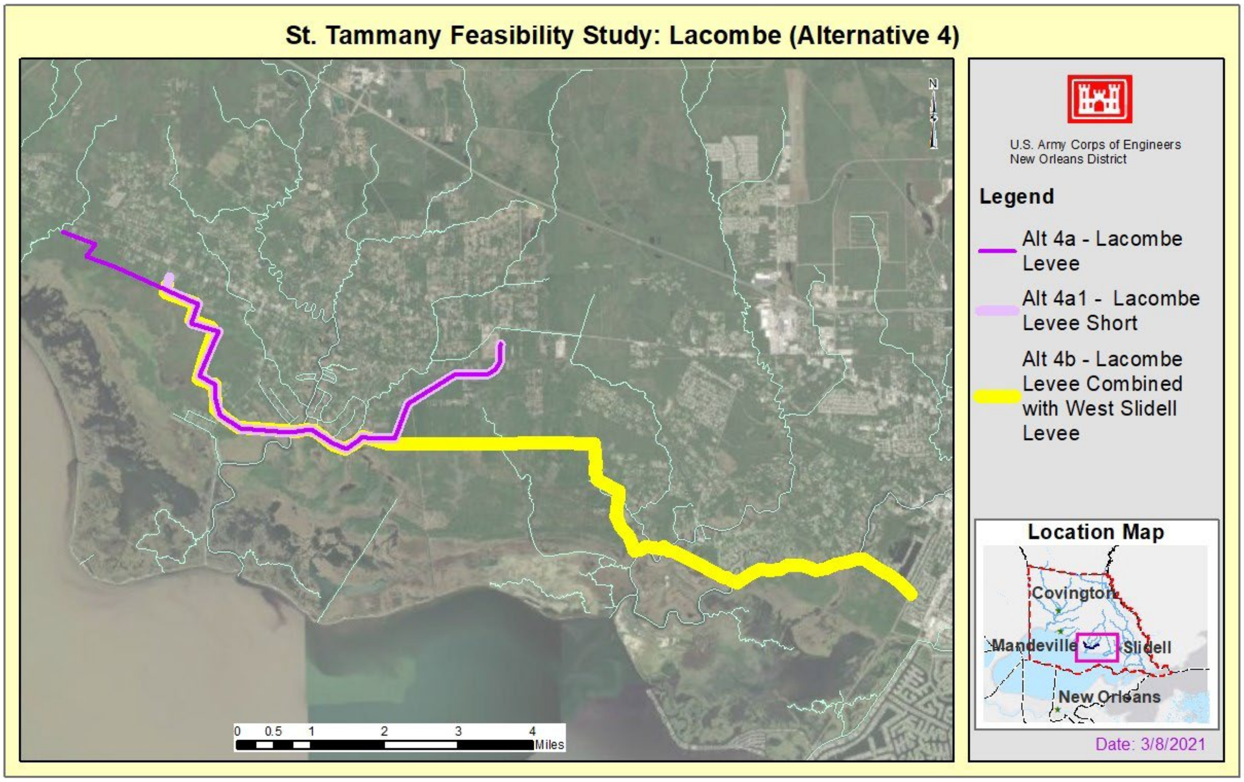


Figure E:6-9. Alternative 4 Measures: West Slidell and Lacombe Proposed CSRM Measures

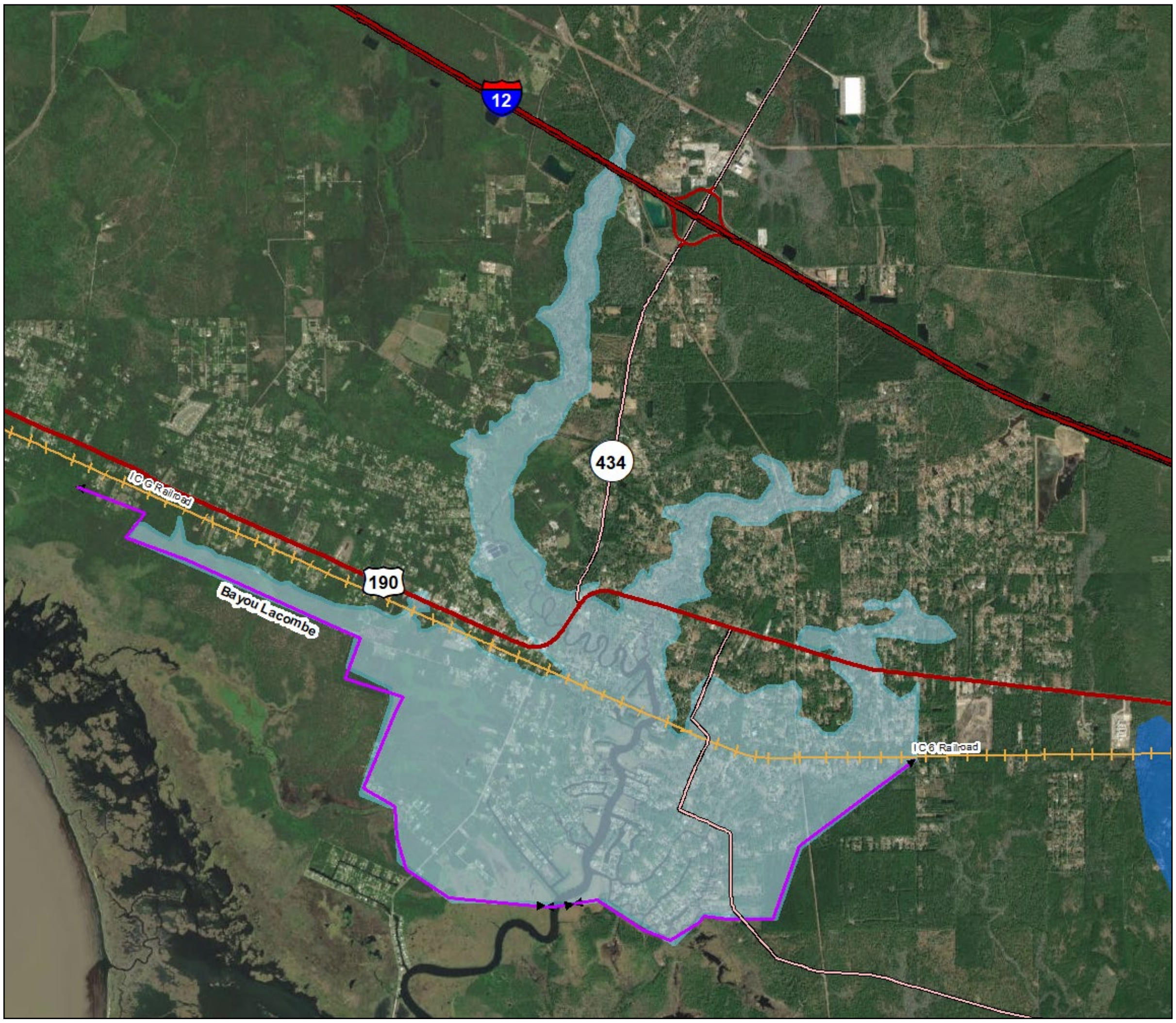


Figure E:6-10. Lacombe Protected Area

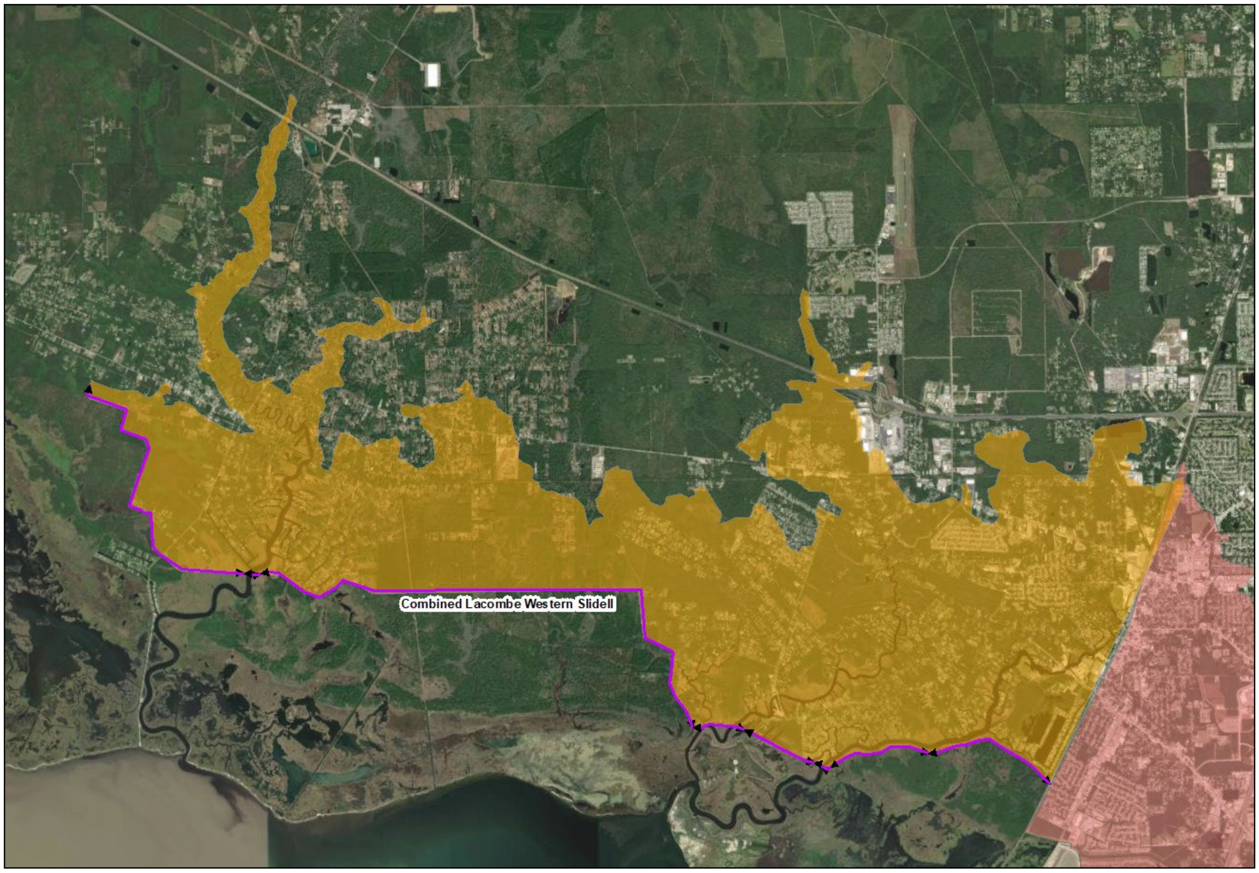


Figure E:6-11. Alternative 4A - Lacombe and West Slidell Protected Area

6.2.2 Alternative 5 – Bayou Liberty/Bayou Vincent/Bayou Bonfouca

Figure E:6-12 illustrates the four measures investigated under Alternative 5. Under Alternative 5, the only CSRM measure investigated was the West Slidell levee. Figure E:6-13 depicts the alternative analysis performed for this measure explained previously in Section 6.2. Furthermore, Section 7 explains the abbreviated interior drainage analysis conducted for the CSRM measure considered to mitigate for interior rainfall within the approximately 23 square mile area of protection.

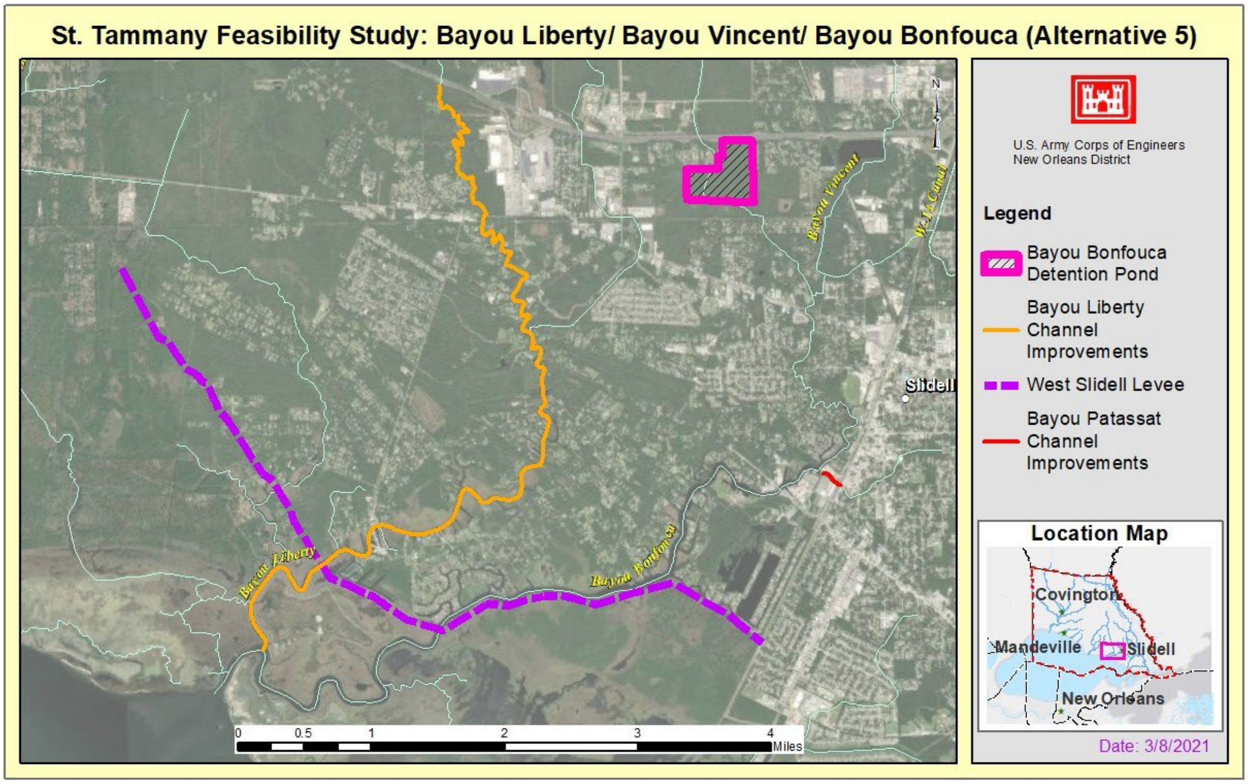


Figure E:6-12. Alternative 5 Measures: Bayou Bonfouca Detention Pond, Bayou Liberty Channel Improvements, West Slidell Levee, and Bayou Patassat Channel Improvements

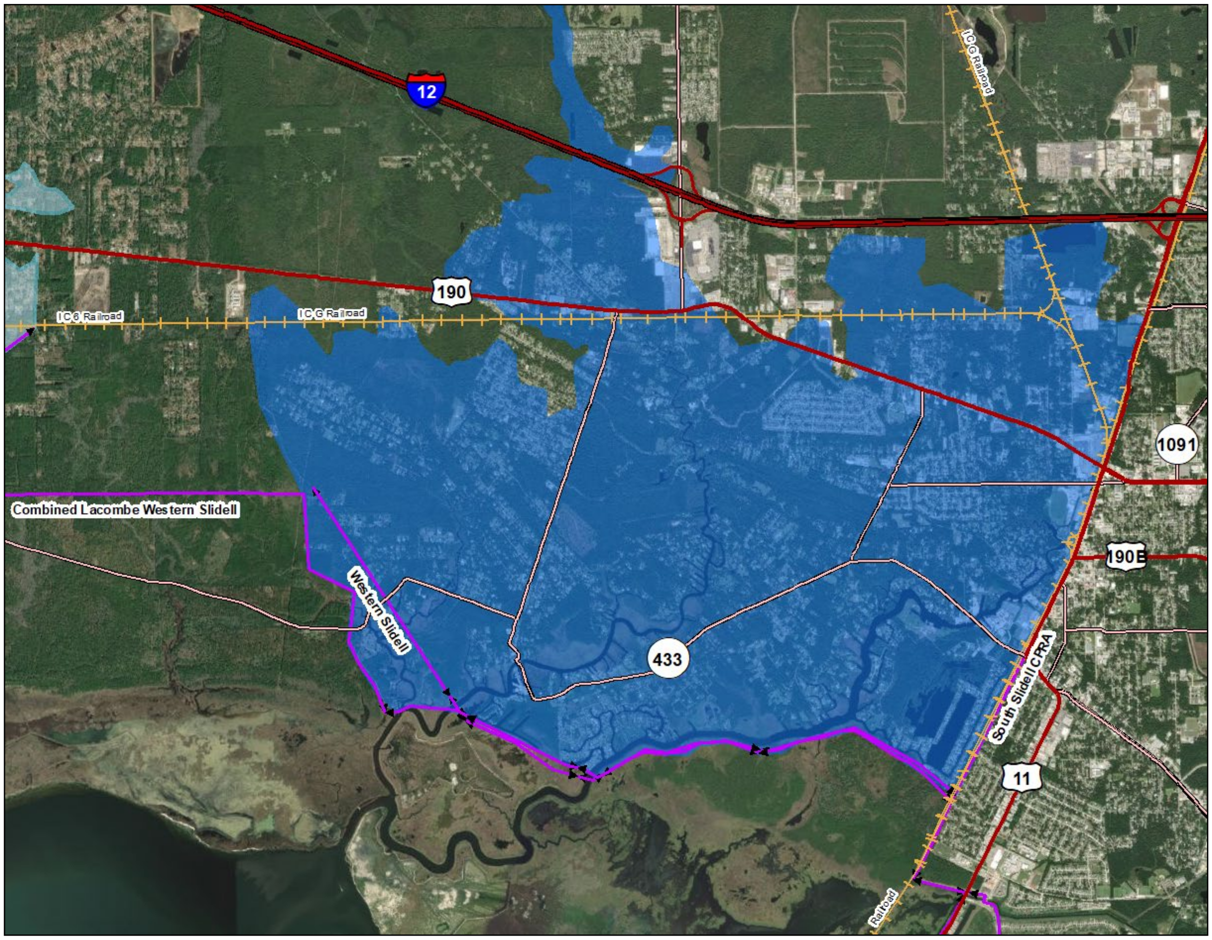


Figure E:6-13. West Slidell Protected Area

6.2.3 Alternative 6 – South Slidell Storm Surge

Figure E:6-14 illustrates the two measures investigated under Alternative 6 along with existing alignments in the South Slidell region. Figures E:6-15 and E:6-16 depict the alternative analysis performed for the following two measures of Alternative 6: Alternative 6a - the South Slidell Federal levee alignment with pump stations and Alternative 6b - the South Slidell Federal levee alignment with pump stations plus Eden Isle. The analysis for these measures is explained in Section 6.2. Please note Alternative 6c3 is a combination of features evaluated in Alternative 5 and 6. Furthermore, Section 7 explains the abbreviated interior drainage analysis conducted for the CSRM measure considered to mitigate for interior rainfall within the approximately 15 square mile area of protection.

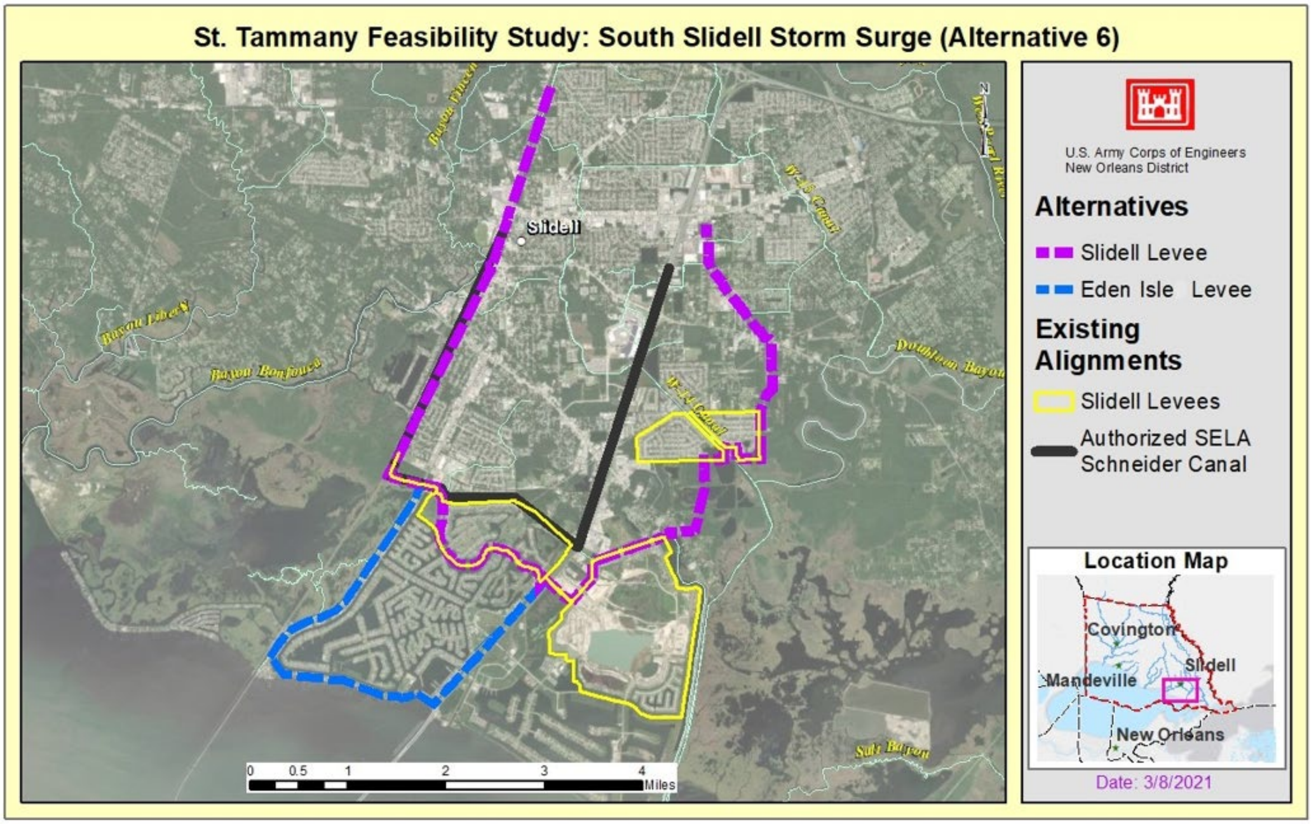


Figure E:6-14. Alternative 6 Measures: Proposed Slidell Levee Alignment and Eden Isle Levee

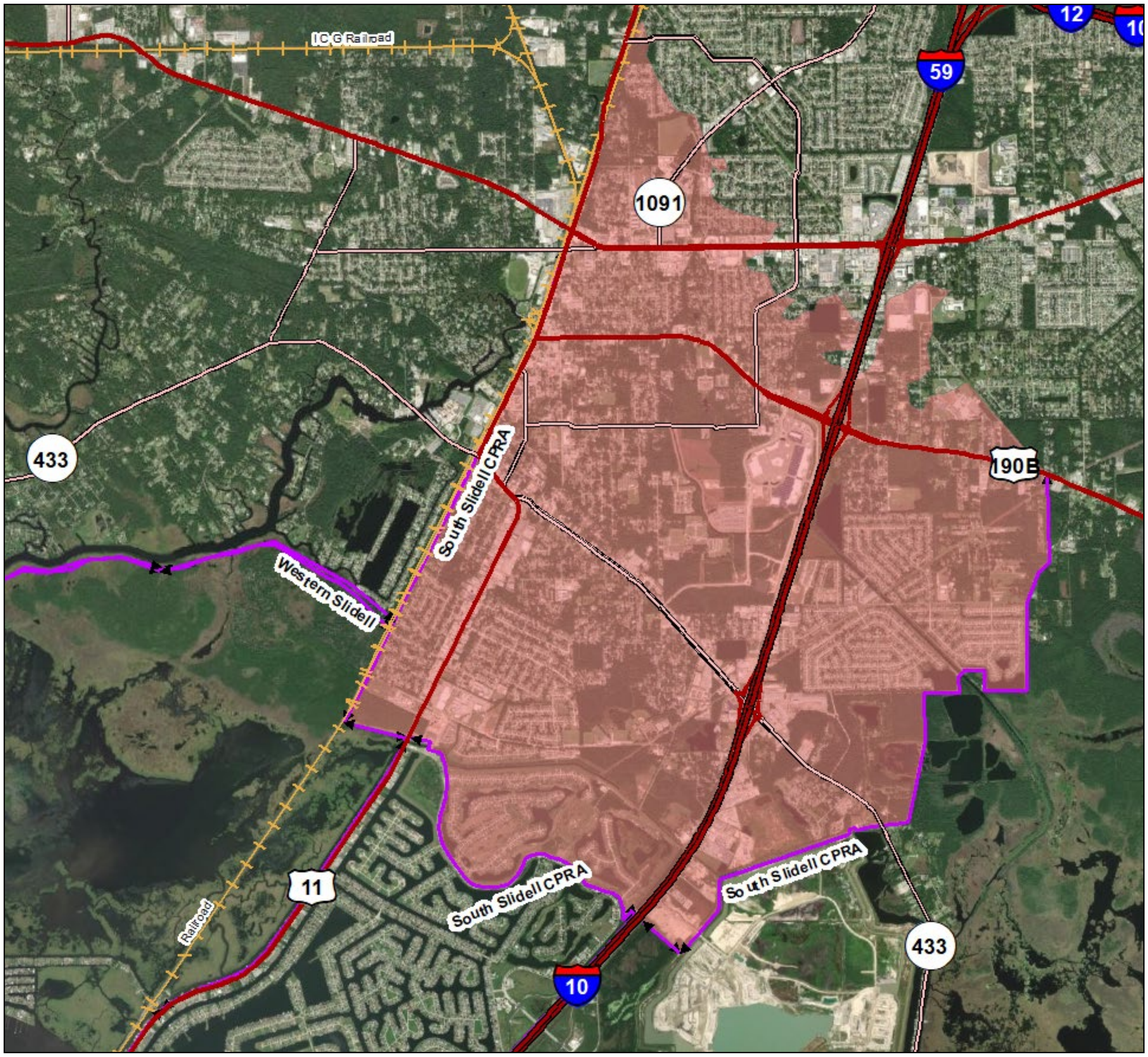


Figure E:6-15. South Slidell (CPRA Alignment) Protected Area

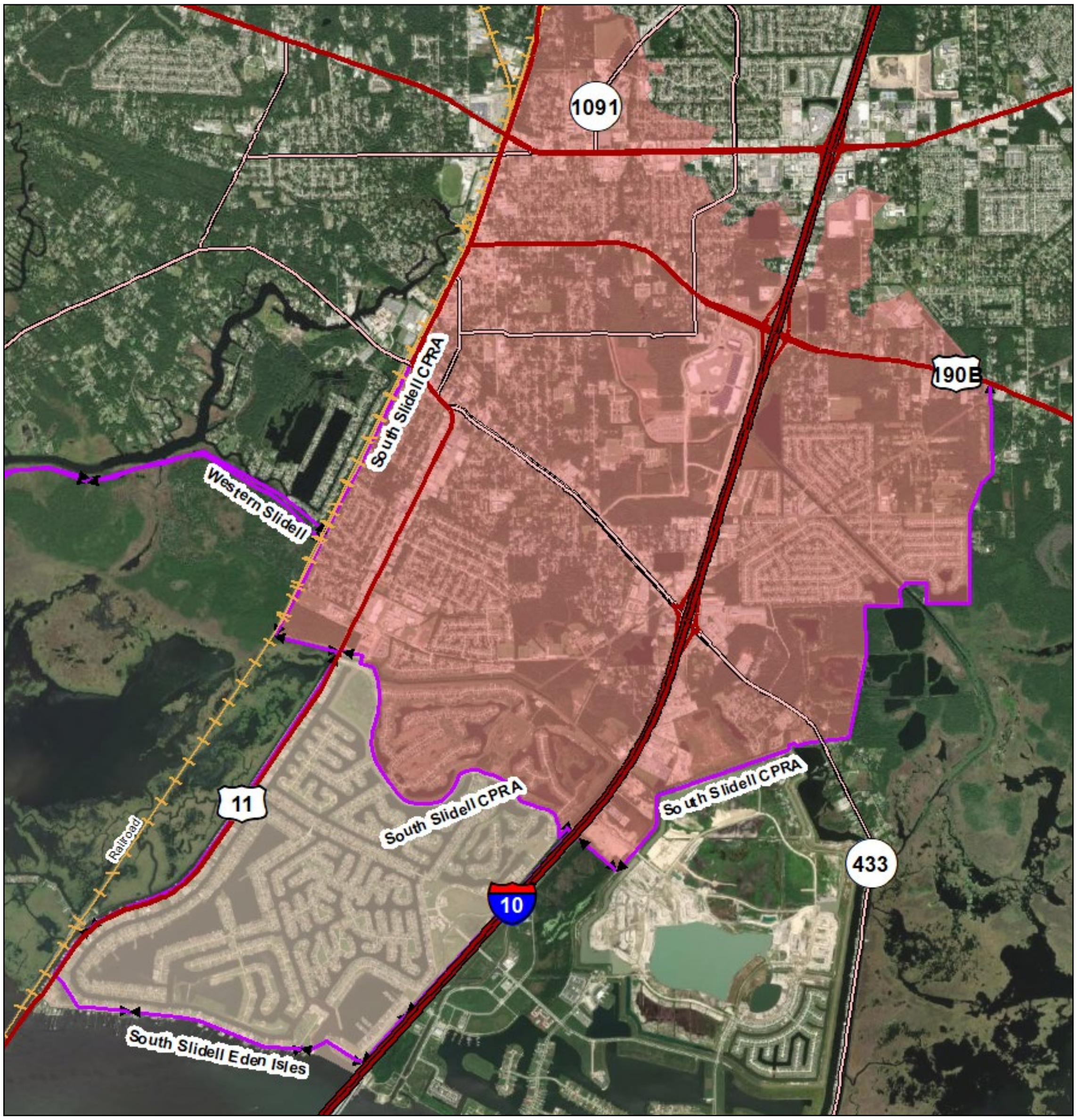


Figure E:6-16. South Slidell + Eden Isle Protected Area

6.2.4 Alternative 9 – Mandeville Lakefront

Figure E:6-17 illustrates measures investigated under Alternative 9 in the Mandeville Lakefront area. Figure E:6-18 depicts the alternative analysis performed for the Mandeville Lakefront region. The analysis for this Alternative is explained in Section 6.2. Variations of this alternative – in the form of Alternastives 9a, 9b, and 9c – are desbribed in Section 7.1.4. Furthermore, Section 7 explains the abbreviated interior drainage analysis conducted for the CSRM measure considered to mitigate for interior rainfall within the approximately 2 square mile area of protection.

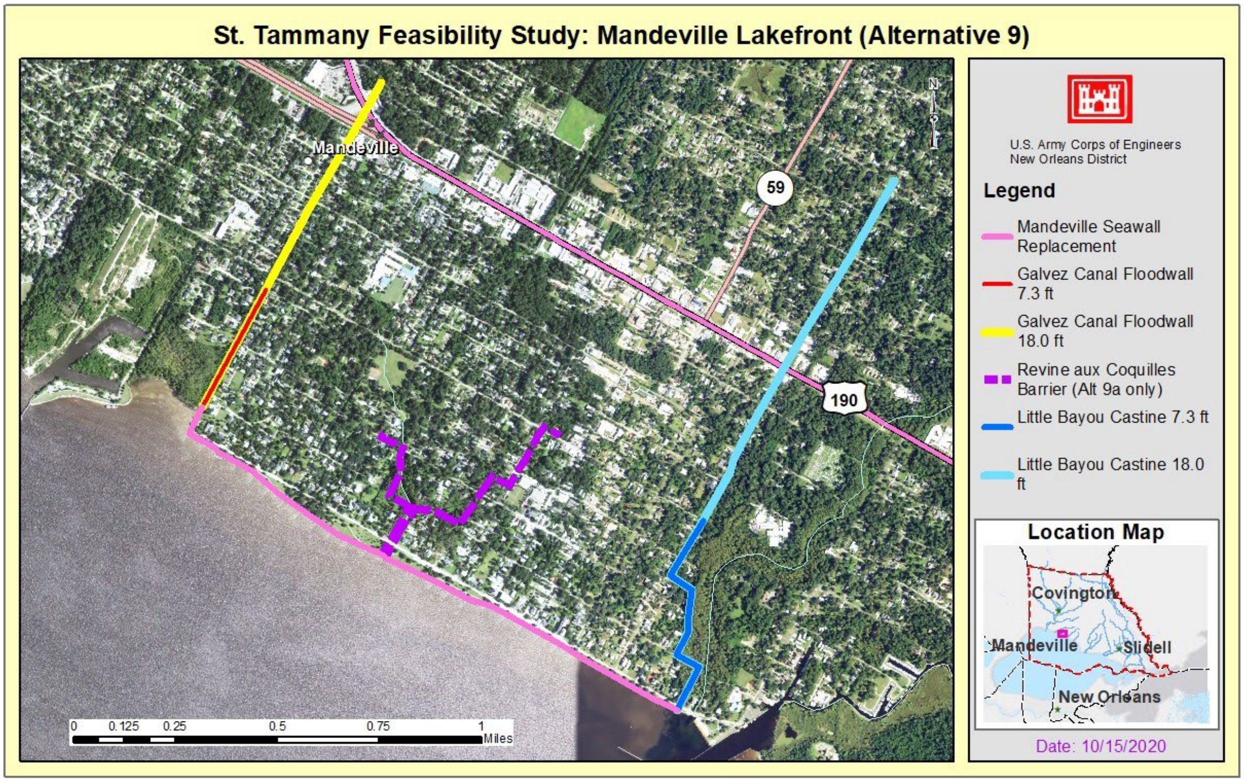


Figure E:6-17. Alternative 9 Measures: Mandeville Seawall Replacement, Galvez Canal Floodwall, Ravine Aux Coquilles Passive Barrier, and Little Bayou Castine Passive Barrier

Figure E:6-18. Mandeville (7.3') Protected Area

6.3 GENERAL ESTIMATES OF FLOODSIDE WATER LEVEL CHANGES FOR ALTERNATIVE ANALYSIS

The strongest caution and caveats should be taken with the quantitative estimates made for the purposes of making comparisons between the different Alternatives. The measures proposed in the Alternatives were not directly modeled in ADCIRC. Determining storm surge response to proposed measures, and for a wide range of storms, requires numerous simulations of storms with different characteristics. Modeling of the RP is required to show detailed responses to the proposed measure. Prior coastal modeling for the 2009 LACPR study, the USACE Morganza to the Gulf project, and the ongoing USACE West Shore Lake Pontchartrain project provided some context for the estimates. However, storm surge and wave response are highly dependent on the geometry of the area. Therefore, response in one location cannot be assumed to be the same in another location.

Hurricane risk reduction systems that protect areas not currently protected reduce the “floodplain” volume available for storm surge. This reduction has the potential to increase water levels outside of the new alternatives and measures for some storms.

Based on modeling of other systems, it is possible to see increases of 1-3 feet in the 1 percent AEP water level on the flood side of the new system(s). The 1 percent AEP water level is computed based on a statistical analysis of a variety of storms with different characteristics. A particular storm could show changes near the high end of that estimated range, while another could show small to negligible changes.

The alternatives in the Final Array would not be expected to cause significant changes to storm surge levels for the USACE Lake Pontchartrain and Vicinity project, nor to the USACE West Shore Lake Pontchartrain project.

Section 7
Interior Drainage Estimates

Interior drainage estimates for hydraulic infrastructure was provided to the PDT during the alternative analysis phase. It should be noted that no in-depth interior drainage modeling has been completed for this phase of the study. All estimations provided herein must be re-evaluated for any measures that are included in the TSP.

Interior drainage estimates came from a variety of sources due to funding and schedule constraints. For alternatives where design data was available for hydraulic infrastructure, capacities from those design sources were verified using the 10-year existing conditions flows. For alignments where no prior design alternatives were available, the 10-year existing conditions flows were used as the basis of hydraulic infrastructure sizing. Sources of pumping capacities for drainage features along each alignment investigated are summarized in section 7.1.

7.1 CSRM DRAINAGE NOTES

7.1.1 Alternative 4 –Lacombe (4a. 4a.1 and 4b)

7.1.1.1 Drainage Features Associated with -Lacombe Levee

Bayou Lacombe Floodgate and Pump Complex: A new flood gate and pump control complex would be required at the intersection of Bayou Lacombe and the proposed alignment. Ten-year 2032 flow for capacity calculation used is 3,200 cfs.

Bayou Paquet Floodgate and Pump Complex: A new floodgate and pump complex would be required where the proposed Combined Levee alignment intersects with Bayou Paquet. The 10-year 2032 flow for capacity calculation used is 500 cfs.

Bayou Paquet/Liberty Floodgate and Pump Complex: A new floodgate and pump control complex would be required at the confluence of Bayou Paquet and Bayou Liberty because the Combined Levee alignment crosses this confluence. The 10-year flow for capacity calculation used is 500 cfs.

7.1.2 Alternative 5 – Bayou Liberty/Bayou Vincent/Bayou Bonfouca

7.1.2.1 Drainage Features Associated with -Combined Levee

Bayou Liberty Floodgate and Pump Complex: A new floodgate and pump complex would be required at the intersection of the proposed West Slidell Levee alignment and Bayou Liberty. The 10-year flow for capacity calculation used is 3,200 cfs.

Bayou Bonfouca Floodgate and Pump Complex: A new floodgate and pump complex would be required for this measure at the intersection of the proposed West Slidell levee alignment and Bayou Bonfouca. The 10-year flow for capacity calculation used is 3,700 cfs.

7.1.3 Alternative 6 – South Slidell (6a & 6b)

7.1.3.1 Drainage Features Associated with Slidell Levee

W-14 Floodgate/Pump Station: A new floodgate and pump complex would be required at the intersection of the Slidell levee alignment and the W-14 canal. The 10-year flow used for capacity of pump station design is 1,200 cfs.

Schneider Canal Pump Complex: There is a pumping station at the intersection of Schneider Canal and the proposed levee alignment, which was constructed by the City of Slidell. The 1990 USACE Schneider Canal, Slidell, LA Hurricane Protection Reconnaissance Report identified a capacity of 100 cfs. It is important to note that the Schneider Canal pump station was constructed by the City of Slidell at a capacity of 850 cfs. It is unlikely that additional capacity is needed there. The existing pump station does not have fronting protection, but that need has been identified in the ongoing USACE Southeastern Louisiana Project (SELA) Schneider Canal hurricane protection study.

7.1.4 Alternative 9 (9a, 9b, 9c) – Mandeville Lakefront

7.1.4.1 Alternative 9a Mandeville Lakefront-Seawall Passive Drainage

This Alternative has the 7.3 foot wall at the lakefront, is open at Ravine Aux Coquille, and has walls along the banks of Ravine aux Coquille. In total, four pump stations are proposed for this alternative. From information provided by Principal Engineering and later confirmed, the rational method peak flows are:

1. West Beach Parkway – 116 cfs
2. Lafayette Street – 33 cfs
3. Coffee Street – 106 cfs
4. Girod Street – 139 cfs

7.1.4.2 Alternative 9b - Mandeville Lakefront-Seawall Pump Stations

This Alternative includes the 7.3 foot wall at the lakefront and closure with a pump station at Ravine aux Coquille. In total, two pump stations are proposed for this Alternative. The Ravine aux Coquille pump station will accommodate a larger drainage area that includes the peak flows in-taken from the smaller pump stations stated in Alternative 9a previously. The smaller pump stations for individual basins are only needed when the natural drainage to ravine aux coquille is cut off by the passive alignment walls. The pump stations that would not be required include West Beach Parkway, Lafayette Street, and Coffee Street.

The two pump stations required and the capacity of each are:

1. **Girod St (**location to drain the area intercepted by the eastern side floodwall adjacent to Little Bayou Castine)**– 200 cfs**
2. **Ravine aux Coquille** (would be in conjunction with a 25 ft wide gate near the mouth of the waterway that can be closed when needed) – **500 cfs**

Note: For documentation, the sizing of these pump stations came from the report by GEC for the town of Mandeville and the pumping capacity is based on a 10-year, 24-hour storm. USACE H&H analysis of interior drainage inside proposed alternatives for coastal protection has been limited to high-level estimates and use of previous analyses.

7.1.4.3 Alternative 9c – Mandeville Lakefront – 18 feet

This Alternative includes an 18 foot wall at the lakefront, and a closure and pump station at Ravine aux Coquille. In total, two pump stations are proposed for this measure. The Ravine aux Coquille pump station would accommodate a larger drainage area that includes the peak flows in-taken from the smaller pump stations stated previously in Alternative 9a. The smaller pump stations for individual basins are only needed when the natural drainage to ravine aux coquille is cut off by the passive alignment walls. The pump stations that would not be required include West Beach Parkway, Lafayette Street, and Coffee Street.

The two pump stations required and the capacity of each are:

1. **Girod St** (location to drain the area intercepted by the eastern side floodwall adjacent to Little Bayou Castine and then continues inland)**– 450 cfs**
2. **Ravine aux Coquille** (would be in conjunction with a 25 ft wide gate near the mouth of the waterway that can be closed when needed) – **500 cfs**

Note: For documentation, the sizing of these pump stations came from the report by Gulf Engineers and Consultants (GEC) for the town of Mandeville and the pumping capacity is based on a 10-year, 24-hour storm. USACE H&H analysis of interior drainage inside proposed alternatives for coastal protection has been limited to high-level estimates and use of previous analyses.

7.2 FRM DRAINAGE NOTES

7.2.1 Alternative 5 – Bayou Liberty/Bayou Vincent/Bayou Bonfouca

7.2.1.1 Bayou Liberty Channel Improvements

The Bayou Liberty channel improvements (clearing and snagging) measures includes the clearing and snagging of Bayou Liberty from I-12 downstream to the confluence with Bayou Bonfouca. This measure was originally documented in the 2007 Bayou Liberty Watershed Management Plan. This measure was modeled with a reduced Manning’s n value of 0.3 along that section of the river. No specific interior drainage information was requested from the PDT.

7.2.1.2 Bayou Patassat Channel Improvements

The Bayou Patassat Channel Improvements measure was modeled as a clearing and snagging alternative. Bayou Patassat has a pump station at its confluence with Bayou Bonfouca, but this detail was not included in the model. The analysis was acceptable because Bayou Patassat drainage pattern in the Existing Conditions model acted as anticipated. No channel deepening was performed for this alternative. This was modeled with a reduced Manning's n value along the main stem of Bayou Patassat of 0.3. No specific interior drainage information was requested from the PDT.

7.2.1.3 Bayou Bonfouca Detention Pond

This measure was derived from the 2014 St. Tammany Watershed Management Study conducted by CPRA and St. Tammany Parish Government. That study recommended a 100-acre detention pond but cited no recommended capacity or dimensions of the pond. The design team optimized the detention pond to maximize storage. Therefore, the optimized detention pond modeled has a footprint of 109 acres, a depth of 12 feet, and 1V:3H side slopes. This measure provides 1,308 acre-feet of storage capacity.

7.2.2 Alternative 7 – Eastern Slidell

7.2.2.1 Doubloon Bayou and Poor Boy Canal Channel Improvements

The Doubloon Bayou and Poor Boy Canal channel improvement measures were modeled as a deepened channel. This measure was modeled by lowering the existing conditions invert by 5 feet along the entire alignment. Poor Boy Canal flows in both directions between the W-15 Canal and Gum Bayou. No specific interior drainage information was requested from the PDT.

7.2.2.2 Pearl River Levee

A new flood gate and pump control complex would be required at the intersection of Gum Bayou and the proposed alignment. The necessary interior drainage modeling to give an accurate capacity estimate has not been completed. Therefore, the uncertainty of the below estimated rough order of magnitude (ROM) capacity of the Pearl River Levee may be +/- nearly 100 percent.

The protected side of the proposed Federal levee naturally drains overland to the West Pearl and by Gum Bayou. Rough model results show a 10-year flow around 540 cfs in the channel and up near 560 cfs if the entire channel and low-lying overbank is included. Therefore, 600 cfs is the proposed capacity for this pump station.

7.2.2.3 Gum Bayou Diversion

The Gum Bayou Diversion alignment was placed along an old drainage path of the West Pearl River. The lowland areas surrounding Gum Bayou drain towards the West Pearl River. No specific interior drainage information was requested from the PDT.

7.2.3 Alternative 8 – Upper Tchefuncte/Covington

7.2.3.1 Mile Branch and Lateral A Channel Improvements

These measures came from the 1991 USACE Tangipahoa, Tchefuncte, and Tickfaw Rivers Reconnaissance Study. That study recommended the deepening of both Mile Branch and Lateral A to provide flood protection up to the 25-year frequency storm. These measures were modeled by deepening both rivers' inverts by 5 feet along the entire reach. Both Mile

Branch and Lateral A drain into the Tchefuncte River. No specific interior drainage information was requested from the PDT.

Section 8

TSP Optimization - General Description of Work

USACE, MVD, MVN, HH&C performed hydrologic and hydraulic modeling for the RP. The purpose of this hydrologic and hydraulic modeling effort is to evaluate in greater depth, the FRM and CSRM features identified in the TSP. It should be noted that Sections 1 through 7 of this appendix pertain to the alternative analysis phase of this study. Section 8 through the end of this appendix covers the RP modeling effort.

Riverine modeling was performed for the 2, 5, 10, 25, 50, 100, 200, and 500-year rainfall events for existing conditions, with-project base (year 2032), and future conditions (year 2082). Coastal storm surge and wave modeling was completed for existing conditions, with-project base (year 2032), and future conditions (year 2082). WSE results for the coastal storm surge and wave modeling were statistically computed and provided to the PDT for use in economic, environmental, and engineering analyses for the following return periods: 10, 20, 50, 100, 200, 500, and 1000-year events.

Listed below in Table E:8-1. TSP measures and modeling methodology are the alternatives included in the RP. The three structural plans including Alternative 5, Alternative 6c3, and Alternative 8 were all evaluated using HEC-RAS modeling. The coastal protection system, Alternative 6c3, was also modeled using ADCIRC modeling. For the nonstructural plan, Alternative 2, HH&C applied model refinements to the entire model domain to prepare Economics for their analysis.

Table E:8-1. TSP Measures and modeling methodology

Alternative Number	Alternative Description	Modeling Methodology
Alternative 2	Nonstructural Elevations and Flood Proofing	Refinements applied to entire HEC-RAS model domain to aid in nonstructural plan analysis
Alternative 5	Bayou Patassat Channel Improvements-Clearing and Snagging	Modeled in HEC-RAS
Alternative 6c3	South Slidell and West Levee and Floodwall System	Modeled in ADCIRC for storm surge output and in HEC-RAS for flood control structure sizing
Alternative 8	Mile Branch Channel Improvements	Modeled in HEC-RAS

Section 9
RP – Software and Model Development

9.1 HEC-HMS 4.8

The latest version of the USACE HEC-HMS available at the time of model development was used for the hydrologic modeling. A new HEC-HMS model was developed for the RP. Elements from the HEC-HMS model used in the alternative analysis phase were carried over to the newly developed HMS model for the RP. Further discussion on the HEC-HMS model used for this study may be found in Section 10 of this appendix.

9.2 HEC-RAS 6.2

The latest version of the USACE HEC-RAS available at the time of model development was used for the hydraulic modeling in this study. A new HEC-RAS model was developed for the RP. Various elements from the HEC-RAS model used in the alternative analysis phase were carried over to the newly developed model for the RP. It should be noted a few different versions of HEC-RAS were released during the lifetime of this modeling effort. At the time the modeling effort began, HEC-RAS 6.0 was being used for model development. By the time production runs were being executed, HEC-RAS 6.2 was being used. Additionally, known issues in the software that affected model results were uncovered during the timespan of this study. For all known issues, fixes or workarounds were developed and incorporated. Further discussion on the HEC-RAS model used for this study may be found in Section 12 of this appendix.

9.3 ADVANCED CIRCULATION (ADCIRC) MODEL

Coastal modeling simulations used the ADCIRC v55 coupled with the SWAN model to develop storm surge elevations, wave heights, and wave periods. A suite of 36 synthetic tropical storms were conducted using the Costal Storm Modeling System (CSTORM-MS) modeling framework (Massey et al., 2011) and run using the Onyx supercomputer as part of the Department of Defense High Performance Computing Modernization Program. ADCIRC statistics were computed using MATLAB code developed by Engineer Research and Development Center (ERDC). The coastal modeling process is discussed in more detail in Section 13.

Section 10

RP - Hydrology

As explained in Section 3 of this Appendix, St. Tammany Parish is comprised of 10 major watersheds: the Pearl River, Gum Bayou, W-14/W-15 basin, Bayou Bonfouca, Bayou Lacombe, Bayou Cane, Bayou Castine, Little Bayou Castine, Bayou Chinchuba and the Tchefuncte River. A comprehensive list of the bodies of water in these watersheds may be found in Figure E:3-1 and Table E:3-1. Additionally, the study area experiences flood risk from three primary sources: coastal storm surge and waves from Lake Pontchartrain, local rainfall on and around the study area, and the Pearl River basin that outlets to the Gulf of Mexico along the eastern boundary of St. Tammany Parish.

10.1 PRECIPITATION AND RUNOFF

During this modeling effort, eight precipitation events were evaluated: the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year, and 500-year recurrence interval 24-hour duration events. Frequency storm precipitation hyetographs were developed for each of those events based on rainfall intensities from the NOAA Atlas 14 Volume 9 Version 2 Point Precipitation Frequency Estimates. Figure E:10-1 and Figure E:10-2 depict the NOAA Atlas 14 Precipitation frequency depth-duration and depth-frequency, respectively. Annual Maximum Series data was used for Lacombe, LA, a site near the center of St. Tammany Parish. Aerial reduction was applied using the TP-40 method.

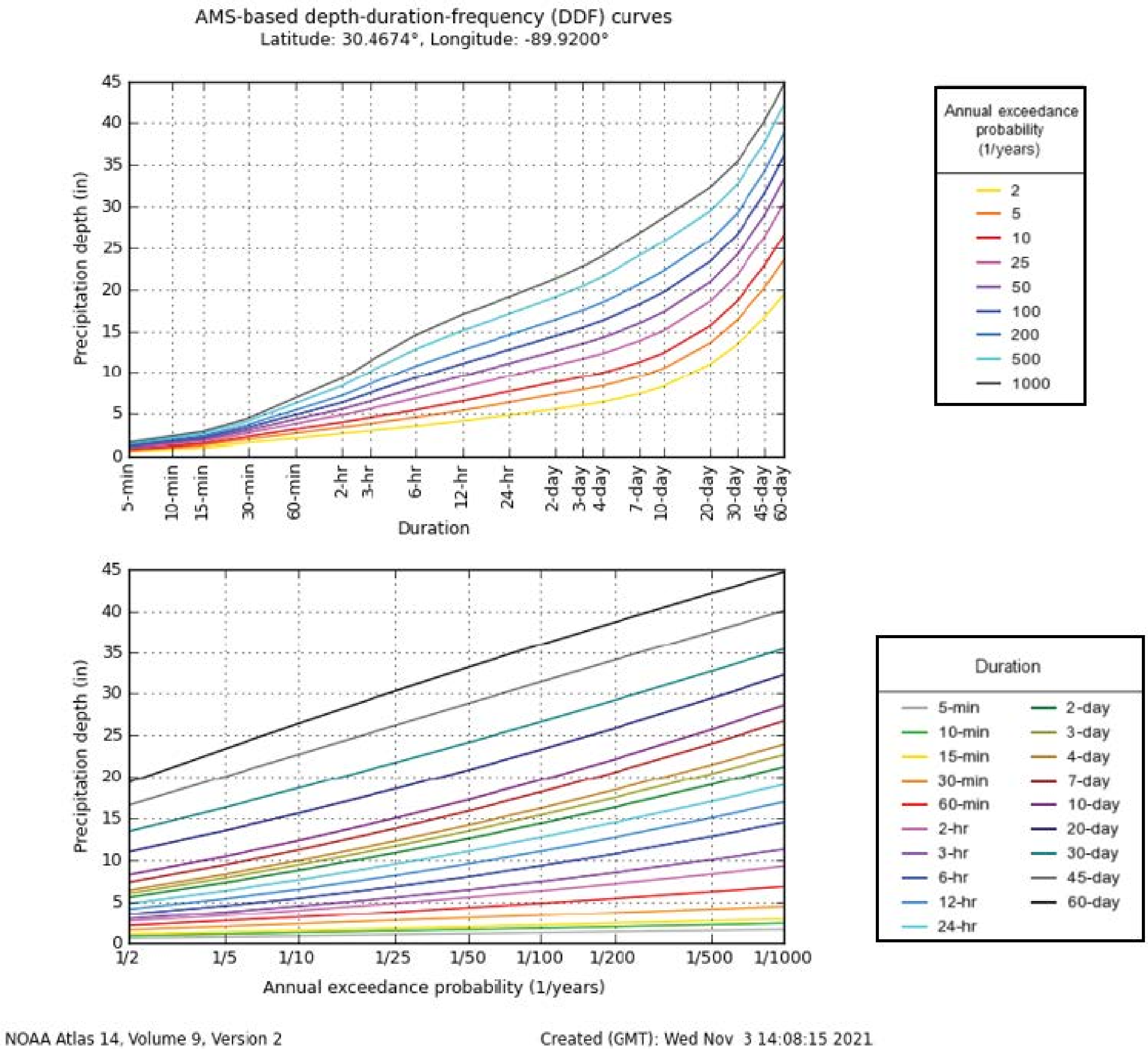


Figure E:10-1. NOAA Atlas 14 Precipitation Data by Annual Exceedance and Duration

AMS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Annual exceedance probability (1/years)								
	1/2	**1/5**	**1/10**	**1/25**	**1/50**	**1/100**	**1/200**	**1/500**	**1/1000**
5-min	**0.584** (0.471-0.721)	**0.729** (0.587-0.902)	**0.841** (0.673-1.04)	**0.991** (0.769-1.25)	**1.11** (0.841-1.42)	**1.22** (0.901-1.59)	**1.34** (0.953-1.78)	**1.50** (1.03-2.03)	**1.62** (1.09-2.22)
10-min	**0.855** (0.690-1.06)	**1.07** (0.859-1.32)	**1.23** (0.985-1.53)	**1.45** (1.13-1.84)	**1.62** (1.23-2.07)	**1.79** (1.32-2.33)	**1.96** (1.40-2.60)	**2.19** (1.51-2.97)	**2.37** (1.59-3.24)
15-min	**1.04** (0.841-1.29)	**1.30** (1.05-1.61)	**1.50** (1.20-1.86)	**1.77** (1.37-2.24)	**1.97** (1.50-2.53)	**2.18** (1.61-2.84)	**2.39** (1.70-3.18)	**2.67** (1.84-3.62)	**2.89** (1.94-3.96)
30-min	**1.59** (1.28-1.96)	**2.00** (1.61-2.47)	**2.31** (1.85-2.87)	**2.73** (2.12-3.46)	**3.06** (2.32-3.91)	**3.38** (2.49-4.40)	**3.70** (2.63-4.92)	**4.14** (2.84-5.60)	**4.47** (3.00-6.12)
60-min	**2.12** (1.71-2.61)	**2.68** (2.16-3.32)	**3.14** (2.52-3.90)	**3.79** (2.96-4.84)	**4.32** (3.30-5.56)	**4.87** (3.60-6.37)	**5.44** (3.88-7.27)	**6.25** (4.30-8.50)	**6.89** (4.62-9.43)
2-hr	**2.65** (2.15-3.24)	**3.37** (2.73-4.13)	**3.97** (3.20-4.89)	**4.85** (3.83-6.18)	**5.58** (4.30-7.16)	**6.36** (4.74-8.29)	**7.18** (5.17-9.55)	**8.36** (5.81-11.3)	**9.30** (6.29-12.7)
3-hr	**2.95** (2.41-3.60)	**3.78** (3.07-4.62)	**4.50** (3.64-5.51)	**5.57** (4.43-7.11)	**6.48** (5.02-8.31)	**7.47** (5.61-9.74)	**8.54** (6.18-11.3)	**10.1** (7.04-13.6)	**11.3** (7.69-15.4)
6-hr	**3.51** (2.88-4.25)	**4.55** (3.72-5.51)	**5.46** (4.45-6.65)	**6.86** (5.49-8.71)	**8.05** (6.29-10.3)	**9.35** (7.08-12.1)	**10.8** (7.86-14.2)	**12.8** (9.03-17.3)	**14.5** (9.92-19.6)
12-hr	**4.12** (3.41-4.96)	**5.41** (4.46-6.52)	**6.53** (5.35-7.89)	**8.19** (6.59-10.3)	**9.58** (7.52-12.1)	**11.1** (8.44-14.3)	**12.7** (9.33-16.7)	**15.1** (10.7-20.1)	**17.0** (11.7-22.7)
24-hr	**4.82** (4.01-5.74)	**6.36** (5.28-7.60)	**7.66** (6.32-9.18)	**9.54** (7.70-11.9)	**11.1** (8.75-13.9)	**12.7** (9.75-16.2)	**14.5** (10.7-18.9)	**17.0** (12.1-22.5)	**19.0** (13.2-25.3)
2-day	**5.58** (4.68-6.61)	**7.34** (6.13-8.70)	**8.79** (7.31-10.5)	**10.9** (8.84-13.4)	**12.6** (10.00-15.6)	**14.4** (11.1-18.2)	**16.3** (12.1-21.0)	**19.0** (13.6-25.0)	**21.2** (14.8-28.0)
3-day	**6.05** (5.08-7.13)	**7.91** (6.63-9.34)	**9.45** (7.88-11.2)	**11.7** (9.52-14.3)	**13.5** (10.8-16.7)	**15.4** (11.9-19.4)	**17.5** (13.0-22.4)	**20.4** (14.7-26.7)	**22.7** (15.9-29.9)
4-day	**6.42** (5.41-7.54)	**8.35** (7.02-9.83)	**9.96** (8.33-11.8)	**12.3** (10.1-15.0)	**14.2** (11.4-17.5)	**16.2** (12.6-20.4)	**18.4** (13.8-23.6)	**21.5** (15.5-28.0)	**23.9** (16.8-31.4)
7-day	**7.37** (6.25-8.61)	**9.47** (8.01-11.1)	**11.2** (9.45-13.2)	**13.8** (11.4-16.8)	**15.9** (12.8-19.5)	**18.2** (14.2-22.6)	**20.6** (15.5-26.2)	**24.0** (17.4-31.1)	**26.7** (18.9-34.9)
10-day	**8.27** (7.04-9.61)	**10.5** (8.90-12.2)	**12.3** (10.4-14.4)	**15.0** (12.4-18.2)	**17.2** (13.9-21.0)	**19.6** (15.3-24.4)	**22.1** (16.7-28.1)	**25.7** (18.7-33.2)	**28.6** (20.3-37.2)
20-day	**11.0** (9.44-12.7)	**13.6** (11.6-15.7)	**15.6** (13.3-18.1)	**18.5** (15.4-22.1)	**20.9** (16.9-25.2)	**23.3** (18.3-28.6)	**25.9** (19.6-32.4)	**29.4** (21.5-37.7)	**32.2** (23.0-41.6)
30-day	**13.4** (11.6-15.4)	**16.3** (14.0-18.8)	**18.6** (15.9-21.5)	**21.7** (18.0-25.7)	**24.2** (19.6-28.9)	**26.6** (21.0-32.5)	**29.2** (22.2-36.4)	**32.7** (24.0-41.6)	**35.4** (25.3-45.5)
45-day	**16.6** (14.3-18.9)	**20.1** (17.3-23.0)	**22.7** (19.5-26.1)	**26.2** (21.8-30.7)	**28.8** (23.5-34.2)	**31.4** (24.8-38.0)	**34.0** (25.9-42.1)	**37.5** (27.6-47.3)	**40.0** (28.8-51.3)
60-day	**19.3** (16.7-22.0)	**23.4** (20.2-26.7)	**26.4** (22.7-30.3)	**30.3** (25.2-35.3)	**33.2** (27.1-39.1)	**35.9** (28.4-43.2)	**38.6** (29.5-47.5)	**42.1** (31.0-52.9)	**44.6** (32.2-57.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of annual maxima series (AMS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and annual exceedance probability) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Figure E:10-2. Precipitation Frequency for Lacombe, LA (Central Location of the Parish)

10.2 HYDROLOGIC MODELING

HEC-HMS was used to model hydrology for the basin. Hydrology for frequency storms 2, 5, 10, 25, 50, 100, 200, and 500 years were computed based on the basin square mileage, canopy and loss calculations, and the model was run for a time period of three days. Precipitation occurred in the first day. The additional two days of hydrology model simulation provided inputs to the hydraulic model for a long enough duration for the storm peak to reach the outlets. Parameters from the alternative analysis phase HEC-HMS model were carried to this model. The alternative analysis phase model used a subset of the SLaMM model which has been calibrated for the March 2016 rain event. For these reasons, HEC-HMS model calibration was not originally planned for the combined model. Additionally, the HEC-HMS alternative analysis model that was used as a starting point for the RP phase had four separate subbasins within the study area, which corresponded to the HEC-RAS 2D areas used in the last phase. It was determined that the HEC-RAS 2D areas should be combined in an effort to reduce model instability, and in turn, the HEC-HMS subbasins were combined into a single subbasin area for the RP. During calibration of the HEC-RAS model for the RP, it was identified that parameters in the hydrology required adjustments.

Hydrologic losses, or infiltration, were calculated in the HEC-HMS model using the deficit and constant loss method. The deficit and constant loss method uses a single soil layer to account for continuous changes in moisture content. The deficit is the amount of water required at any point in time to bring the soil layer to saturation. Four parameters must be estimated using the deficit and constant loss method. The first parameter, initial deficit, specifies the amount of available water storage capacity in the soil layer at the beginning of the simulation. An initial deficit of 0.08 inches was used for the model subbasin. The second parameter, maximum deficit, specifies the maximum amount of water that can be held in the soil layer. A maximum deficit of 2 inches was used for the model subbasin. The constant rate defines how quickly water enters the soil while it is saturated and precipitation is occurring. A constant rate of 0.1 inches/hour was used for the model subbasin.

The constant rate parameter is the only parameter found that required adjustment between the two phases of this study and was identified during model calibration of the HEC-RAS model. During model calibration of the HEC-RAS model, spatially varied precipitation was applied to the single 2D area. It was found that the constant loss, identified as the potential percolation rate in HEC-RAS, needed to be increased from 0.05 to 0.1 inches/hour during calibration. This was determined because the hydrograph volume in every major waterway and gage location was biased high. A higher constant loss rate found to reduce error between observed and modeled stages. Therefore, this increase in the constant loss rate was applied to the HEC-HMS model.

Of the total precipitation depth at each computation interval, HEC-HMS computes the infiltration and runoff (excess precipitation) depth. This excess precipitation variable was used as the precipitation boundary condition on the single 2D area in the HEC-RAS model.

Section 11
RP - Climate Assessment

11.1 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 E:11- 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.

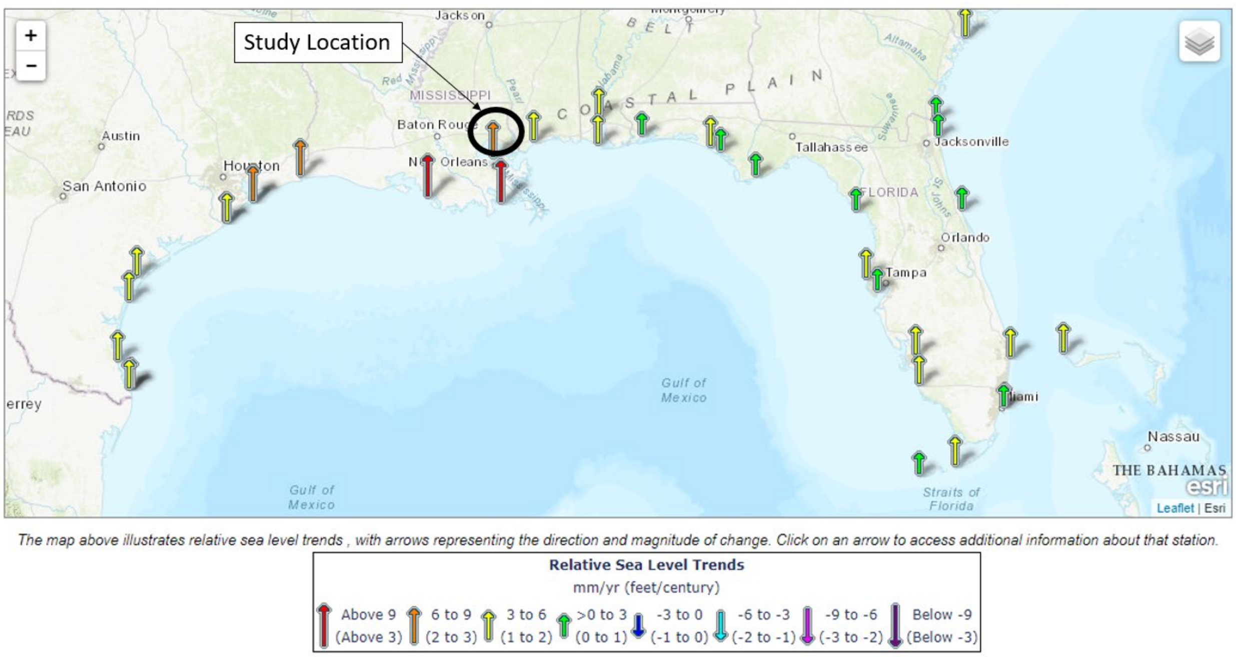


Figure E:11-1. Sea level trends measured by tide gages presented as local RSL trends as opposed to global sea level trend. [1]

[1] The Center for Operational Oceanographic Products and Services has been measuring sea level for over 150 years, with tide stations of the National Water Level Observation Network operating on all U.S. coasts. Changes in RSL, either a rise or fall, have been computed at 142 long-term water level stations using a minimum span of 30 years of observations at each location. These measurements have been averaged by month which removes the effect of higher frequency phenomena in order to compute an accurate linear sea level trend. The trend analysis has also been extended to 240 global tide stations using data from the Permanent Service for Mean Sea Level (PSMSL).

In accordance with USACE guidance, an assessment of climate change impacts must be performed in support of STPFS. Climate change impacts include SLR and inland hydrologic changes such as increases in temperatures, precipitation, storm intensity, and flood volumes.

The STPFS climate assessment analyzes climate change impacts from two hydrologic aspects. One of those is RSLC, 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 FRM and CSRM improvements within the study area, which are at risk to impacts of climate change. The study area is located within two regions: the Lower Mississippi Region or HUC 08, and the South Atlantic-Gulf or HUC-03, both shown in Figure E:11-2. The farthest southwestern boundary of Region 03 covers the eastern portion of St. Tammany Parish (the boundary is located along the Pearl River Basin). Region 08 covers nearly the entirety of the coastline of St. Tammany Parish along Lake Pontchartrain and the remaining inland region of the parish outside of the Pearl River basin floodplain. Figure E:11-3 depicts the area of interest for the study along with tide gages near the project area.

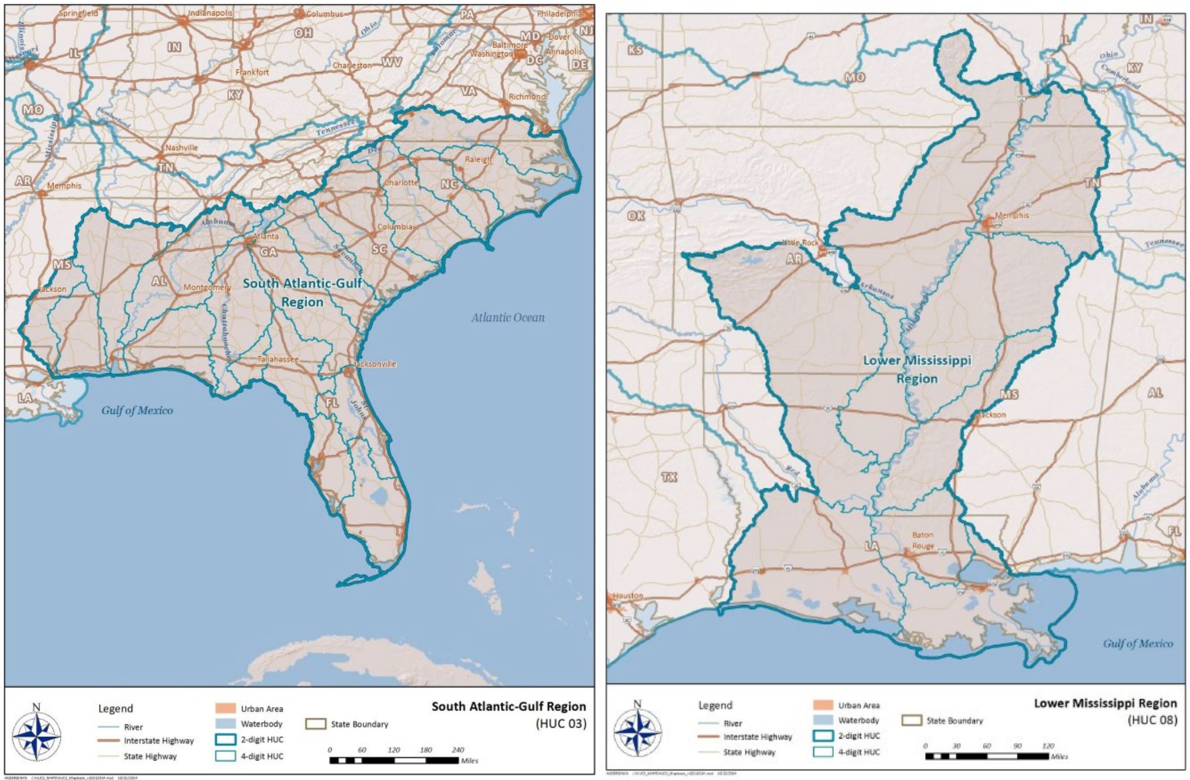


Figure E:11-2. Lower Mississippi River Region and South Atlantic-Gulf Region Boundaries. (USACE, Recent Climate Change and Hydrology Literature Applicable to U.S. Army Corps of Engineers Missions – Lower Mississippi River Region 08, 2015)

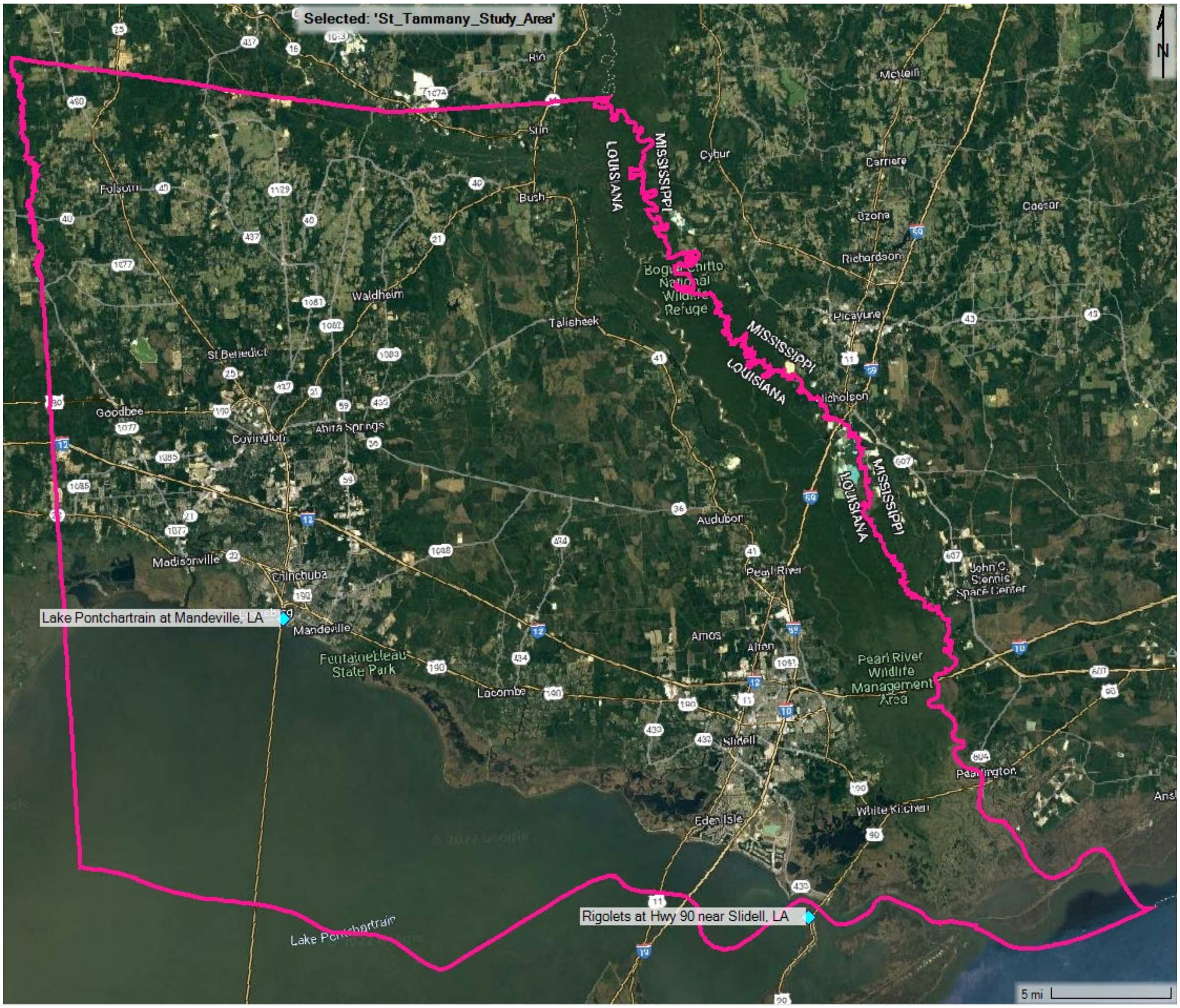


Figure E:11-3. St. Tammany Parish Extents and location of tide gages in Mandeville, LA and at the Rigolets near Slidell, LA.

11.2 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 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.

11.3 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), hydrologic unit code (HUC) watersheds in the United States (U.S). St. Tammany Parish is located between two 2-digit HUC basins: HUC 08, the Lower Mississippi River Region and HUC 03, South Atlantic-Gulf Region. These references 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 RSLC. 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 E:11-4 represents the steps and order required to perform a qualitative assessment of the impacts of climate change in hydrologic analyses.

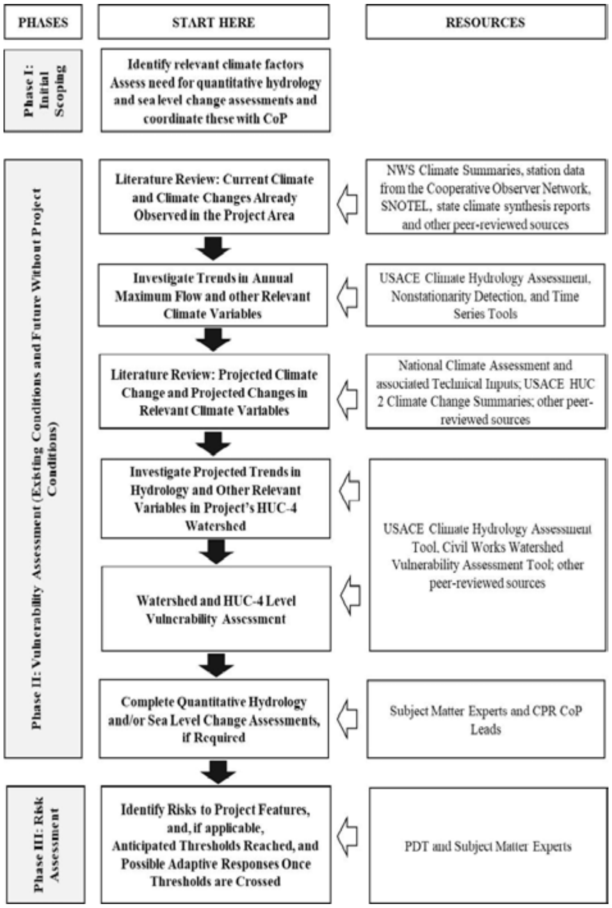


Figure E:11-4. Qualitative Assessment Steps (ECB 2018-14 2020)

11.4 CLIMATE CHANGE IMPACTS

11.4.1 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 change (SLC) 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 SLC are divided into three scenarios: 1) Low, 2) Intermediate, and 3) High SLC. Based on the data the three scenarios are broken down into the following:

LOW: Based on historic rates of SLC (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.

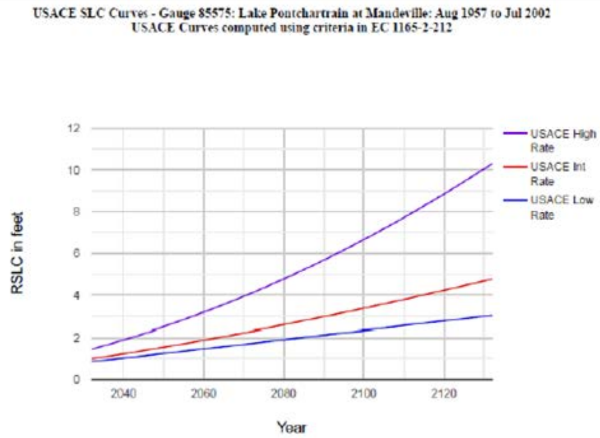
HIGH: Computed from the modified NRC Curve III considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement added.

The ER directs to use the USACE Sea Level Change 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 E:11-5. A base year of 2032 is used in the tool as that is the selected base year of the project and the selected location for computation of the Sea Level Change Curve Calculator is Mandeville, Louisiana. Each rate of SLC and the impact these rates pose on proposed projects performance in the RP is evaluated and discussed in Section 14.

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
2032	0.87	1.01	1.46
2037	0.97	1.15	1.73
2042	1.08	1.30	2.01
2047	1.19	1.46	2.31
2052	1.30	1.62	2.63
2057	1.41	1.78	2.97
2062	1.52	1.95	3.33
2067	1.62	2.12	3.71
2072	1.73	2.30	4.10
2077	1.84	2.48	4.52
2082	1.95	2.67	4.95
2087	2.06	2.86	5.40
2092	2.17	3.05	5.87
2097	2.27	3.25	6.36
2102	2.38	3.46	6.87
2107	2.49	3.67	7.39
2112	2.60	3.88	7.94
2117	2.71	4.10	8.50
2122	2.81	4.32	9.08
2127	2.92	4.54	9.68
2132	3.03	4.77	10.30



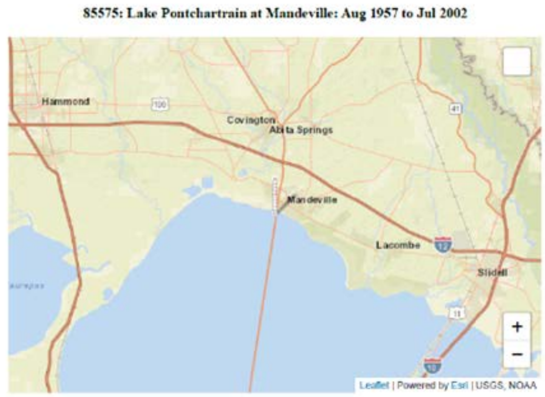


Figure E:11-5. USACE Sea Level Change Curves for Mandeville, Louisiana

11.4.2 Inland Hydrologic Change

Inland hydrologic change can include multiple climate change variables that are at risk of changes. Figure E:11-6 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 E:11-7 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 St. Tammany 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.

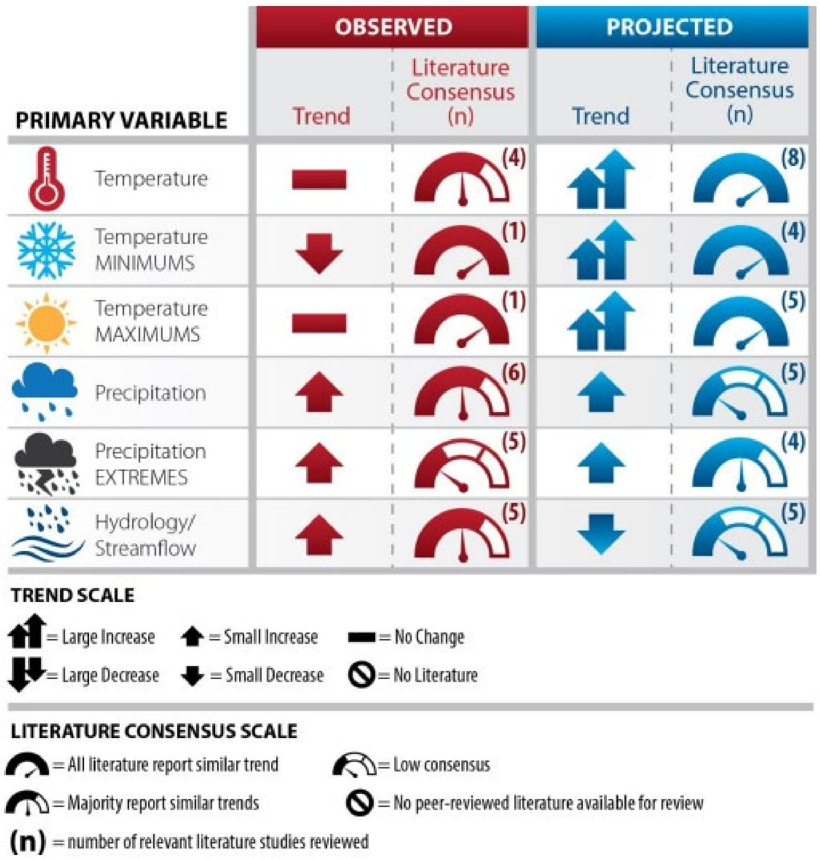


Figure E:11-6. Summary Matrix of Observed and Projected Climate Trends and Literary Consensus for Region 08 Source: U.S. Army Corps of Engineers (USACE 2015)

Figure E:11-7 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.

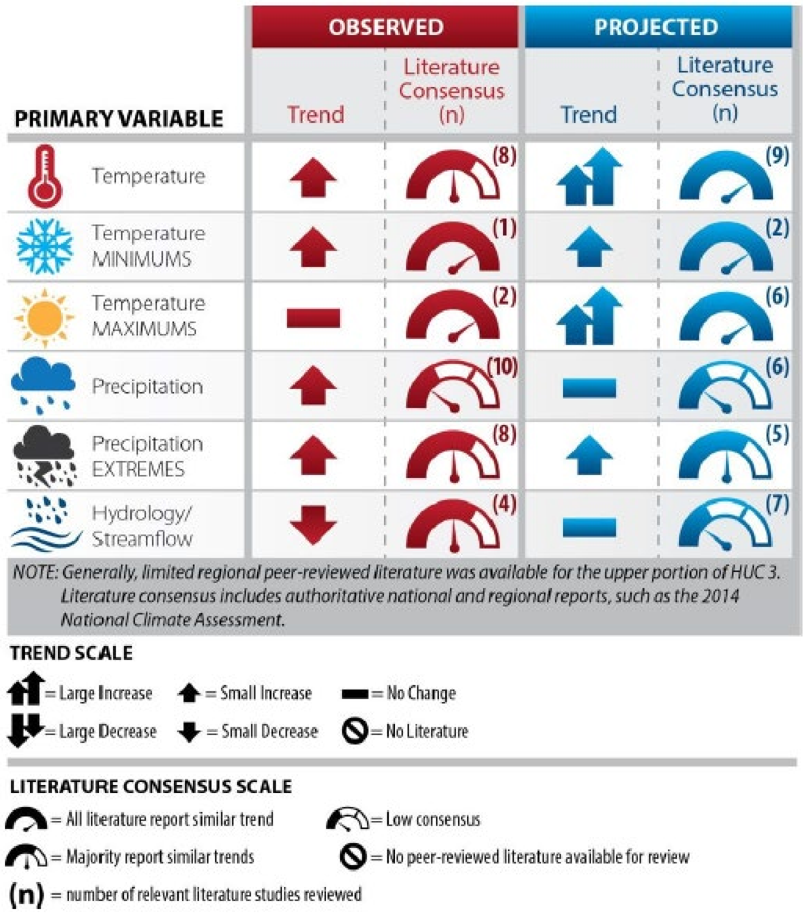


Figure E:11-7. Summary Matrix of Observed and Projected Climate Trends and Literary Consensus for Region 03 Source: U.S. Army Corps of Engineers (USACE 2015)

Additionally, the TST was utilized to evaluate nonstationarity detections (NSDs) in the seven gages used for calibration of the hydraulic model and are listed in Table E:12-3. Of the seven calibration gages utilized for this study, two gages have nonstationarities detected. USGS Gage 02492600 - Pearl River at Pearl River, LA has nonstationarities detected at years 1974, 1900 and 1874 using the Smooth Lombard Mood statistical method. USGS Gage 07375230 - Tchefuncte River at Folsom, LA has nonstationarities detected at years 2013, 2014, and 2015 using the Smooth Lombard Mood statistical 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.

11.5 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 E:11-8 depicts CHAT results for the Lower Mississippi HUC-4 basin, Liberty Bayou-Tchefuncte HUC-8 Basin and Figure E:11-9 depicts CHAT results for the Pearl HUC-4 Basin, Lower Pearl 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.

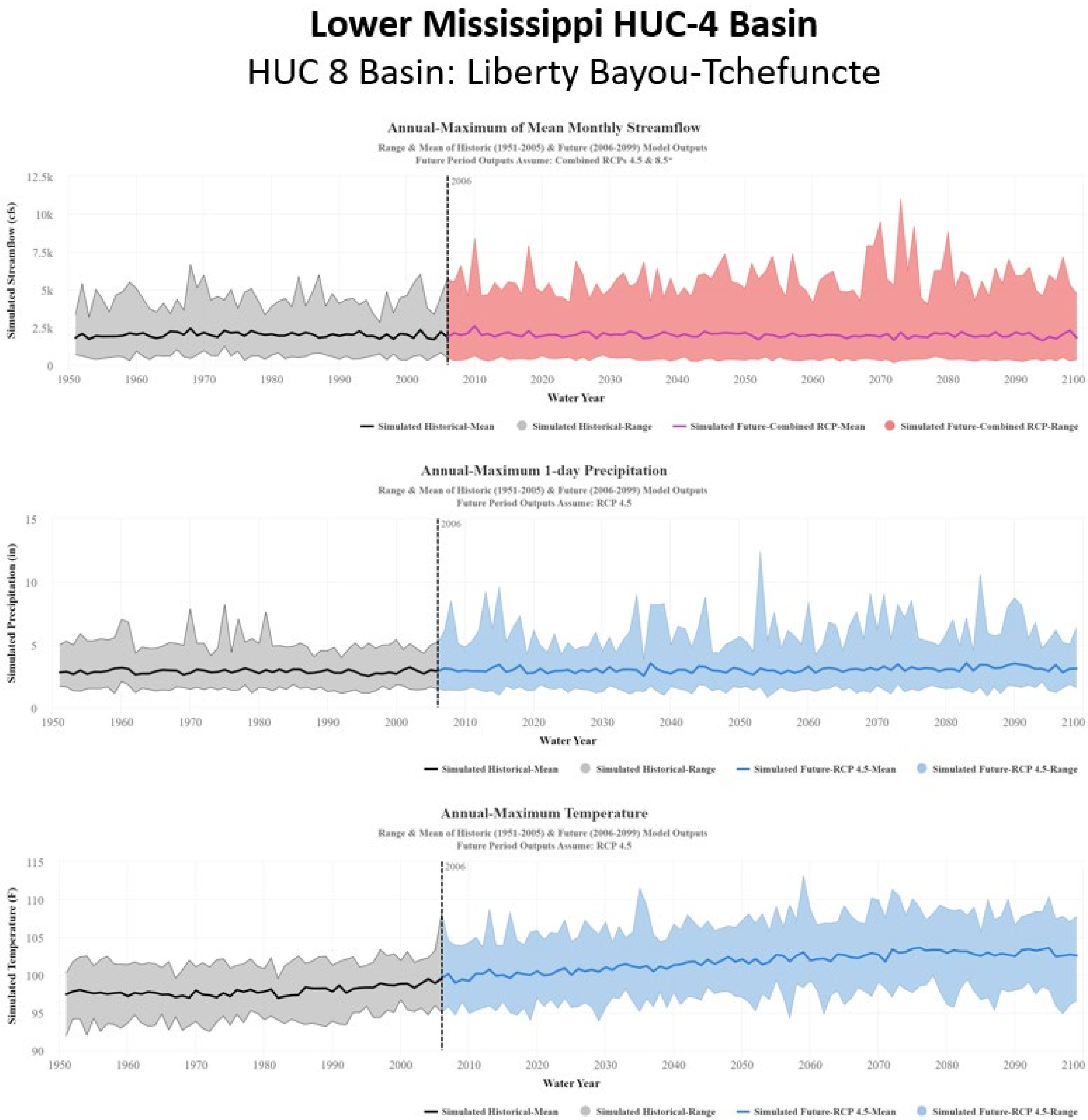


Figure E:11-8. Lower Mississippi River Region 08 CHAT results depicting annual-maximum of mean streamflow, annual-maximum 1-day precipitation, and annual-maximum temperature for the Lower Mississippi HUC-4 basin, Liberty Bayou-Tchefuncte HUC-8 Basin

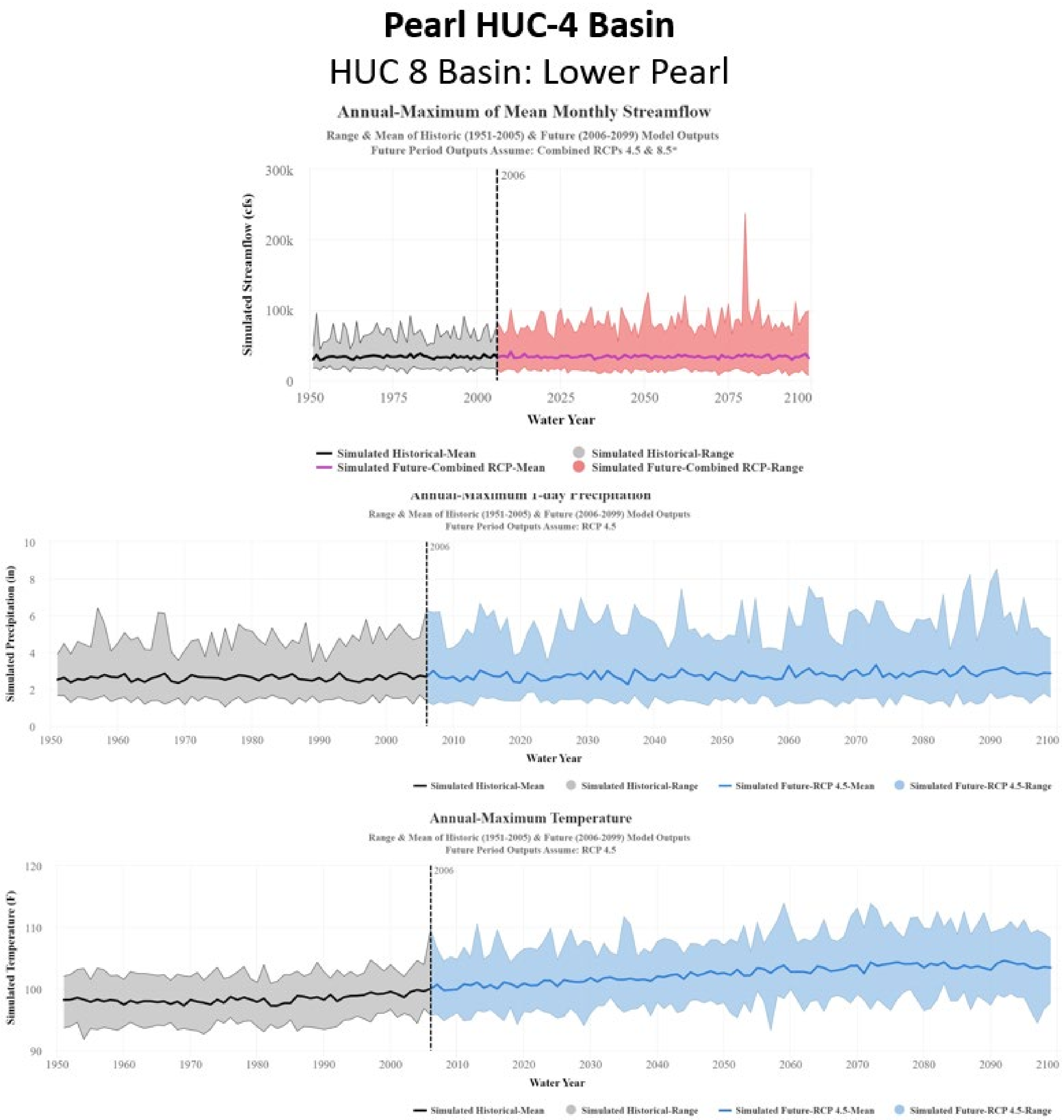


Figure E:11-9. South Atlantic-Gulf Region 03 CHAT results depicting annual-maximum of mean streamflow, annual-maximum 1-day precipitation, and annual-maximum temperature for the Pearl HUC-4 Basin, Lower Pearl HUC-8 Basin

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 the Lower Mississippi region, HUC-8 Basin Liberty-Bayou Tchefuncte, the annual maximum temperature is simulated to reach between 100°F and 105°F by the year 2100. For the Pearl, HUC-8 Basin Lower Pearl, annual maximum temperatures are simulated to reach temperatures of 100°F to 110°F by the year 2100.

For the selected project baseline year of 2032, temperatures are predicted to have a future simulated range of 66.88°F-71.77°F and 97.25°F-107.44°F for the Lower Mississippi and Lower Pearl regions respectively. For the selected project future year of 2082, temperatures are predicted to be 69.13°F-73.77°F and 98.3°F-112.53°F for the Lower Mississippi and Lower Pearl regions respectively. The Lower Mississippi, Liberty Bayou-Tchefuncte HUC-8 basin has a future simulated range in precipitation of 1.57in-4.38 in in the year 2032, and 1.66in-4.91in in the year 2082. The Lower Pearl HUC-8 basin has a future simulated range in precipitation of 1.5in-5.77in in 2032, and 1.34in-5.08in in 2082. The simulated future mean annual-maximum monthly streamflow for the Lower Pearl region is 33,852 cfs for year 2032 and 36,153cfs for year 2082. The simulated future mean annual-maximum monthly streamflow for the Lower Mississippi region is 2,006 cfs for year 2032, and 2,202 cfs for year 2082.

11.6 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 STPFS, the MVD HUC-4 watersheds of interest include the Lower Mississippi Basin HUC4-0809 and Pearl Basin HUC4-0318.

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.

Flood Risk Reduction

Figure E:11-10 and Figure E:11-11 depict the VA tool's summary of WOWA results for the flood risk reduction business line for HUC-0809 and HUC-0318. WOWA scores for the Lower Mississippi HUC-0809 projections are: dry 2050-51.86, wet 2050-54.31, dry 2085-52.71, and wet 2085-55.97. The Lower Mississippi HUC-0809 Basin is identified as vulnerable under Flood Risk Reduction for the dry 2050, wet 2050, dry 2085, and wet 2085 projections. WOWA results for the flood risk reduction business line for the Pearl HUC-0318 are: dry 2050-42.22, wet 2050-48.41, dry 2085-42.13, and wet 2085-48.54. The Pearl Basin is not identified as vulnerable under flood risk reduction for any of the analyzed projections.

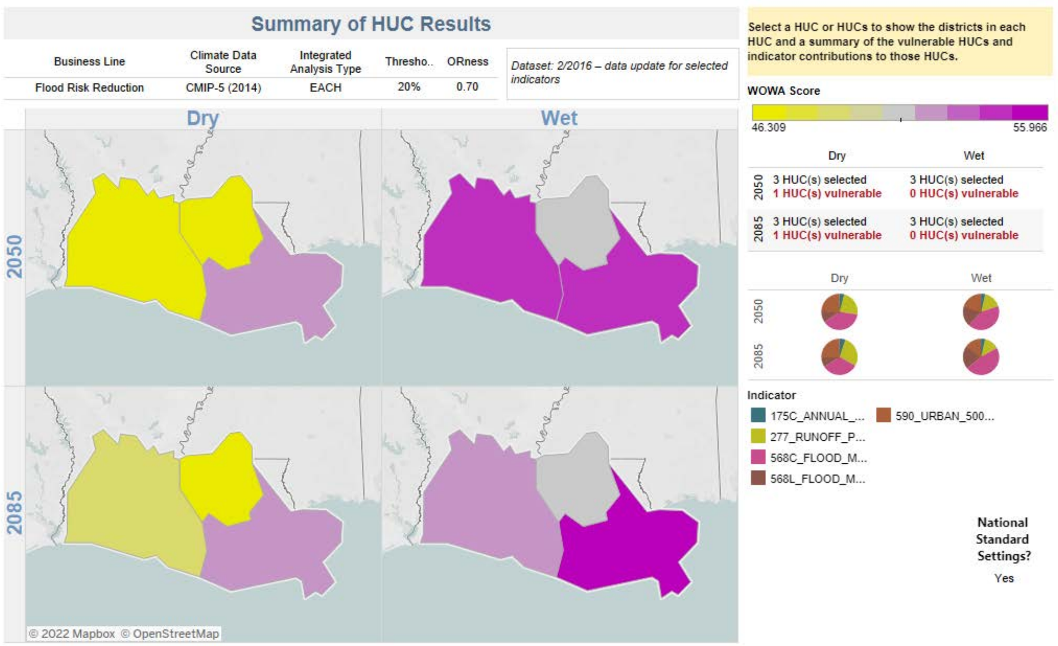


Figure E:11-10. Lower Mississippi HUC-0809 summary for flood risk reduction

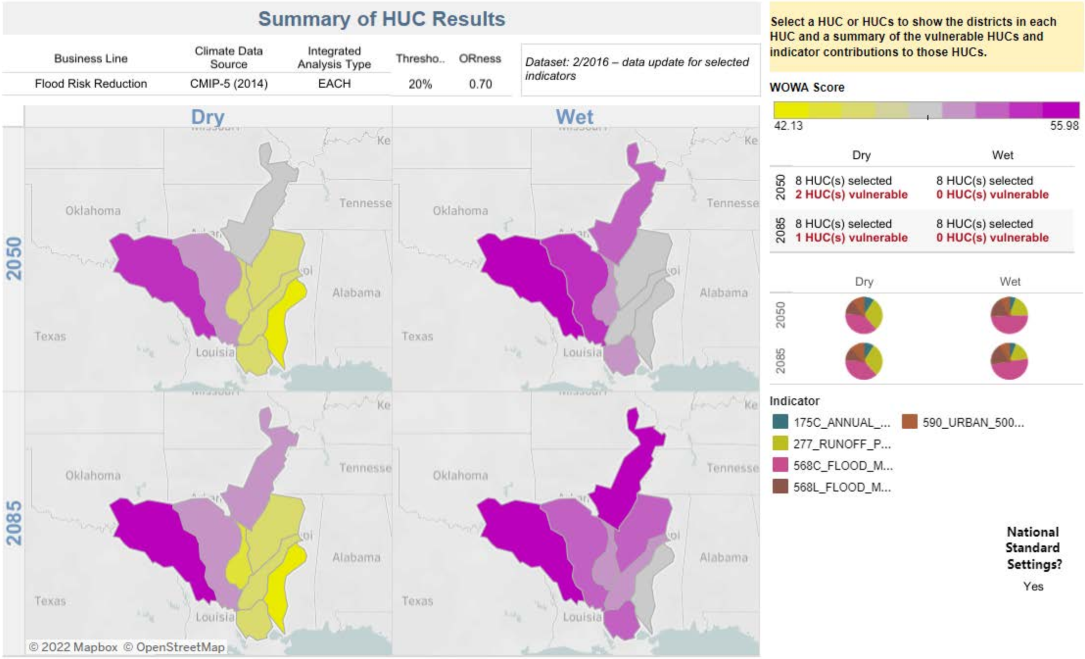


Figure E:11-11. Pearl HUC-0318 summary for flood risk reduction

Ecosystem Restoration

Figure E:11-12 and Figure E:11-13 depict the VA tool's summary of WOWA results for the ecosystem restoration business line of HUC-0809 and HUC-0318. WOWA scores for the Lower Mississippi HUC-0809 projections are: dry 2050-75.83, wet 2050-76.50, dry 2085-75.47, and wet 2085-76.58. The Lower Mississippi HUC-0809 Basin is identified as vulnerable under Flood Risk Reduction for the dry 2050, wet 2050, dry 2085, and wet 2085 projections. WOWA results for the ecosystem restoration business line of the Pearl HUC-0318 are: dry 2050-64.56, wet 2050-64.19, dry 2085-65.66, and wet 2085-64.01. The Pearl Basin is not identified as vulnerable under ecosystem restoration for any of the analyzed projections.

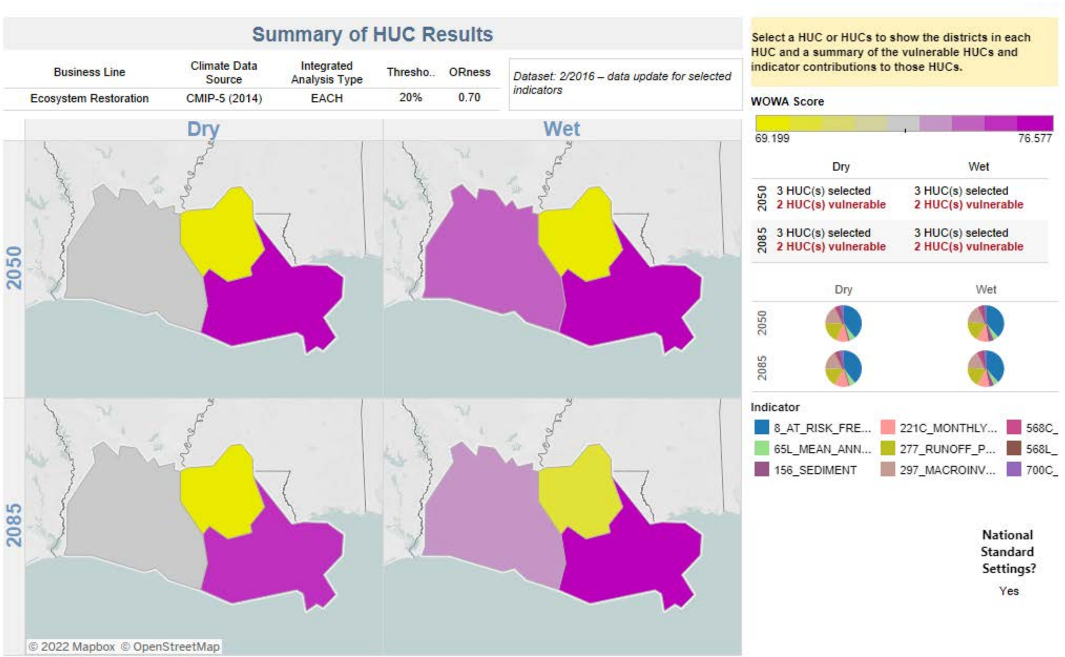


Figure E:11-12. Lower Mississippi HUC-0809 summary for ecosystem restoration

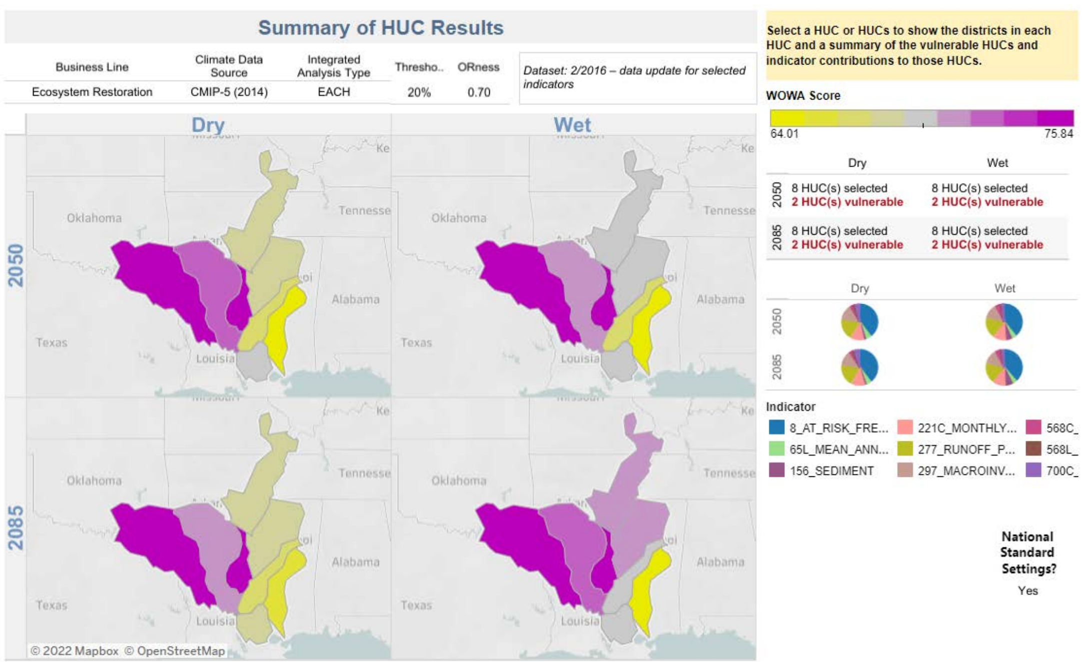


Figure E:11-13. Pearl HUC-0318 summary for ecosystem restoration

Emergency Management

Figure E:11-14 and Figure E:11-15 depict the VA tool's summary of WOWA results for the emergency management business line of HUC-0809 and HUC-0318. WOWA scores for the Lower Mississippi HUC-0809 projections are: dry 2050-68.52, wet 2050-66.78, dry 2085-69.80, and wet 2085-67.8. The Lower Mississippi HUC-0809 Basin is identified as vulnerable under emergency management for the dry 2050 and dry 2085 projections. WOWA results for the emergency management Business line of the Pearl HUC-0318 are: dry 2050-68.53, wet 2050-64.34, dry 2085-76.77, and wet 2085-64.69. The Pearl Basin is identified as vulnerable under emergency management for the dry 2085 projection.

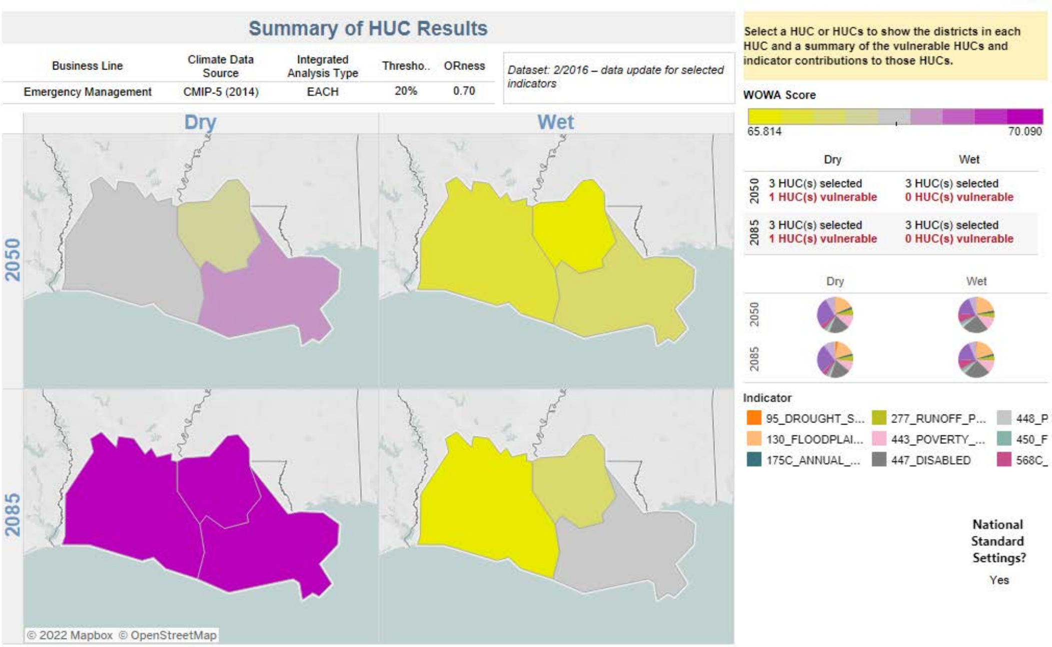


Figure E:11-14. Lower Mississippi HUC-0809 summary for emergency management.

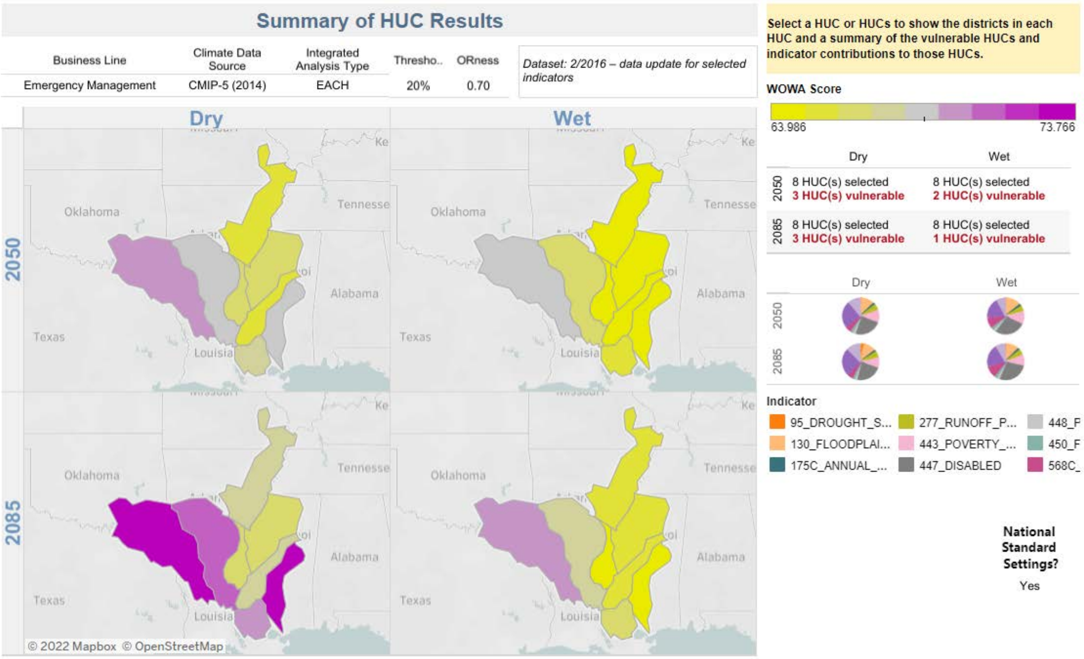


Figure E:11-15. Pearl HUC-0318 summary for emergency management.

11.7 SUMMARY

Based on the guidance from USACE and data from the available tools, the STPFS can identify climate change risks based on specific project features. Table E:11-1 summarizes how a specific project feature may be triggered by a climate change variable, which then produces a hazardous and harmful impact to the community.

Table E:11-1. Climate Risks Features and Outcomes

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood
Levee	-Increased precipitation -Land subsidence	-Areas subject to induced flooding may change with sea level rise. The recommended plan and induced flooding analysis are based on 2.7 feet of relative sea level rise. -Future flood volumes may be larger than	-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	High Likelihood

		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	land loss rates and coastlines receding, location of the flood control feature may be more exposed to coastal surge and wave events	
Floodwall	-Increased precipitation -Land subsidence	-Areas subject to induced flooding may change with sea level rise. The recommended plan and induced flooding analysis are based on 2.7 feet of relative sea level rise. -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
Pump Stations	-Increased precipitation	-Future flood volumes and durations may be larger than present	-Designed pumping capacities may not be sufficient to accommodate increased volumetric runoff along with longer flood durations caused by larger precipitation event;	Likely

			this may in turn cause increased flooding to the protected side of flood control structures -Pump stations may be utilized more frequently requiring additional maintenance	
Flood Control Gates	-Increased precipitation	-Future flood volumes and durations may be larger than present	-Designed pumping capacities may not be sufficient to accommodate increased volumetric runoff along with longer flood durations caused by larger precipitation events; this may in turn cause increased flooding to the protected side of flood control structures -Flood control gates may be utilized more frequently requiring additional maintenance	Likely
Channel Excavation	-Increased precipitation -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 excavated channel	-Low Likelihood
Channel Clearing and Snagging	-Increased precipitation -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	-Low Likelihood

			snagged channel may support sustaining surge height because surge and wave energy will not be dampened by the once present vegetative growth	
Diversion	-Increased precipitation	-Future flood volumes may be larger than present -Large flood volumes may occur more frequently	-With increased flood volumes, and higher frequency of larger flood volumes, diversions would be loaded more than anticipated in design. This may lead to unintentional flooding of structures near locations of diversions	-Low Likelihood
Nonstructural Plan Riverine	-Increased precipitation -Land subsidence -Relative sea level rise	Compound flooding	-With increased flood volume, current day projections of the necessary height to raise structures may not be adequate. -The flood plain will migrate upland above the 2.7 feet of relative sea level rise used for the recommended plan, and in some areas the level of risk reduction cannot be maintained.	-Likely
Nonstructural Plan Coastal	-Land subsidence -Relative sea level rise	-Land loss rates in southern Louisiana may increase -Risk increases with RSLR	-The level of risk reduction cannot be maintained above the 2.7 feet of sea level rise used for the recommended plan. -With increasing land loss rates and	-Likely

			coastlines receding, surge may travel further inland and impact structures further inland than initially identified in the Non-Structural Plan.	

It should be noted two features in Table E:11-1, 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.

11.8 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 12

RP – Hydraulic Modeling

12.1 OVERVIEW

Hydraulic modeling was performed using 2D unsteady flow capabilities of HEC-RAS. The model covers the extents of St. Tammany Parish, all within the Lake Pontchartrain watershed. The vertical datum of elevations in the model is NAVD 88 (Geoid 12B). Detailed discussion of model development and parameter selection is included in this section.

12.2 MODEL GEOMETRY

Three different model geometries were used in this modeling effort. One model geometry represents the parish baseline, or without-project, condition. The second and third model geometries represent the with-project condition, including all structural TSP projects. The reason two with-project geometries were created is because the CSRM levee alignment, or Alternative 6c3, requires independent modeling of the pumping complexes and water control structures to estimate sizes and capacities of those elements of the system. Therefore, one with-project model geometry has Alternative 6c3 (defined in Table E:8-1) modeled with gates fully closed and pumping ongoing through the entire simulation, representing a scenario with a high Lake Pontchartrain water level. The other with-project geometry has the gates fully open during the entirety of the simulation and no pumping, representing a scenario with typical daily conditions in Lake Pontchartrain. Figure E:12-1 below depicts the without-project geometry used in this study.

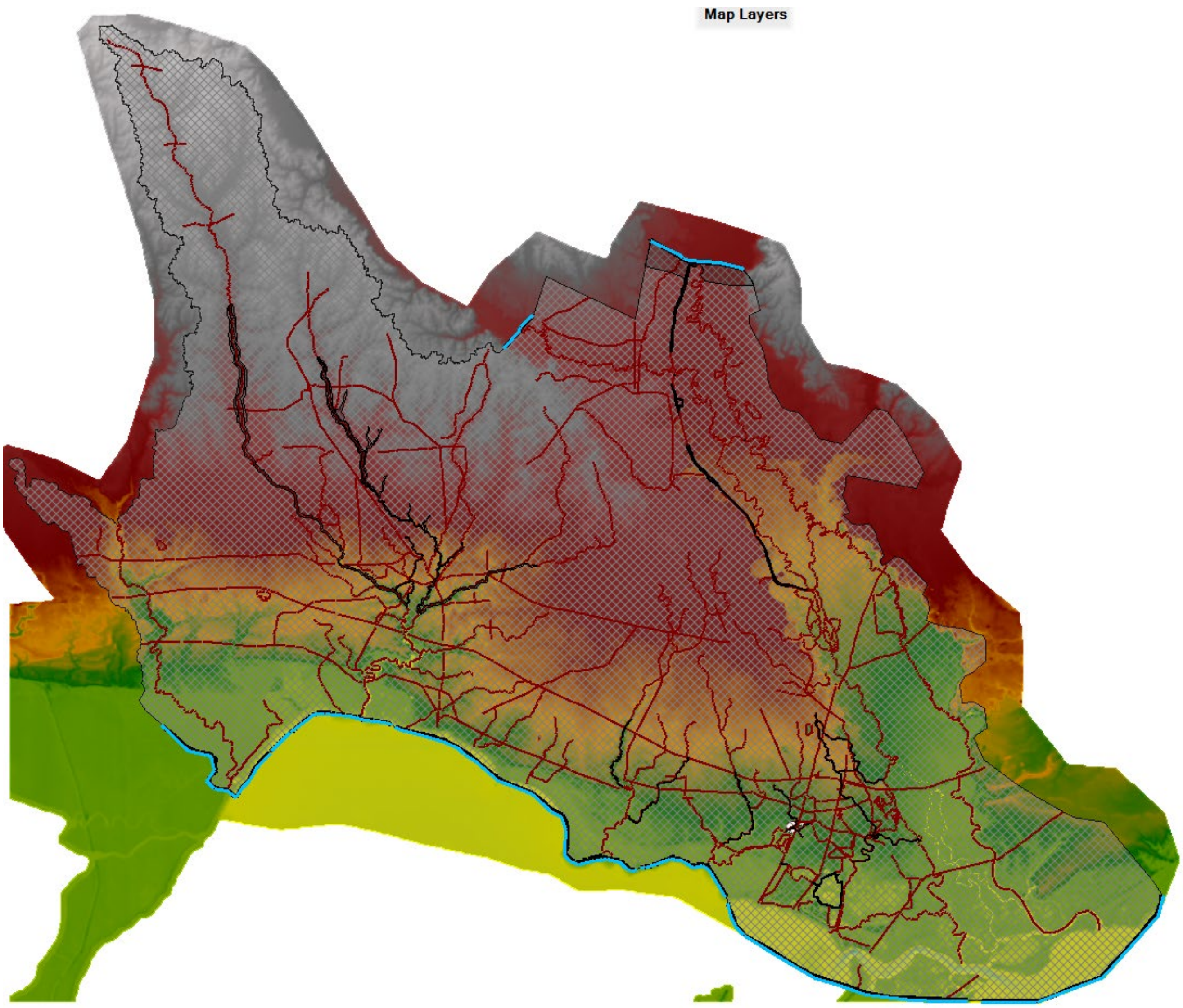


Figure E:12-1. Existing Conditions Model Domain

The without-project and two with-project geometries use the 2D unsteady flow equations in HEC-RAS. A single 2D area encompasses the spatial extent of the study area, including all rivers and streams. The 2D cell sizes in the geometry mesh varied. Waterways that intersect a structural TSP feature and the mesh surrounding the CSRM levee alignment have finer resolution cells of 25x25 feet. Outside of these areas of interest, the cell definition increases with a range between 50x50 up to 1500x1500 feet cells. Additionally, near 2D inflow points, smaller cells were used to allow better model stability and accuracy.

Mesh definition and cells are the same between the with-project and with-out project geometries to ensure equivalent computations between the different geometries. This was done using break lines and cell enforcement at the same locations in the mesh between the different geometries.

12.3 TERRAIN

The terrain developed for the alternative analysis phase model was used as a starting point for the RP phase model terrain. Reference to what went into the development of the alternative analysis phase terrain may be seen in Section 4.3 of this appendix. Modifications made to that terrain for the RP phase modeling are explained below. Additionally, two different terrains were generated for this effort: a without-project and with-project terrain. Details about the difference between the with and without-project terrains will be discussed in Section 14 of this appendix.

Elevation data – bathymetry and topography – is used by 2D flow areas to calculate storage within and flow between 2D cells. Topography data for the alternative analysis phase came from various sources, and details including pixel resolution, layer order of the previous rasters may be seen in Table E:12-1. One change from the terrain used in the last phase is that a new dataset with higher resolution was layered on top of the existing terrain. This dataset came from the Coastal National Elevation Database (CoNED), and provides periodically updated and enhanced topographic (land elevation) and bathymetric (water depth) datasets that serve as valuable resources for coastal hazards research and Earth science applications. Details of this new elevation data may be seen in Table E:12-1 below. Figure E:12-2 below depicts the final terrain used in this modeling effort.

Table E:12-1. Raster Resolution Sizes, Layer Order, Description, and Source Information

Raster File	Resolution Scale	Resolution Cell Size (ft)	Layer Order: Top (1) to Bottom (7)	Description	Source	Datum / Year LiDAR Captured if Available
CoNED	1:193.343	3.28	1	The geographic extents of this file include the shoreline of St. Tammany Parish along Lake Pontchartrain.	CoNED	NAVD88 / 2011-Present (modeling completed in 2021)
CE-Hyd	1:55.810	4.79	2	The geographic extents of this file include the entirety of the Tchefuncte and Bogue Falaya River Basin. It is a combination of LiDAR and channel elevations in the Tchefuncte and Bogue Falaya Rivers.	Contractor furnished topography	NAVD88
MVK Pearl	1:38.192	7	3	The geographic extents of this file include the Pearl River Basin within the St. Tammany Parish Boundary	USACE MVK	NAVD88
DEM 23	1:27.179	9.83	4	The geographic extents of this file include the Bayou Lacombe, Bayou Bonfouca, and Bayou Liberty River Basin. Includes topographic and some bathymetric elevations.	USGS Topobathymetric Elevation Model of Northern Gulf of Mexico	NAVD88 / 2000-2015
DEM 22	1:27.167	9.84	5	The geographic extents of this file include the Tchefuncte River from the intersection of Hwy 1077 and 1078 westward to the St. Tammany Parish Boundary. Includes topographic and some bathymetric elevations.	USGS Topobathymetric Elevation Model of Northern Gulf of Mexico	NAVD88 / 2000-2015
NG20ft	1:13.367	20	6	The geographic extents of this file include the North Eastern extents of the Parish, West of the Pearl River Basin	USGS Northern Gulf of Mexico Topobathymetric Dataset	NAVD88 / 2000-2015
USGS National Elevation Dataset 11ft	1:2.805	95.30	7	The geographic extents of this file include the Bogue Falaya and Tchefuncte River from Folsom, Louisiana north to the St. Tammany Parish Boundary	USGS National Elevation Dataset topography	NAVD88 / 2000-2015

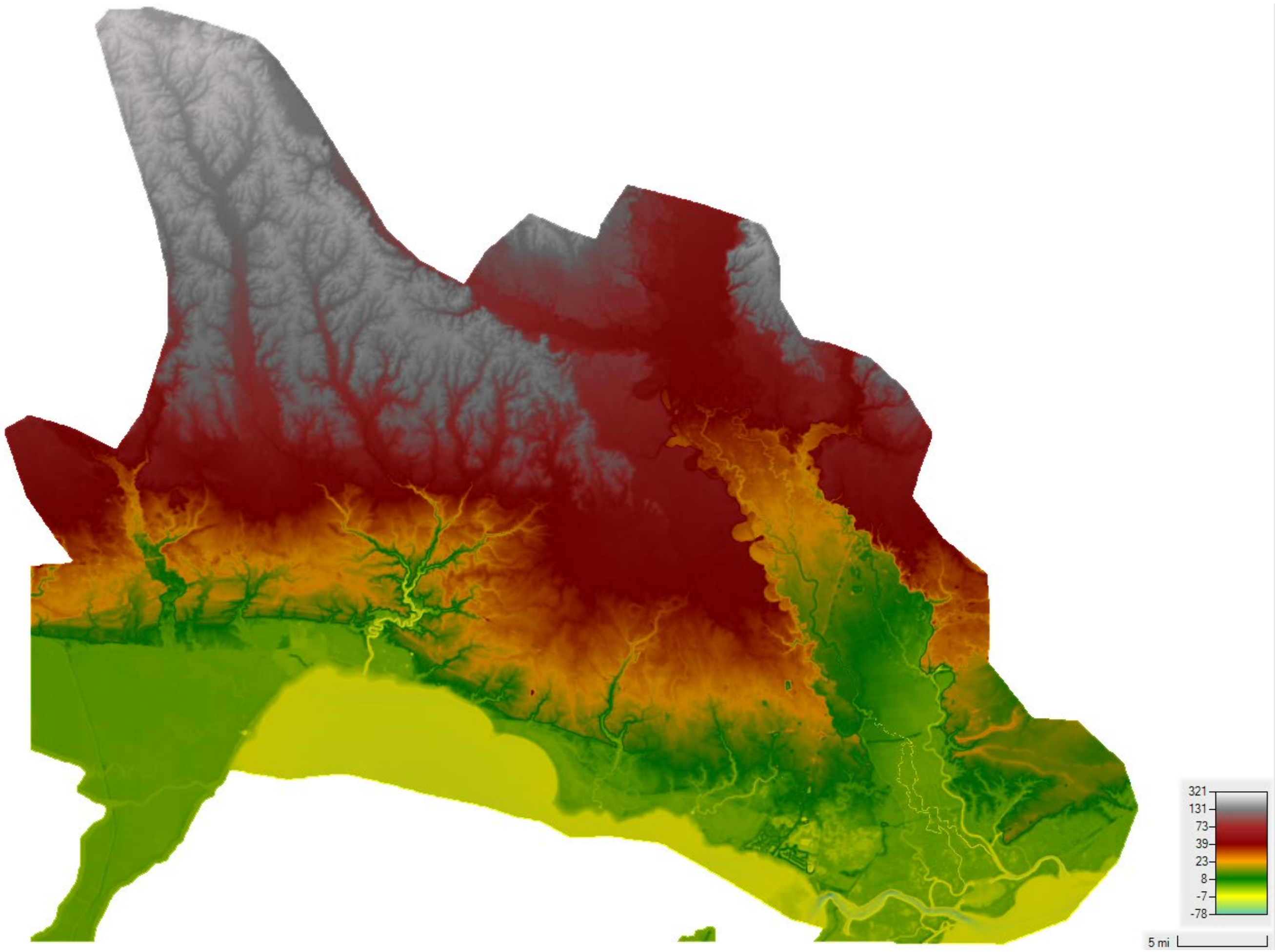


Figure E:12-2. LiDAR Dataset for RP Phase modeling

In addition to the new CoNED dataset, a novel feature called terrain modifications available starting in HEC-RAS version 6.2 was used to edit the terrain. Any locations where burned bathymetry needed to be smoothed, or there were areas that required some attention, the channel modification tool was used. Waterways that required a terrain modification to adjust the LiDAR dataset include the Tchefuncte River, Bayou Patassat, Bogue Falaya, Abita River, Pearl River, and West Pearl River. Further discussion on terrain modifications can be found in Section 12.6.2 of this appendix, which summarizes calibration of the model.

12.4 LANDCOVER

Land cover data is used to spatially vary the Manning's n roughness coefficients throughout the 2D flow areas. Manning's roughness coefficients are used in the calculation of flow between 2D cells. Land cover data did not change from the Alternative Analysis phase modeling, which came from the 2016 NLCD. An appropriate Manning's roughness coefficient was selected for each land cover type that is found in the study area. The literature source used to apply land cover values is from the Journal of Spatial Hydrology, and a tabulation of land cover coefficients from the Journal of Spatial Hydrology Article: Land use-based surface roughness on hydrologic model output can be reviewed in Table E:12- 4. Figure E:12-3 depicts the 2016 NLCD layer used in HEC-RAS.

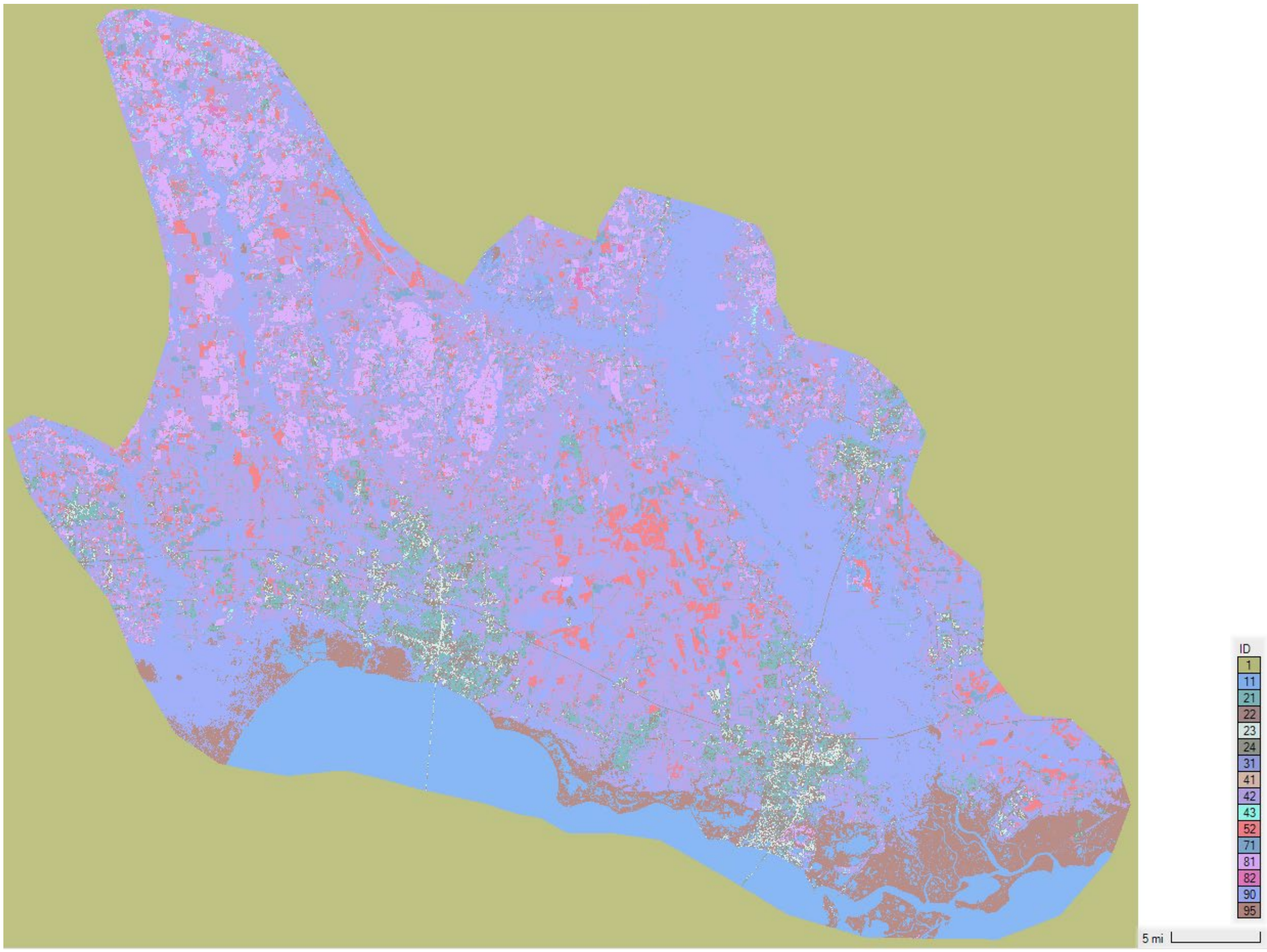


Figure E:12-3. USGS 2016 National Landcover Dataset

During model calibration, it was found that various Manning's override regions were needed to replicate realistic environmental conditions in the field. Further discussion of override regions used to calibrate the model is addressed in Section 12.6.2 of this appendix on model calibration.

12.5 BOUNDARY CONDITIONS

Inflow and precipitation boundary conditions to the hydraulic model were calculated for each return period. The precipitation boundary conditions use HEC-HMS output to apply the calculated excess precipitation directly on the single 2D area. The inflow boundary conditions in this model are 2D inflow hydrographs that represent the Bogue Chitto and Pearl Rivers. The downstream boundary conditions in this model are stage hydrographs representing Lake Pontchartrain applied to the 2D area.

12.5.1 2D Inflow Hydrographs

Inflow hydrographs are applied to the 2D portions of the model at 2D boundary condition lines. In the northeastern region of the parish, the model has two inflow boundary condition lines: one is for the Bogue Chitto River and the other is for the Pearl River. Inflow for return periods 2-500 years were applied for both the Bogue Chitto and Pearl Rivers. The inflow boundary condition line extends the entire length of the 500-year floodplain for each river. These flows were calculated for the previous iteration of modeling during the alternative analysis phase and were not revised during this phase. Section 4 of this appendix goes into detail of how regression equations were used to calculate the appropriate inflows for the Bogue Chitto and Pearl Rivers.

12.5.2 2D Stage Hydrographs

The downstream boundaries of the hydraulic model are stage boundaries that represent the water level of Lake Pontchartrain. Stage boundaries are used along the entire extents of the southern boundary of the model domain where the 2D domain interacts with Lake Pontchartrain. There are two long-term water level gages on the north shore of Lake Pontchartrain that were used to determine downstream boundary conditions: Lake Pontchartrain at Mandeville and Rigolets near Lake Pontchartrain. Calculations for these downstream boundary conditions were performed for the prior phase of modeling and were found to be appropriate for the updated RP modeling as well.

Downstream boundary conditions vary along the model extents in the RP phase model. The model boundary is broken up into six different downstream boundary conditions. Table E:12-2 includes the stages used for the Low, Intermediate, and High rates of SLR for this analysis. These stages reflect the mean daily stage for the Mandeville and Rigolets gages for each of the different SLR scenarios. Further discussion of SLR may be found in Section 14.1.8 of this appendix. Figure E:12-4 depicts the locations of the six different downstream boundary condition lines.

Table E:12-2. Downstream Boundary Condition Stages along the Extents where the Model Domain Interacts with Lake Pontchartrain

		Boundaries B1, B2, B3 (Mandeville Gage)	**Boundaries B4, B5, B6 (Rigolets Gage)**
Low Rate of Sea Level Rise	Existing Conditions – 2032	1.21ft	0.87ft
	Future Conditions – 2082	2.21ft	1.67ft
Intermediate Rate of Sea Level Rise	Existing Conditions – 2032	1.31ft	0.97ft
	Future Conditions – 2082	3.01ft	2.27ft
High Rate of Sea Level Rise	Existing Conditions – 2032	1.71ft	1.27ft
	Future Conditions – 2082	5.21ft	4.47ft

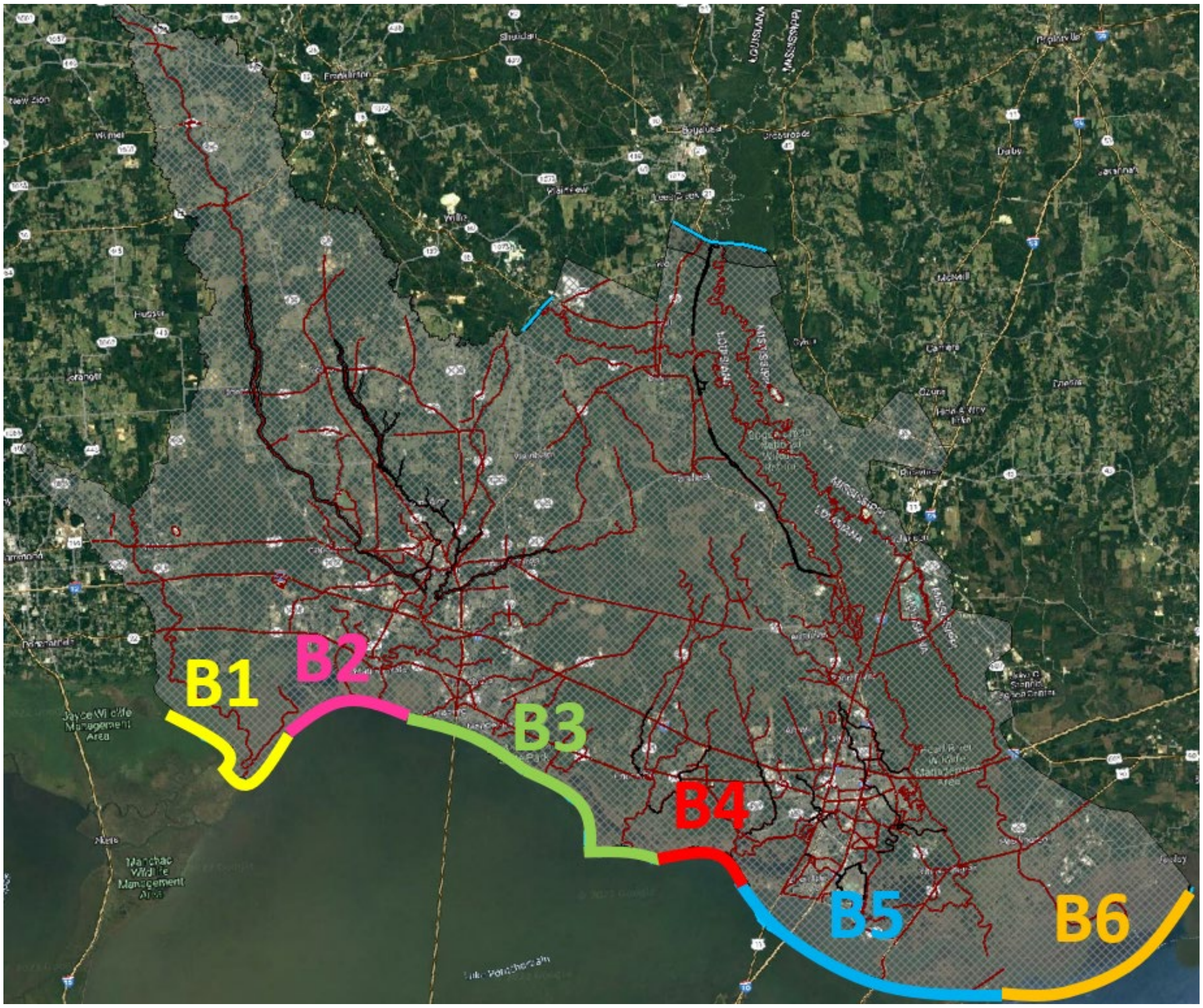


Figure E:12-4. Locations of Downstream Boundary Conditions B1-B6

12.6 HYDRAULIC MODEL CALIBRATION

Model calibration for the RP phase model was completed to benchmark and improve the performance. Two events were chosen to calibrate the model. For the central portion of the parish, the March 2016 rain event was chosen as there was heavy flooding that this event caused in that portion of the parish. For the southeastern region of the parish, an event that occurred in September 2011 that impacted Slidell, Louisiana, was chosen.

Existing USACE and USGS gages were used to evaluate the calibration runs of the updated model geometry and terrain. A complete list of calibration gages may be seen in Table E:12-3 and locations of the gages may be seen in Figure E:12-5. Calibration plots depicting the September 2011 and March 2016 events at the gage locations compared with flows in the final calibrated model may be seen in Annex 4 of this appendix.

Table E:12-3. Calibration Gages for St. Tammany Parish RP phase modeling

Gage Name	Gage ID	Gage Link
Tchefuncte River at Folsom, LA	USACE 07375000	https://waterdata.usgs.gov/nwis/uv?site_no=07375000
Tchefuncte River at Madisonville, LA	USGS 07375230	https://nwis.waterdata.usgs.gov/usa/nwis/uv/?cb_00065=on&format=html&site_no=07375230&period=&begin_date=2016-03-01&end_date=2016-03-31
Tchefuncte at Covington, LA	USGS 07375050	http://waterdata.usgs.gov/usa/nwis/uv?site_no=07375050
Bogue Falaya at Boston St at Covington, LA	USGS 07375175	http://waterdata.usgs.gov/usa/nwis/uv?site_no=07375175
Bogue Falaya River near Camp Covington, LA	USGS 07375105	http://waterdata.usgs.gov/usa/nwis/uv?site_no=07375105
Abita River at Abita Springs	USGS 7375222	https://waterdata.usgs.gov/la/nwis/uv/?site_no=07375222&PARAmeter_cd=00065,72020,63160,00060
Bayou Liberty near Slidell, LA	USGS 07374581	https://nwis.waterdata.usgs.gov/usa/nwis/uv/?cb_00065=on&format=html&site_no=07374581&period=&begin_date=2016-03-01&end_date=2016-03-31
Pearl River at Pearl River, LA	USGS 02492600	http://waterdata.usgs.gov/usa/nwis/uv?site_no=02492600

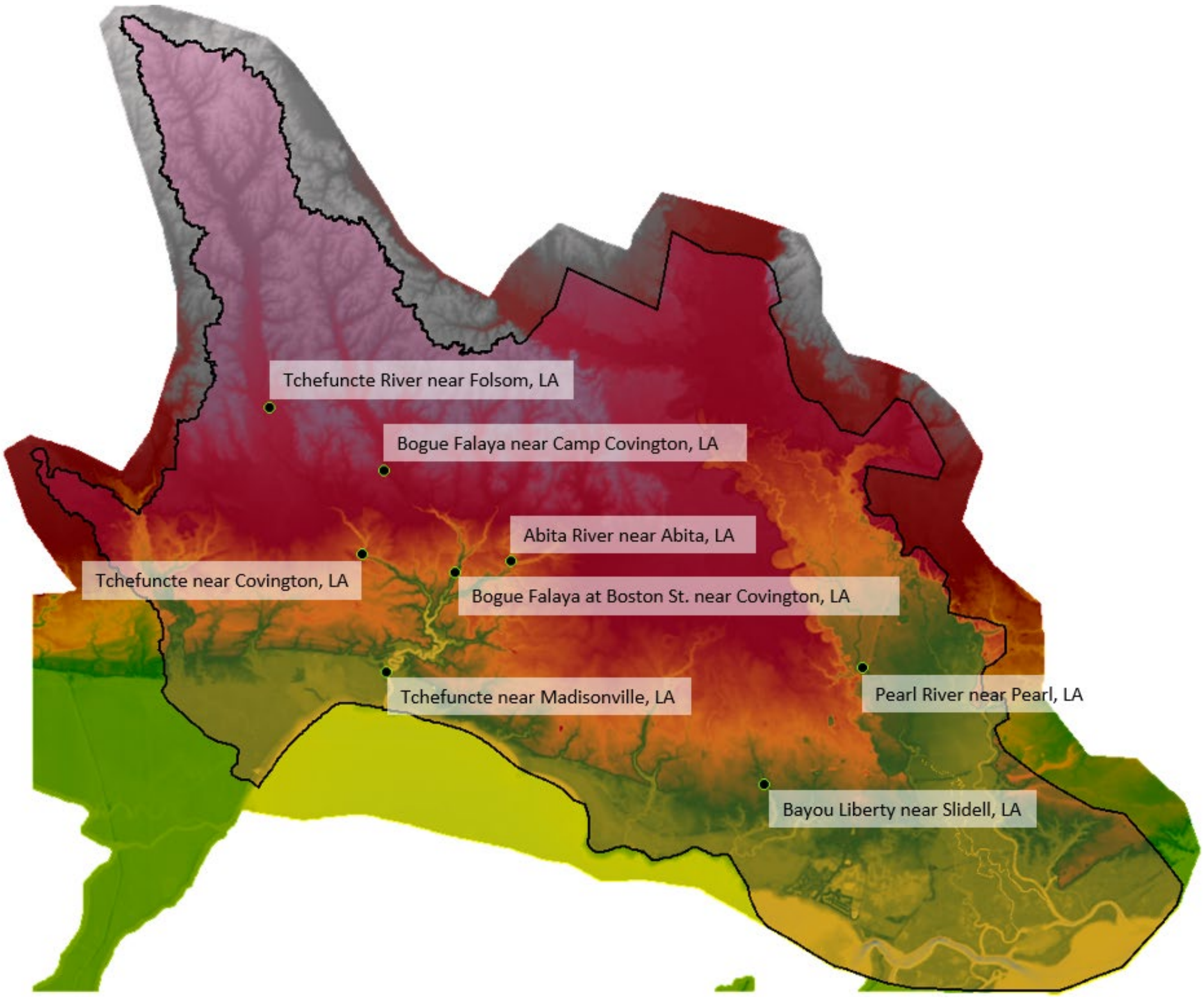


Figure E:12-5. Calibration Gage Locations for September 2011 and March 2016 Events

12.6.1 HEC-RAS Computation Parameters

Various computation parameters were adjusted to reduce error between modeled and observed stages for the September 2011 and March 2016 events. A warm-up period of 72 hours was applied to both the 2011 and 2016 events to ensure flow was established at the beginning of the simulation in the Pearl River basin. The inflow boundary condition for the Bogue Chitto is linked to observed data at the Bogue Chitto gage near Bush, Louisiana (USGS 02492000). The inflow boundary condition for the Pearl River inflow is linked to observed data at the Pearl River gage near Bogalusa, Louisiana (USGS 02489500). Downstream boundary conditions for B1, B2, and B3 are mapped to observed data at the Mandeville gage (USACE 85575). It should be noted that the Pearl River gage at Bogalusa, LA river gage is located approximately 33,000 ft upstream of the location where the mesh begins, and the Bogue Chitto River gage at Bush, LA is located approximately 34,000 ft downstream from the edge of the model domain where the boundary condition is forced.

Calibration points were taken at the edge of the model domain within the Pearl River channel for the Pearl River gage, and at the gage location of the Bogue Chitto gage in an effort to ensure the simulated trend is similar to the observed data.

Downstream boundary conditions for B4, B5, and B6 are linked to observed data at the Rigolets gage (USGS 301001089442600). For both the September 2011 and March 2016 calibration events, the HEC-RAS simulation was run for 3 days to ensure WSEs throughout the model domain had peaked. A 15 second computation interval was used and the diffusion wave equation set was used for model runs.

12.6.2 HEC-RAS Geometry, Terrain and Roughness Coefficient Adjustments

During calibration, refinements were made to various locations in the mesh. Where the 2D area mesh was not capturing hydraulic barriers and depressions in the terrain, additional break lines were added near the Slidell region, around Covington near the Tchefuncte River and Bogue Falaya River, around the Abita River, and close to Madisonville near the mouth of the Tchefuncte River.

A few different locations in the model terrain were identified during calibration that required adjusting using the channel modification tool. One location is a stockpile yard next to the confluence of Bayou Patassat and Bayou Bonfouca. The LiDAR in this location was shot before development of the stockpile yard, where they more recently placed fill in order to raise the elevation and avoid flooding from Bayou Patassat or Bayou Bonfouca. The modification raised the area of the stockpile yard, confirmed with aerial imagery, to an elevation a couple feet higher than what it was prior to construction. A second location of a channel modification is on the Tchefuncte River downstream of I-10 down to Lake Pontchartrain. The LiDAR was capturing a channel invert in the Tchefuncte that was lower at the I-10 crossing and increased in elevation down to the lake. This was corrected by placing a channel modification along this extent of the Tchefuncte River to ensure the channel invert descended down to Lake Pontchartrain. A third location where a channel modification was used is the Abita River. The LiDAR captured for the Abita River was very spotty along the extents close to the FRM measures for Mile Branch. This was corrected by placing a channel modification on reaches of the river to rejoin segments that were not connected.

Revisions were also made to the roughness coefficients that represent the channel and floodplain areas. Manning's n override regions were applied to a few overbanks and waterway channels to supersede the default landcover-based Manning's n value, which achieved a more accurate calibration to observed gage records. Tabulation of the Manning's n override regions may be seen in Table E:4-6. Additionally, the Journal of Spatial Hydrology Article: Land use-based surface roughness on hydrologic model output cited a roughness coefficient of 0.086 and 0.001 for woody wetlands and open water, respectively. Following analysis of the first few calibration runs, it was determined that a Manning's n value of 0.075 for the woody wetlands landcover type provided a better representation of the friction losses in these areas. A Manning's n value of 0.03 for open water provided a better representation of friction losses for those areas throughout the entire model.

Table E:12-4. Manning's n Override Region Values for Waterways in the with and without project geometries. All without-project override regions are carried over to the with-project geometry

	Manning's n Override Region Values	
	Waterway Name	**n**
Without-Project Geometry	Abita River	0.07
	Tchefuncte River Upstream Channel Banks	0.07
	Tchefuncte River Upstream Channel	0.06
	Tchefuncte River Midstream Channel	0.115
	Tchefuncte River Downstream Channel	0.11
	Bogue Falaya Upstream Channel Banks 4/3	0.04
	Bogue Falaya Upstream Channel 2	0.03
	Bogue Falaya Midstream Channel	0.04
	Bogue Falaya Downstream	0.04
	Little Bogue Falaya and Tributaries	0.045
	Bayou Liberty	0.06
	Mile Branch	0.04
	Mile Branch Lateral A	0.04
	Bayou Lacombe	0.04
	Cypress Bayou	0.04
	Bayou Bonfouca	0.04
	Bayou Patassat	0.04
	Doubloon Bayou	0.04
	Gum Bayou	0.04
	Poor Boy Canal	0.04
	W-15 French Branch	0.04
With-Project Geometry	Mile Branch Project Location	0.025
	Bayou Patassat Project Location	0.025

Section 13

RP – Coastal Modeling

13.1 ST. TAMMANY COASTAL WITH-PROJECT MODELING

In early 2021, CPRA released an updated ADCIRC grid to incorporate bathymetric updates due to land subsidence for 2023. The new grid also featured mesh refinements and updated surveys to have more accurate representation of existing levees heights throughout south Louisiana. The 2023 CPRA Master Plan ADCIRC mesh uses the beta 30m topography and bathymetry DEM developed by USGS and builds upon the 3m Northern Gulf of Mexico dataset. The datum of this dataset is NAVD88 2009.65. A team at ERDC ran a suite of synthetic storms and calculated statistics for this new mesh to have an updated dataset of 10-, 50-, 100-year, etc. frequency values for without-project modeling (sample without-project synthetic storm output shown in Figure E:13-3).

The Draft TSP proposed alignment was then added to this updated ADCIRC mesh (Figure E:13-1). All structures added to the ADCIRC for the with-project alignment were then set to be non-overtopping for each simulation. This was done so that the change in water levels as a result of the constructed project could be determined from simulation outputs. All ADCIRC simulations include a two-part simulation—an initial river spin-up simulation so that the slope of the Mississippi River is simulated and the full simulation with time-varying winds and atmospheric pressure for a given synthetic storm (i.e., tropical storm or hurricane). For the with-project analysis, a subset of 36 storms (Figure E:13-2 and Table E:13-1) from the ERDC-developed CSTORM suite (Massey et al., 2011) were simulated on the ERDC Onyx supercomputer for both 2032 and 2082 (as well as without-project 2082). The projected project, or base, year completion is 2032. The base year + 50 years, which is required for economic analysis, is 2082. Sample outputs for future without- and with-project modeling are shown in Figure E:13-4 and Figure E:13-5, respectively. Figure E: 13-6 shows the difference between these two results as a quality check to ensure that differences in the WSE values could be attributed to the presence of the structure (red values indicate an increase, blue values indicate a decrease).

Results from these sets of simulations were then analyzed and statistics were computed to estimate the WSE for various probabilities (often referred to in terms of return period, 1/probability). Steric SLR values—the initial water elevation (0 meters NAVD88) plus that amount of water added on top of it—are 0.362102 meters (1.19 feet) for the present-day intermediate SLR set of simulations and 0.94000 meters (3.1 feet) for the future-year intermediate SLR set of simulations.

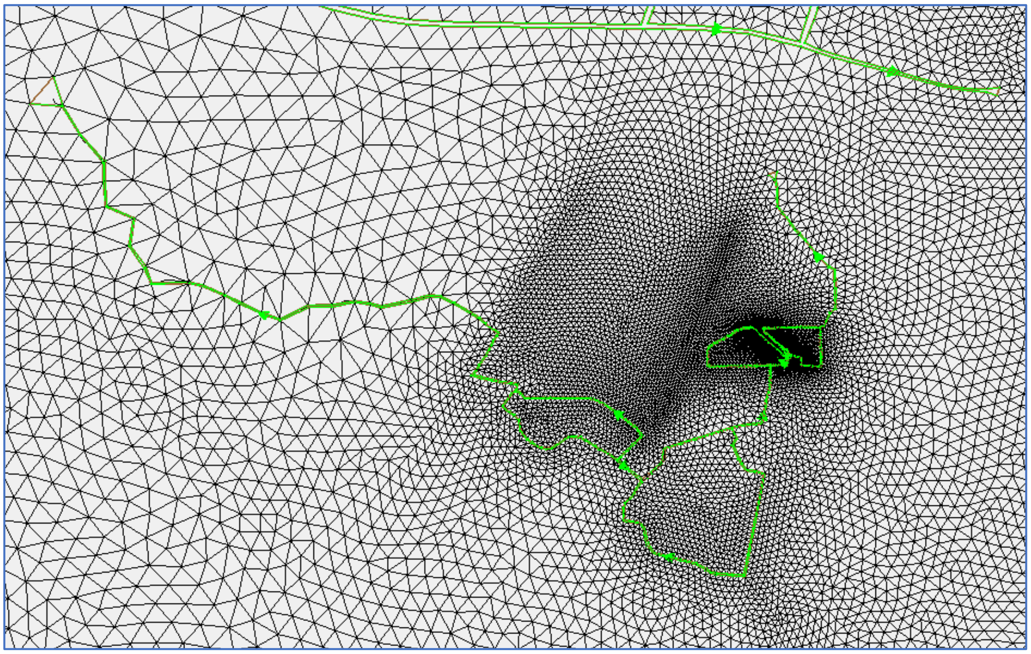


Figure E:13-1. Proposed Draft TSP alignment added to the ADCIRC mesh

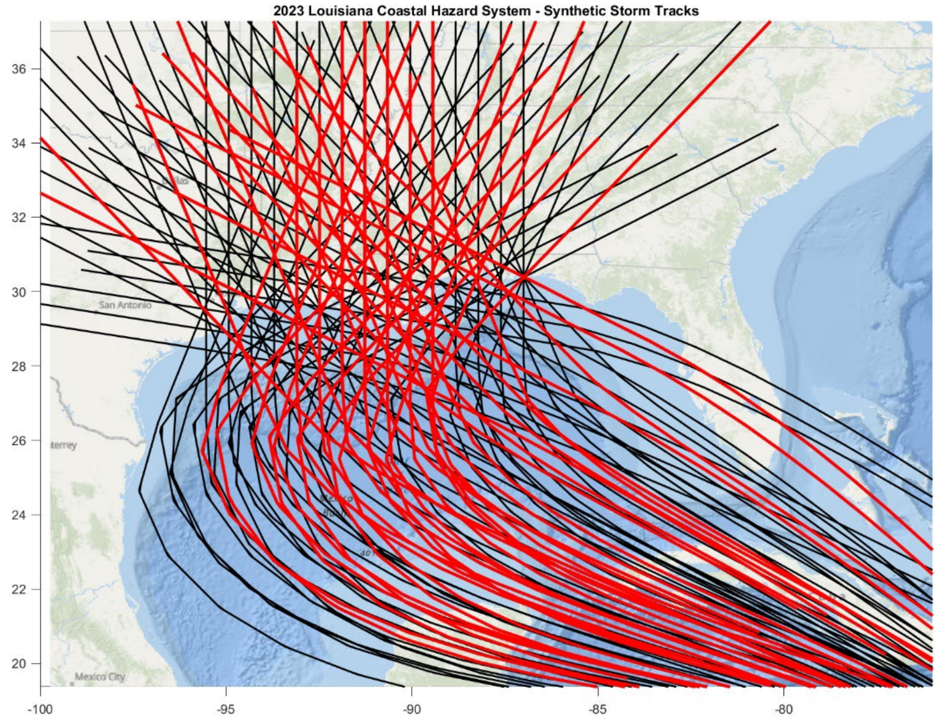


Figure E:13-2. Synthetic storm tracks. Black lines represent the complete suite of 645 storms. Red lines represent the subset of 36 storms simulated with ADCIRC for the STPFS analysis.

Table E:13-1. Storms selected to run for with-project modeling

	Peak Surge (ft NAVD88)		
	-89.7733	-89.7273	-89.7503
Storm ID	30.19529	30.2289	30.19649
11	9	10	10
12	6	7	7
66	10	11	11
79	7	8	7
80	16	18	17
87	13	15	14
131	5	5	5
138	6	6	6
164	7	7	7
171	9	11	10
187	9	10	9
235	2	2	2
253	7	7	7
267	9	9	9
275	8	9	9
276	9	11	10
281	15	17	16
282	8	10	9
288	15	16	15
290	11	13	12
364	5	5	5
374	3	4	3
388	9	11	10
393	12	14	13
394	12	13	12
402	12	14	13
404	7	9	8
405	8	9	8
474	3	3	3

484	7	7	7
506	9	10	9
519	13	14	13
527	8	8	8
528	10	10	10
579	8	9	8
596	10	10	10

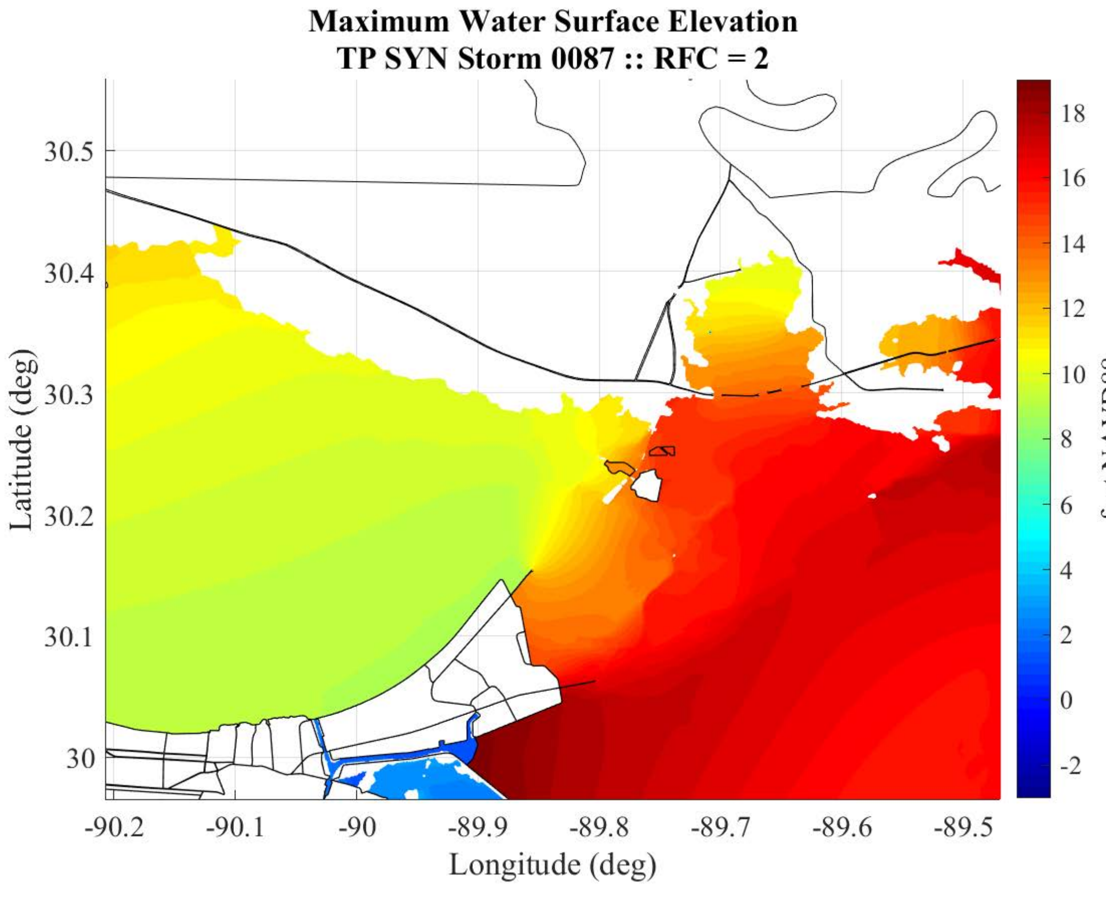


Figure E:13-3. Sample (present-day without-project modeling) maximum WSE output from the CSTORM suite for a given storm.

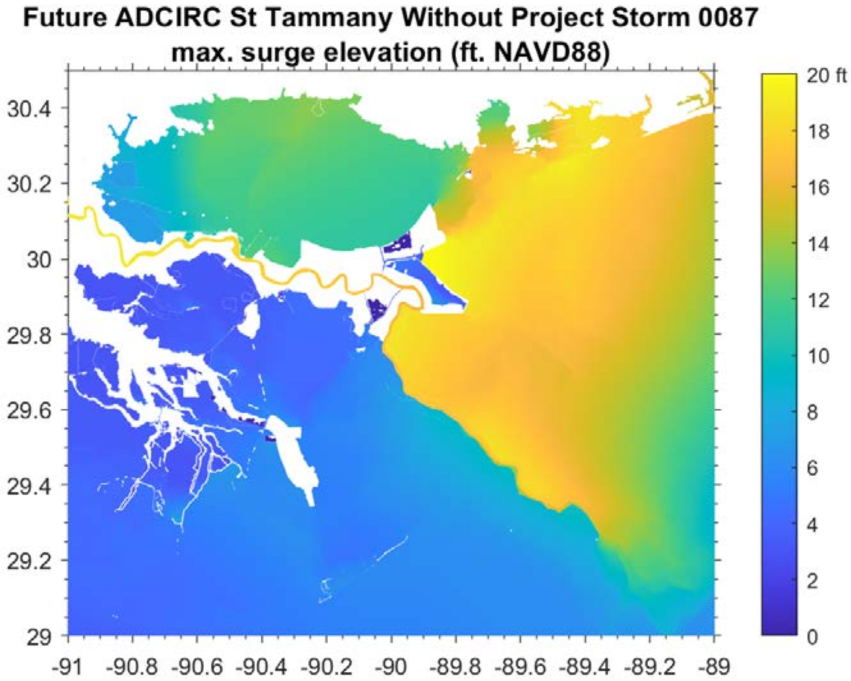


Figure E:13-4. Sample plot of WSE for a future-year without-project simulations from a specific synthetic storm.

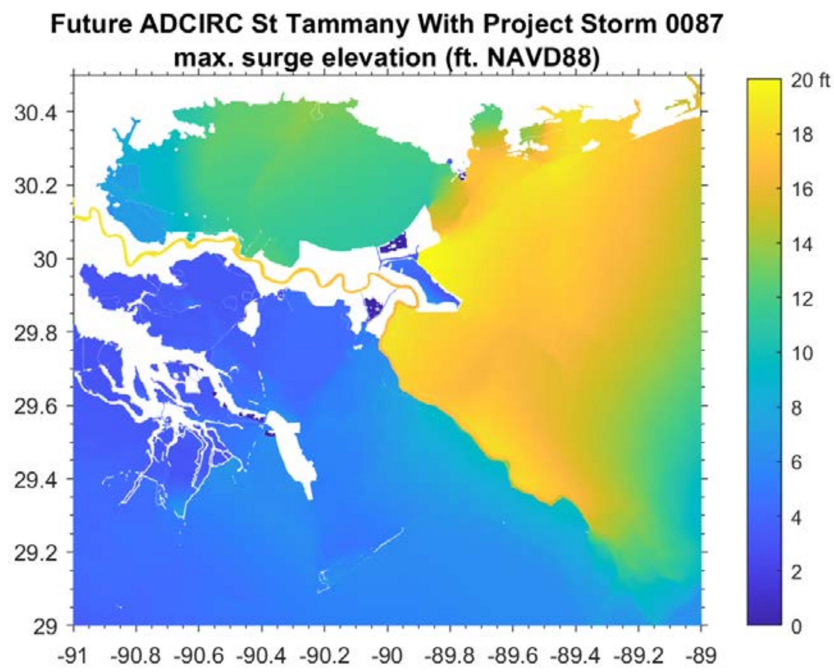


Figure E:13-5. Sample plot of WSE for a future-year with-project simulations from a specific synthetic storm.

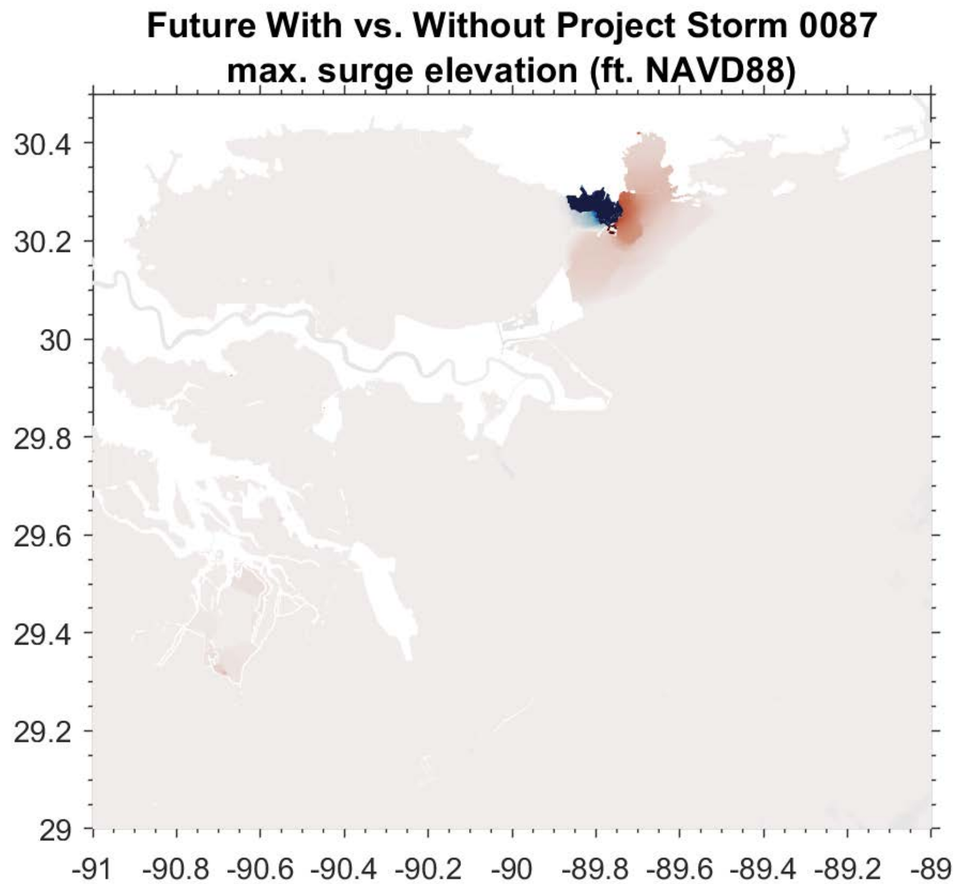


Figure E:13-6. Sample difference plot of WSE between with- and without-project simulations from a specific synthetic storm.

13.1.1 Processed Outputs

The outputs of the 36 modeled storms' maximum surge elevation and maximum wave heights and wave periods were analyzed to determine what a statistical 10-, 50-, 100-, etc. year return period storm characteristic would be at a given location. Values for these frequencies were computed at several locations surrounding the proposed alignment to better understand the potential impacts of the structure. Maps showing the difference between with-project modeling and without-project modeling are shown in Figure E:13-7 for present-case 100-year event, Figure E:13-8 for future 100-year event, Figure E:13-9 for present 500-year event, and Figure E:13-10 for future 500-year event.

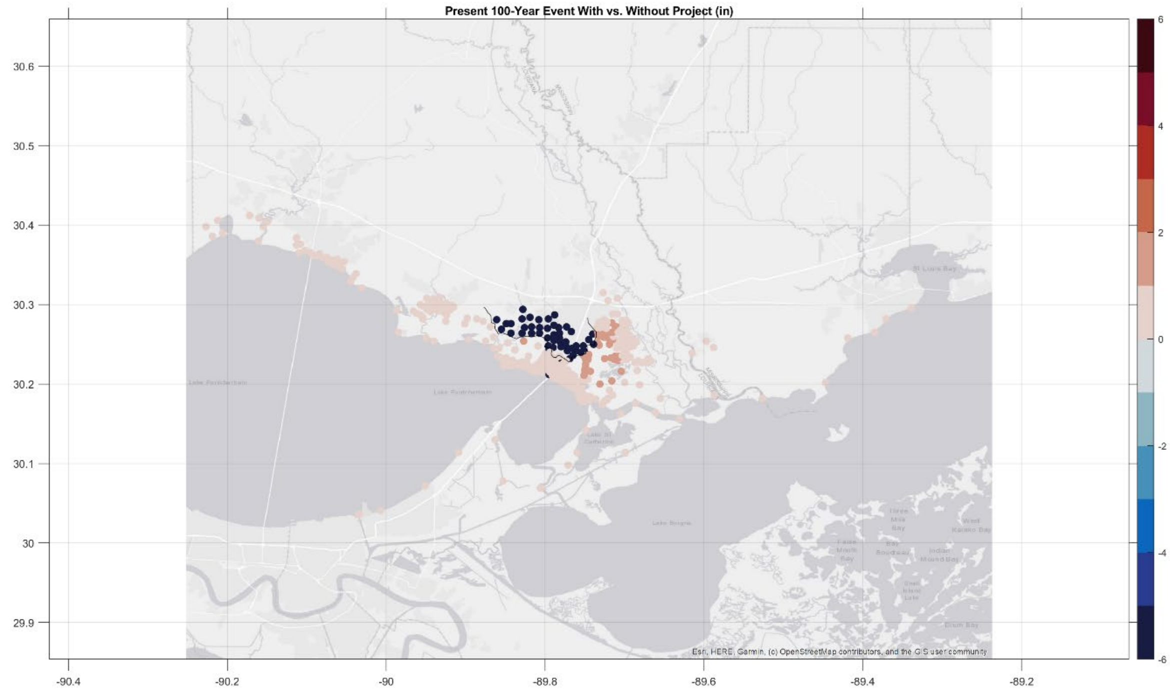


Figure E:13-7. Difference plot of WSE between 2032 with- and without-project values for the 100-year computed WSE (in inches) at various locations surrounding the footprint of the Draft TSP. Blue-colored dots represent reductions with the project in place, on the interior of the proposed system. Red dots represent increases.

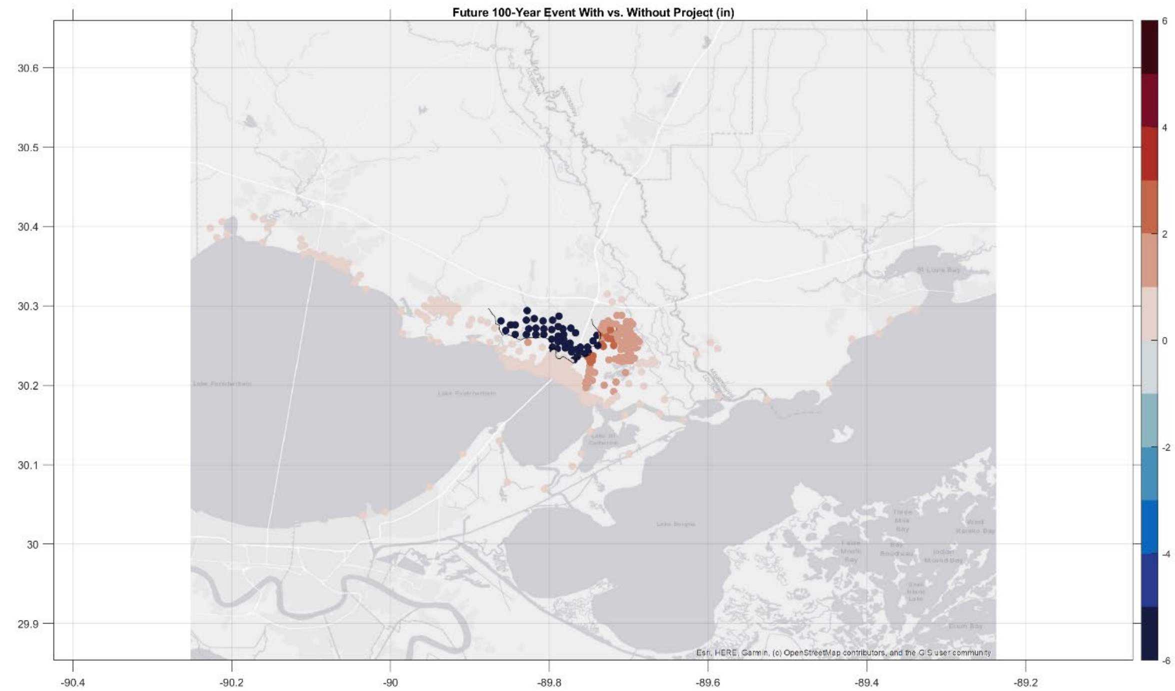


Figure E:13-8. Difference plot of WSE between 2082 with- and without-project values for the 100-year computed WSE (in inches) at various locations surrounding the footprint of the Draft TSP.

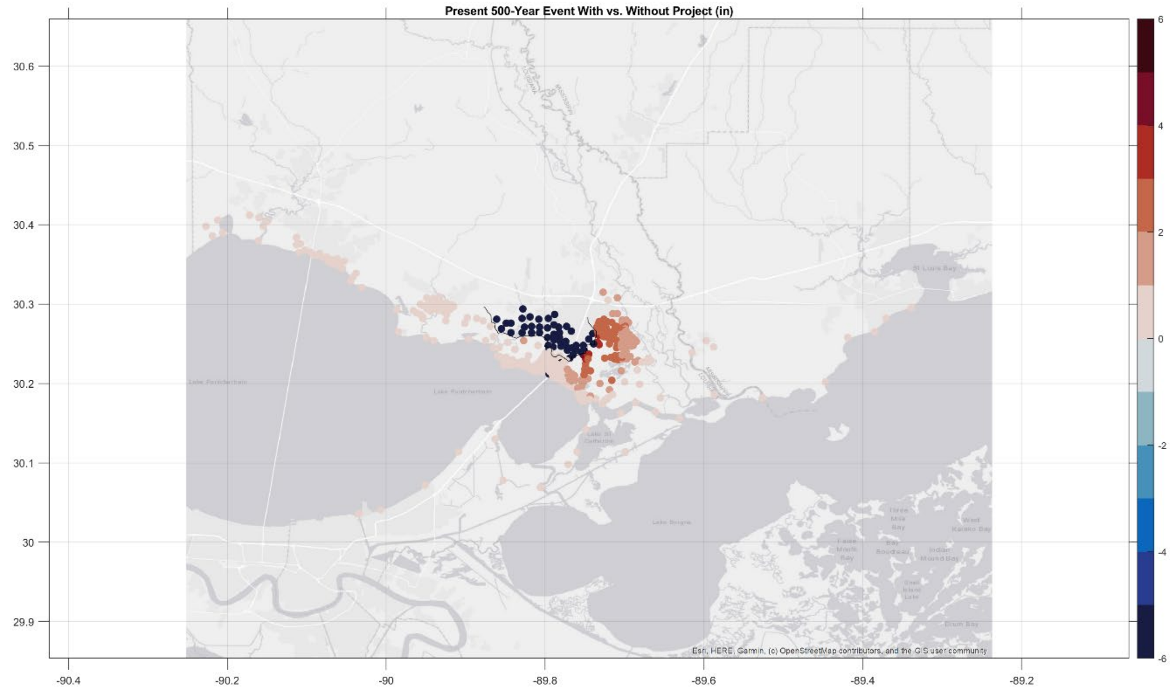


Figure E:13-9. Difference plot of WSE between 2032 with- and without-project values for the 500-year computed WSE (in inches) at various locations surrounding the footprint of the Draft TSP.

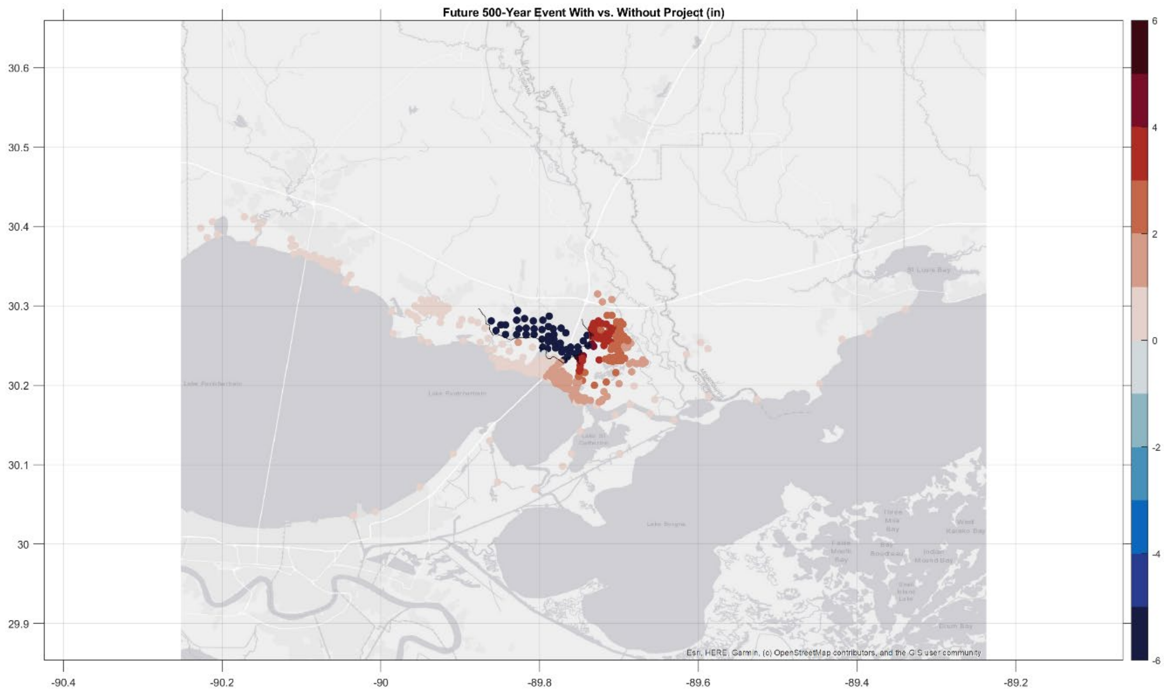


Figure E:13-10. Difference plot of WSE between 2082 with- and without-project values for the 500-year computed WSE (in inches) at various locations surrounding the footprint of the Draft TSP.

In each scenario, there are inducements (red values) outside the project area for the with-project modeling and reductions (blue values) within the systems. Larger inducements occur for 2082 (up to 3" for 100-year and up to 5" for 500-year) than for 2032 (up to 2" for 100-year and up to 4"). The largest inducements are on the east side of the proposed alignments with the largest inducements being on the east side of Lakeshore Estates and Kingspoint levees. The larger inducements on the eastern side of the system are expected as these areas are closer to the Gulf of Mexico where storm surge would enter the Lake Pontchartrain basin via Rigolets.

13.1.2 Design Elevations

Using the values for the 100-year surge elevation, wave height, and wave period for each location, a design elevation was computed using the EurOtop formulation for calculating overtopping (EurOtop, 2018) with an allowed overtopping rate of 0.1 cfs/foot—consistent with the HSDRRS design criteria. Computed design elevations for the feasibility study are shown in green in Figure E:13-11.

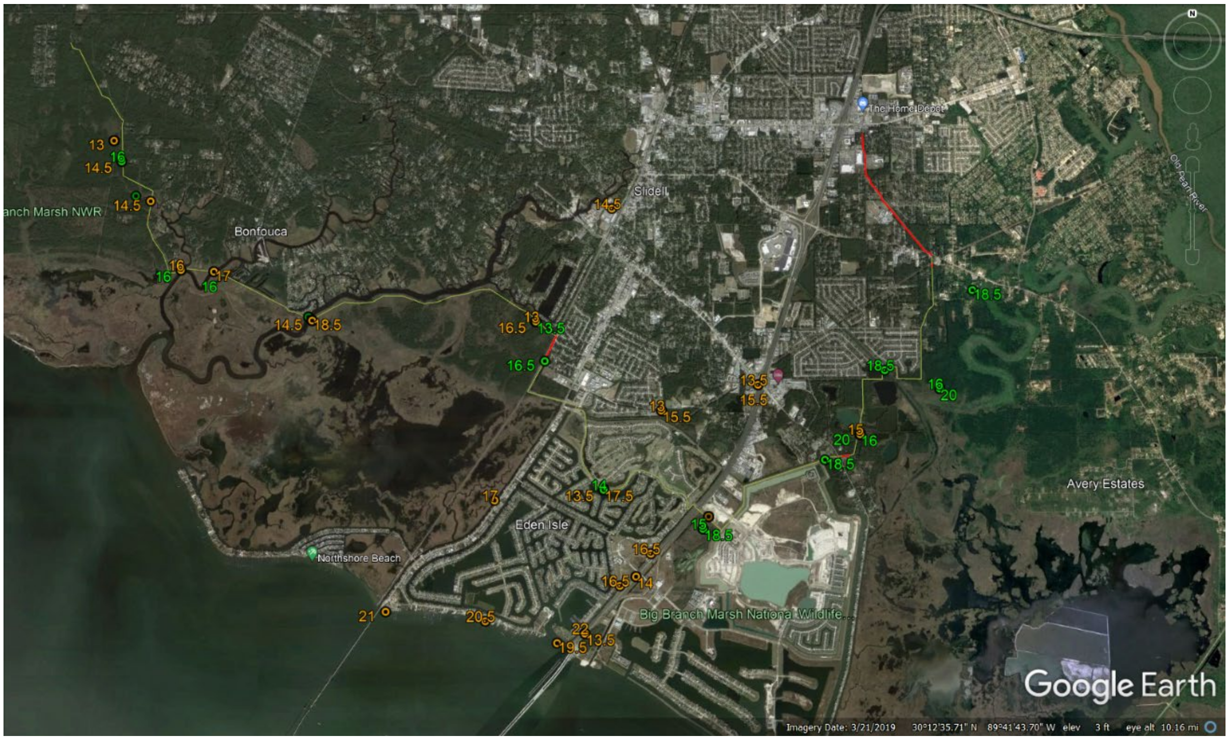


Figure E:13-11. Design heights using prior without-project analysis (orange values) to the updated design heights from the with-project modeling (green values).

13.2 ST. TAMMANY NEW ALIGNMENT AND CHANGES TO WITH-PROJECT MODELING

After the selection of the draft TSP and during feasibility-level design, the PDT considered minor shifts of the alignment for various considerations, also referred to the optimization of the TSP. This process is described in more detail in the main report. Some shifts were accepted and incorporated into the final engineering analysis. The change of the new alignment was minor enough (within the distance of one ADCIRC element) to not necessitate re-running the suite of ADCIRC storms.

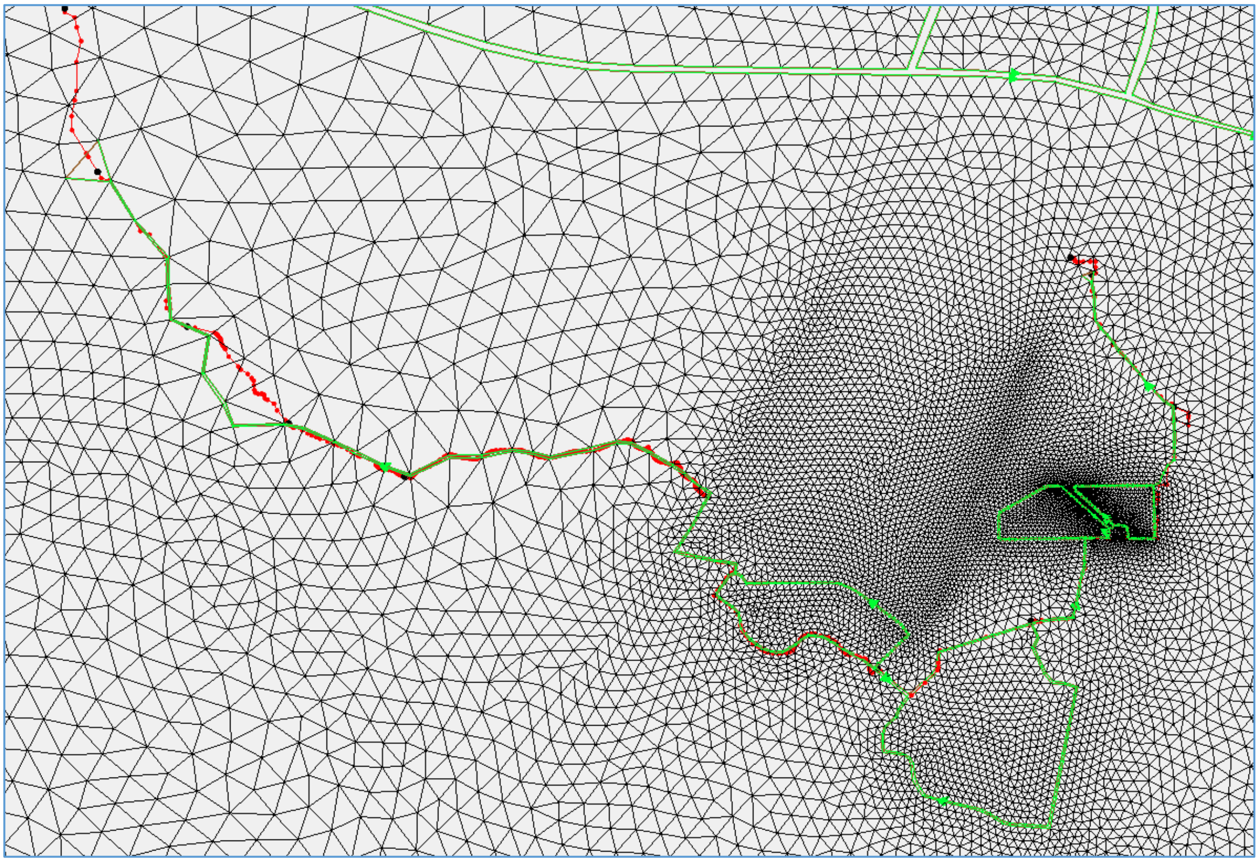


Figure E:13-12. ADCIRC mesh showing the levees/floodwalls as weir pairs (green) with the altered alignment (red)

Since the surge modeling efforts included the squared corner in the southwest corner of Oak Harbor, no points where surge elevation data was computed changed from being inside/outside the system with the new alignment. Additionally, no points where statics were calculated originally on the exterior of the alignment are now on the interior of the alignment following the minor shifts in the alignment footprint. Figure E:13-13 depicts point locations where statistics were calculated along with the original and updated alignment.

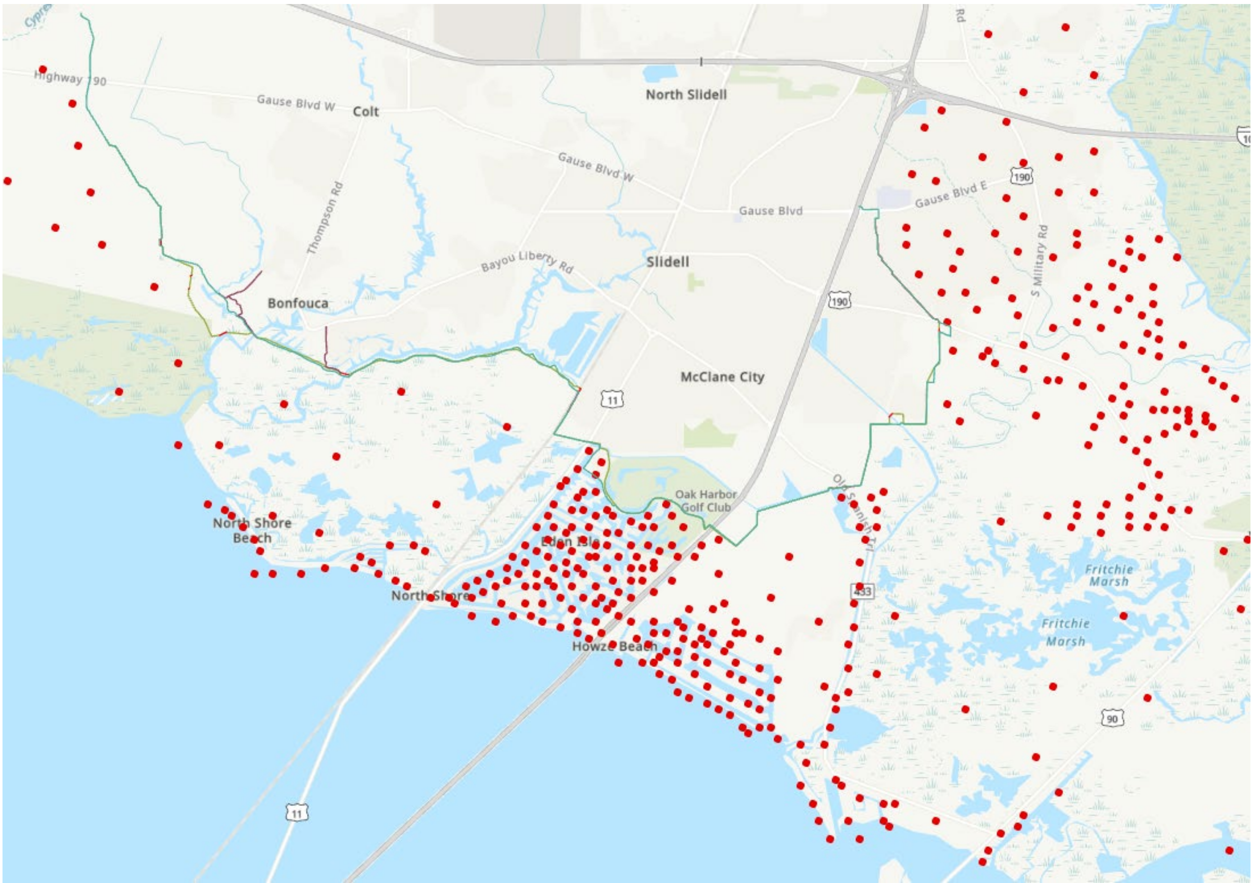


Figure E:13-13. Location of points where surge elevation-frequency data was computed. No points are now outside of the system that were previously modeled as inside of the system. The final alignment of the RP is the blue-green line. The Draft TSP alignment is shown in yellow. Segments of red line indicate gates; maroon segments indicate access roads.

13.3 PROCESS FOR LOW AND HIGH SEA LEVEL RISE (SLR) RATES

ADCIRC simulations run for present-day conditions used a base SLR of 0 ft, and future-year ADCIRC simulations for STPFS were conducted using an intermediate SLR increase of 1.5 ft. A MATLAB script was used to create a linear interpolation of WSE to create future-year low SLR scenario (0.93 ft increase). WSEs are linearly extrapolated to create a high SLR rise scenario (3.59 ft increase) WSE. The SLR change between present and 2032 was considered statistically similar but for the high SLR rate for 2032, values were interpolated 0.45 ft.

Interpolated values were calculated by taking the present-year value at each location and adding the low SLR increase (in feet) multiplied by the difference in future and present WSE divided by the difference between future and present SLR rates. Extrapolated values were calculated by taking the present-year value at each location and adding the high SLR rate multiplied by the difference in future and present WSE divided by the difference between future and present SLR rates. Descriptive statistics were computed on the difference values at each point. For any extrapolated values that exceeded two times the standard deviation plus the median, those values were marked as outliers and corrected by computing the extrapolated value as the WSE value for the intermediate SLR scenario plus the difference between high and intermediate SLR rates, as shown in Figure E:13-14 and Figure E:13-15.

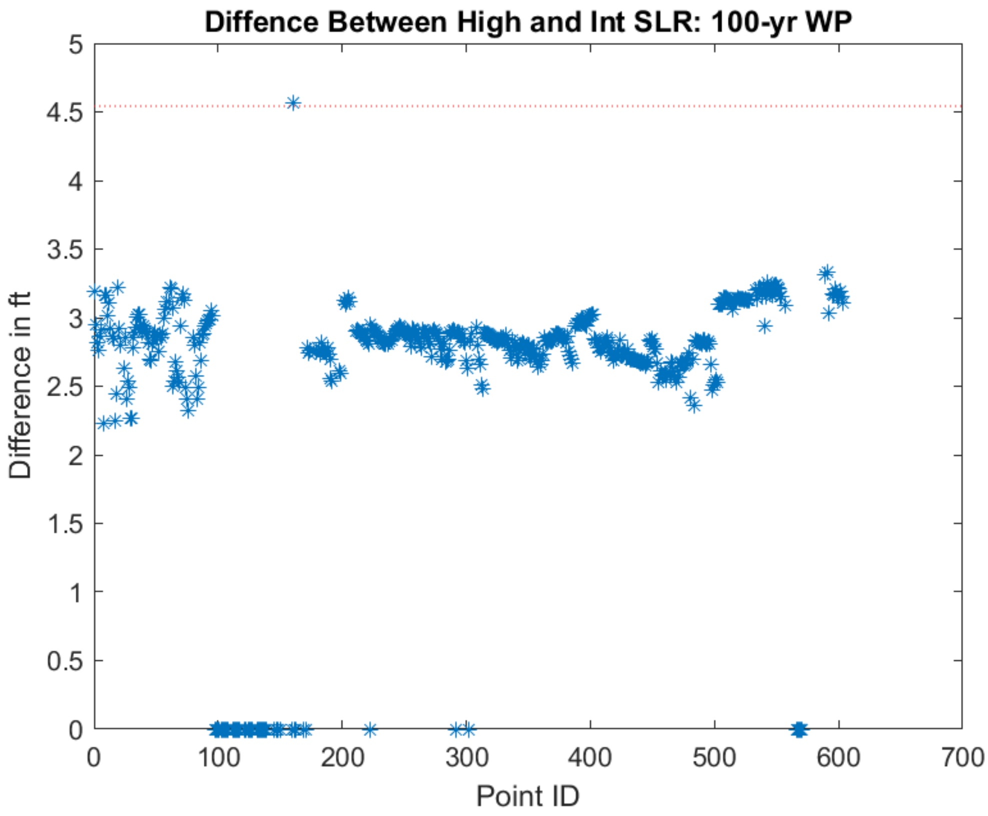


Figure E:13-14. Difference between extrapolated high SLR scenario WSE value and original future intermediate SLR value at a given location. Values of 0 denote locations within the project area where values remained dry during simulation.

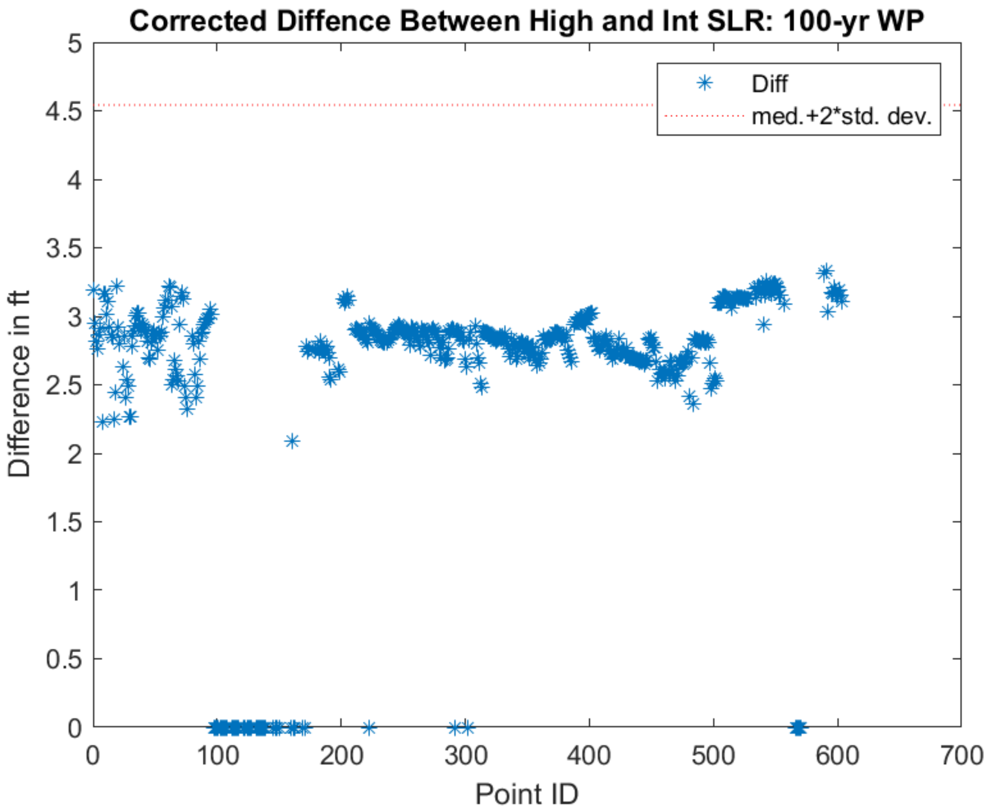


Figure E:13-15. Difference between extrapolated high SLR scenario WSE value and original future intermediate SLR value at a given location with outliers corrected.

13.4 ASSUMPTIONS AND LIMITATIONS

• Interior water level statistics were computed with the latest JPM-OS code from ERDC. The code was applied as-is with no modification or verification.

• The interior stage frequency data does not include the effects of rainfall, wave overtopping, pumping, levee breaching. The interior inundation does include some free flow or weir overtopping of the proposed 100YR design for the lower frequency events.

• The ADCIRC modeling includes a smaller subset of 36 synthetic storms. During a Pre-Construction Engineering and Design (PED) phase, or if the project were to go to construction, design elevations should be reviewed and based on a more thorough analysis.

• The statistical results are based on regression analysis, which introduces some uncertainty into the modeling.

Section 14

Recommended Plan (RP) – Project Analysis Methodology and Results

14.1 HEC-RAS WITH-PROJECT ANALYSIS

As previously stated, three different HEC-RAS model geometries were generated: without-project, with-project with pumps, and with-project with gates. The without-project geometry contains no structural projects identified in the RP. Both with-project geometries have all structural projects outlined in the RP, and a description of how they were modeled are outlined in the following sections of this appendix. Two with-project geometries were needed because Alternative 6c3, the CSRM levee, required independent modeling of the pumping complexes and water control structures to properly size those elements of the system.

14.1.1 Mile Branch Modeling Methodology

The St. Tammany Parish, Louisiana Feasibility Study investigated flood risk management and coastal storm risk management solutions to reduce flood damages caused by riverine, rainfall, and coastal storm flooding in St. Tammany Parish (study area). The Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR) released for review in July 2023 included an Optimized Tentatively Selected Plan that included 3 separable and distinct measures: the construction (and operation) of approximately 18.5 miles of a levee and floodwall system from West Slidell, LA to South Slidell, LA , 2.15 miles of channel improvements to Mile Branch in Covington, LA and nonstructural home elevations for 5,583 preliminarily eligible residences, and floodproofing for 827 eligible non-residential structures in St. Tammany Parish, LA. The DIFR underwent public, policy, and agency technical review (ATR) and refinements were made to address the comments received during the review process to finalize the Integrated Report and EIS and the Recommended Plan within.

Resolution of comments related to the Mile Branch Channel Improvements measure resulted in higher implementation costs than were previously estimated in the DIFR. An updated economic analysis was run based on the revised cost estimate, and it was determined that the cost to implement the channel improvements now exceeded the flood damages avoided and therefore Mile Branch was no longer an economically justified measure and had a benefit to cost ratio below 1. The Mile Branch Channel Improvements were removed from the Final Recommended Plan for the St. Tammany Parish Feasibility Study.

The Recommended Plan in Final Integrated Report and EIS includes two measures: the construction (and operation) of approximately 18.5 miles of a levee and floodwall system from West Slidell, LA to South Slidell, LA , and nonstructural home elevations for 5,583 preliminarily eligible residences, and floodproofing for 827 eligible non-residential structures in St. Tammany Parish, LA.

The Mile Branch consist of both channel deepening and clearing and snagging project and is depicted in Figure E:14-1. The Mile Branch channel improvements start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the confluence of Mile Branch and the Tchefuncte River. The channel improvements are conducted on the lower 2.15 miles (11,341 feet channel) of Mile Branch in Covington. The improvements include clearing and grubbing along with mechanical dredging of the channel to deepen it. The preliminary design assumes an existing bank elevation of 1 foot, a 10-foot bottom width at elevation (-) 5 feet. The bank is at 1V:3H slope. The channel bottom will be lowered by an average of 5 feet with a smooth slope between the beginning and end of the project. This depth was determined based on descriptions of this proposed measure in the USACE 1991 Tangipahoa, Tchefuncte, and Tickfaw Rivers Reconnaissance Report and is planned to be optimized during PED. Approximately 21 acres of channel will be cleared and grubbed prior to mechanical dredging. Clearing and grubbing includes the removal trees, vegetation, debris, trash, or other obstructions within the channel. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel.

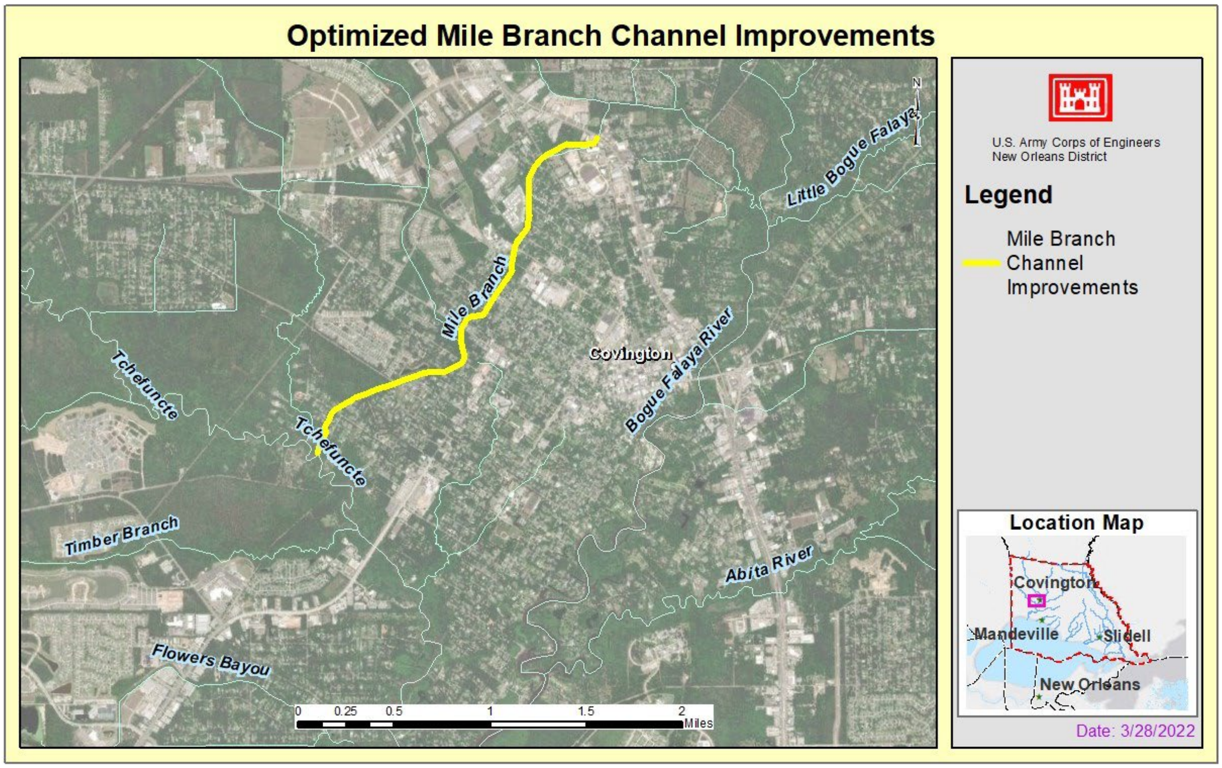


Figure E:14-1. Optimized Mile Branch Channel Improvements

To model this alignment in HEC-RAS, a new with-project terrain was generated. A channel modification layer was applied from the I-190 crossing downstream to the confluence with the Tchefuncte River. The channel modification has 1V:3H side slopes, a 10-feet-wide bottom width and the channel invert is lowered along the entire extent of the project. The lowering of the channel invert was approximately 5 feet at the beginning and 5 feet at the end of the modification layer. The surface terrain in the channel varies a small amount along the extent of the modification layer, so the cut along the extent of the project is not precisely 5 feet from the surface, but it is within a small margin of error. Figure E:14-2 depicts the channel modification applied to the with-project terrain. Additionally, a manning's override region of 0.025 was placed over the extent of the project to represent a cleared and snagged channel. The selected roughness coefficient value is sourced from the 2011 Louisiana Department of Transportation (LaDOTD) Hydraulics Manual.

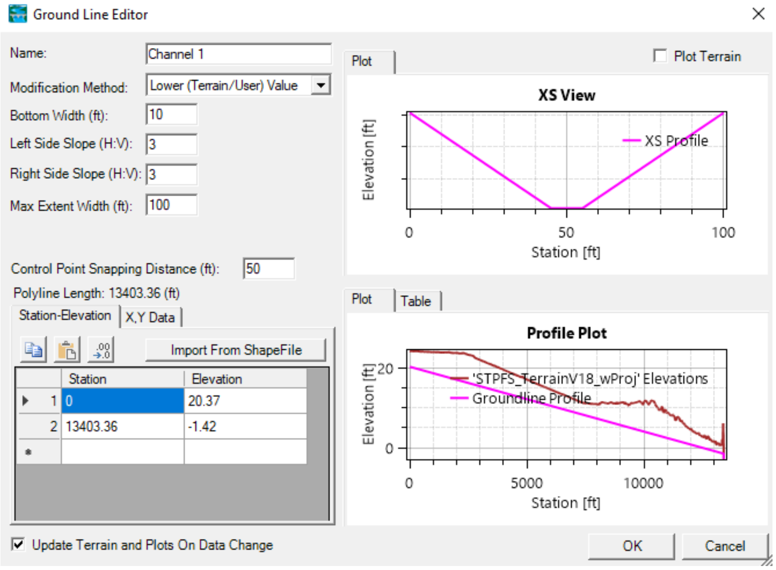


Figure E:14-2. Depiction of channel modification used to apply the Mile Branch channel deepening to the with-project terrain

14.1.2 Mile Branch Modeling Results

The Mile Branch dredging and channel improvement project proved to be effective at reducing WSEs around the project area. Reductions were seen within the floodplain of Mile Branch for each frequency event (2 year – 500 year). Additionally, with the project in place, Mile Branch stays within its banks for the 2-year – 10-year events. For frequency events 25-year – 500-year Mile Branch overtops its banks. Results also indicate that with the project in place on Mile Branch, reductions are seen on Mile Branch Lateral A. With reduction in overtopping volume that overflows from Mile Branch to Mile Branch Lateral A, WSEs in the floodplain of Lateral A is reduced. It should be noted that benefits do not extend past the confluence of Mile Branch and the Tchefuncte River.

There are also reductions upstream of where Mile Branch intersects with Hwy 190. The area directly upstream of Mile Branch is the flood plain for the Bogue Falaya River, and for the

100-year 2032 and 2082 events, lowering's range from 0.1 feet - 0.25 feet. For the 10-year 2032 and 2082 events, lowering's upstream of this crossing range from 0.1feet to 0.3 feet. Very small lowering's, in the hundredths range, are also seen on the Bogue Falaya where the floodplain interacts with the upstream end of Mile Branch at this location. Additionally, for the 100-year runs, a small inducement can be seen on the Tchefuncte River in the hundredths range, which is located between the confluence of Mile Branch and Lateral A. This is likely caused by the additional volume that is channeled to the Tchefuncte River with the project in place along Mile Branch. This inducement does not exit the existing floodplain of the Tchefuncte River and dissipates downstream after passing the confluence of Mile Branch Lateral A. Difference maps depicting the change in WSE with the project in place may be seen in Annex 3 for 10-year and 100-year frequency events, baseline (2032) and future (2082) along with each SLR scenario.

Additionally, model runs were performed at Mile Branch to investigate the impacts of only clearing and snagging the channel, and no dredging. Three frequency events were selected to perform this analysis, including the 10 year, 25-year, and 100-year baseline (2032) with the intermediate SLR rate at Lake Pontchartrain. Figure E:14-3 depicts difference maps of the Mile Branch improvement project compared to clearing and snagging only of the Mile Branch channel for the 10-year 2032 event. Findings indicate with clearing and snagging of the channel only, and no dredging, the magnitude of WSE lowering's is not as high. For example, clearing and snagging lowers WSEs by a maximum of 0.35 feet in various locations. Whereas the RP of dredging, clearing and snagging the channel achieves WSE reductions of up to 1.5 feet for the 10-year 2032 event in some locations. Additionally, clearing and snagging the channel independently of dredging causes an inducement upstream of Hwy 190 for the 10-year, 25-year, and 100-year runs. This is occurring because clearing and snagging the channel moves water at a faster rate from the Tchefuncte River up to the Hwy 190 crossing. Directly upstream of the alignment where this inducement is occurring, WSEs are compounding due to insufficient storage in the channel for the increased volume of flow that travels down the Mile Branch channel at a faster rate.

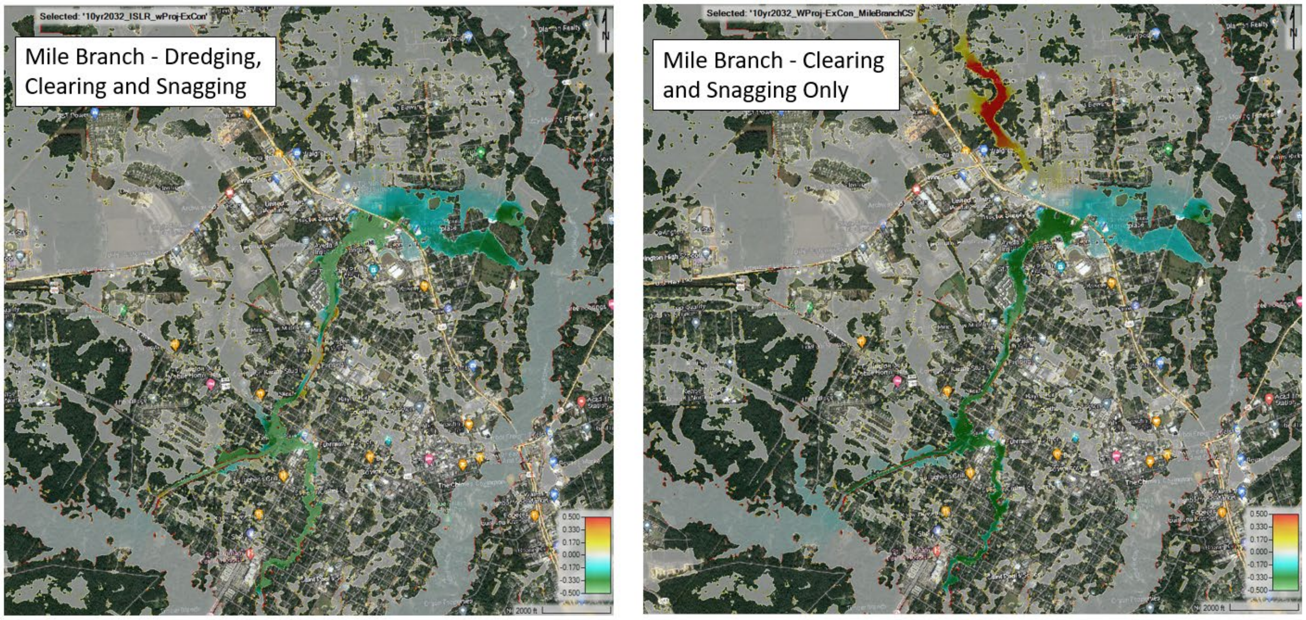


Figure E:14-3. Difference maps for the 10-year 2032 event with the intermediate sea level rise (ISLR) rate at Lake Pontchartrain, in the vicinity of Mile Branch comparing the Optimized_________ TSP with dredging, clearing and snagging of the channel (left) and only clearing and snagging of the channel (right).

14.1.3 Bayou Patassat Modeling Methodology

The draft TSP defines Bayou Patassat as a clearing and snagging project. Bayou Patassat is a small tributary of Bayou Bonfouca in Slidell. The work will be located between City Barn pump station and Highway 11. Approximately 0.17 miles (900 feet) will be cleared and snagged, which includes the removal trees, vegetation, debris, trash, or other obstructions within the channel.

This study was modeled using a Manning's override region along the extent of the defined project. The override region has a Manning's value of 0.025 to represent a cleared and snagged channel, and is sourced from the 2011 LaDOTD Hydraulics Manual. It should be noted following a refined Economics analysis, this project was removed from the RP as it is not producing the net benefits to warrant further study.

14.1.4 Bayou Patassat Modeling Results

The Bayou Patassat clearing and snagging measure showed minimal reductions in peak water levels, limited to hundredths of a foot or less. Figure E:14-4 below depicts the lowering in WSE exhibited for the 10-year 2032 event as an example of the performance for this project. Reductions with the project in place range from 0.01 feet to 0.025 feet upstream of the cleared and snagged portion of the channel. Upon reviewing the figure, it is evident there is an inducement along the 900 feet stretch of the cleared and snagged channel. By smoothing the downstream end of Bayou Patassat, water is able to travel faster to the pumping station, which has a controlled discharge rate. This causes water to pool at the pump station approach as the pump curves are consistent with the current operations of City Barn Pump Station. The inducement is only exhibited in the Bayou Patassat channel banks at a maximum of 0.02 feet (directly adjacent to the pumping station) and does not overtop its banks into the floodplain. Additionally, it should be noted that inducements in the figure along Bayou Bonfouca are not caused by the Bayou Patassat project because the discharge rate into the waterway is consistent between runs. Inducements in Bayou Bonfouca depicted in the figure below are caused by the presence of the RP levee and are exaggerated due to the scale of the layer. This is discussed further in the following section. As stated above, refined evaluation from Economics indicated this measure is not producing the benefits to warrant further study and has been removed from the RP.

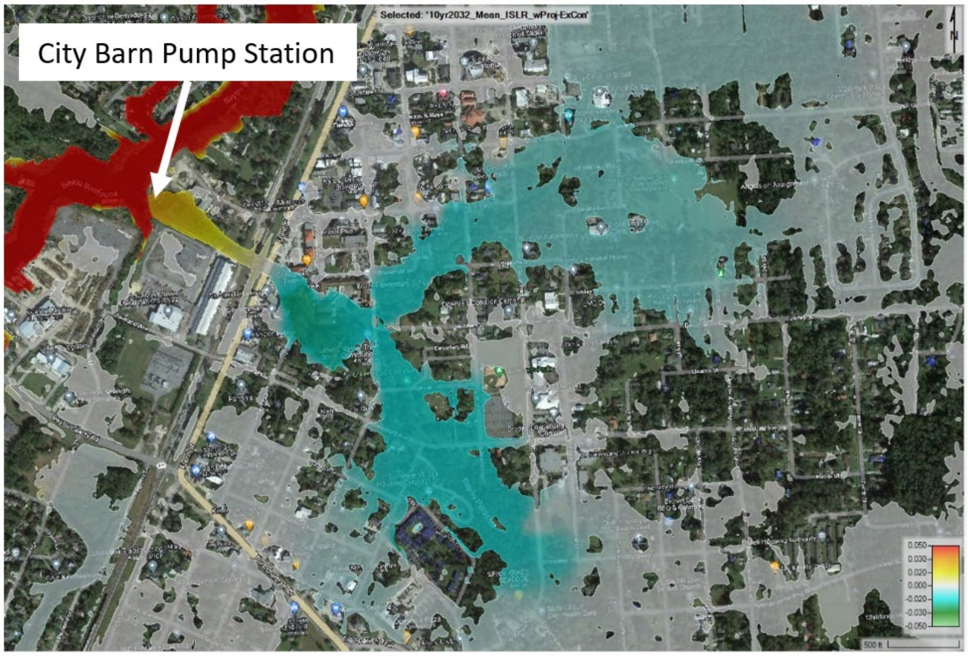


Figure E:14-4. Difference map at Bayou Patassat depicting maximum WSE lowering's with project in place. Blue, green, and cool tones indicate a lowering in WSE in the hundredths range. Red, yellow, and warm tones represent an increase in WSE. Note that there is a pump station at the confluence of Bayou Patassat and Bayou Bonfouca controlling discharge from Bayou Patassat into Bayou Bonfouca called City Barn Pump Station. Inducements exhibited in Bayou Bonfouca are a result of the proposed Levee and scale of the layer, not the Bayou Patassat project.

14.1.5 South Slidell and West Slidell Levee and Floodwall System

The RP for the levee and floodwall system consists of a combination of portions of the West Slidell levee alignment proposed in Alternative 5 and the South Slidell levee alignment proposed in Alternative 6. The two alignments would be connected by a new railroad gate across the existing Norfolk Southern Railway Corporation railroad tracks. The initial draft of the levee and floodwall system was further refined after additional modeling and input from the PDT, agency and public comments to create the RP. The RP alignment for the levee and floodwall system consists of a total of approximately 18.4 miles (96,950 feet) of levee and floodwall, with approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and 3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall. Refer to Figure E:14-5 for the levee alignment. The RP also consists of pump stations, floodgates, vehicular floodgates, and ramps.

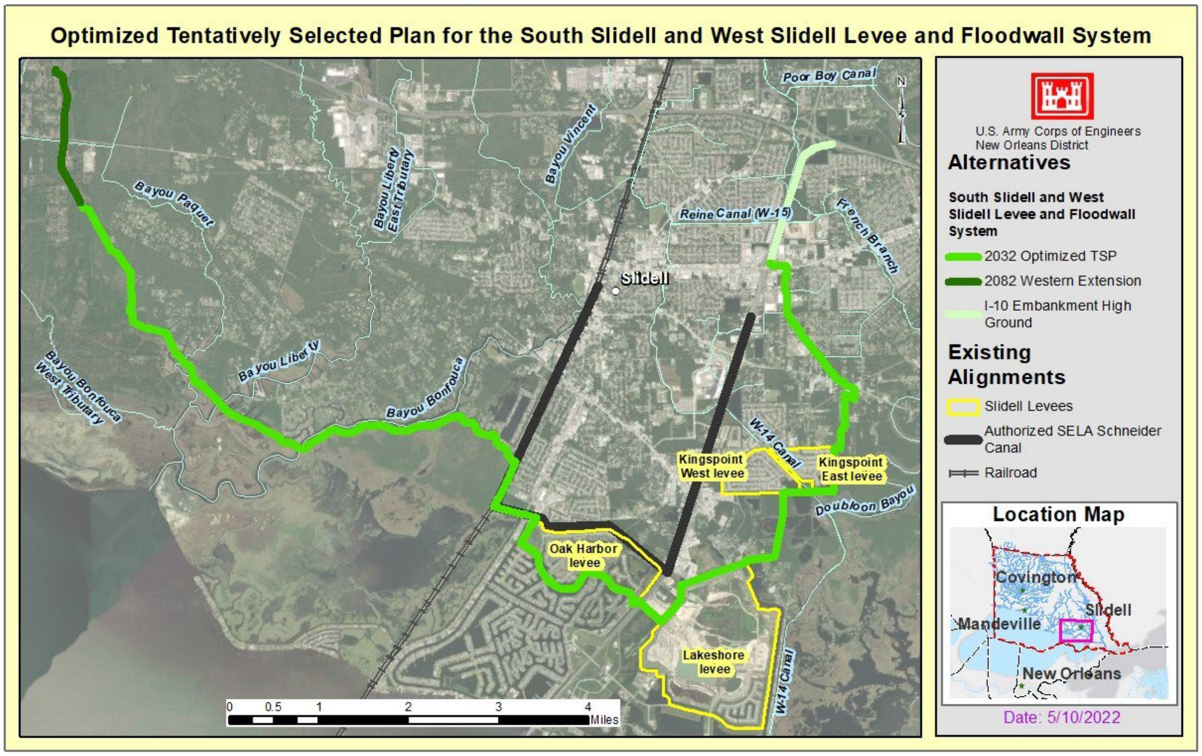


Figure E:14-5. RP for the South Slidell and West Slidell Levee and Floodwall System

14.1.6 South Slidell and West Slidell Levee and Floodwall System Modeling Approach

Section 12.6.1 of this appendix describes the computation parameters used in this modeling effort. Version 6.2 of HEC-RAS was used for all production runs. The diffusion wave equation set was selected for all runs. A computation interval of 6 seconds was deemed necessary for analysis of WSE around gate and pump locations. This differs from the existing conditions runs, which were able to run with a higher computation interval of 15 seconds. Initial conditions warm-up time is consistent with the existing conditions geometry of 72 hours.

The alignment is modeled as a 2D area connection within the 2D area mesh. Break lines are used to enforce the entirety of the alignment to ensure cell faces identify it as a hydraulic barrier. A weir elevation of 20 feet was used along the alignment as that simplified elevation is high enough to prevent overtopping of the proposed levee during all modeled rainfall and riverine frequency storms. For context, the maximum WSE for the coincident Pearl River and Bogue Chitto flood and precipitation for the 500-year 2032 event is 14.2 feet near the eastern terminus and 18.20 feet near the western terminus. Coastal levee and structure design elevations were completed subsequent to the initiation of rainfall modeling of the RP and vary from 13.5’ to 20.0’ NAVD88. A weir width of 10 feet and a weir coefficient, Cd, of 3 is used along the entire alignment.

To size the drainage features necessary for this alignment, two different model geometries were developed. This is done because the South Slidell and West Slidell levee and floodwall system requires independent modeling of the pumping complexes and water control structures to properly size those elements of the system. Therefore, one with-project model geometry has the alignment modeled with the gates fully open during the entirety of the simulation and no pumping, representative of day-to-day operation of the project when Lake Pontchartrain is at a normal stage. The second with-project geometry has gates fully closed and pumping ongoing through the entire simulation, representative of a scenario with the levee system closed in preparation for an incoming storm and pump stations used to evacuate floodwater from the interior of the alignment.

To estimate the minimum dimensions and capacities of these drainage features, metrics were used to evaluate both gate and pump sizing consistently. Based on Engineering Manual (EM) 1110-2-1413 Hydrologic Analysis of Interior Areas, the minimum facility should pass the local system design event with essentially no increase in interior flooding. The system design event was based on the current regional best practice of applying the 10-year frequency for the interior rainfall. For the RP, compound flooding was not analyzed explicitly, and considered as it relates to the separate flooding risks, coastal and interior rainfall-runoff. This approach represents the flooding characteristics for the design event.

An iterative process was used to determine gated opening widths and pumping capacity estimates that would limit modeled WSE increases to less than half a foot for the 10-year frequency intermediate SLR event. The estimated minimum requirements were made in the interest of providing economical flood conveyance features. Future decisions to add gates, pumps, or use larger features in the same locations is considered an additional benefit to interior flooding considerations and would likely lower the maximum WSE on the interior. One limitation of the feasibility-study-level drainage estimates was that some interior drainage details were not investigated, such as canals and channels to connect to the proposed drainage facilities, pump station forebay design, or additional retention storage near the alignment. Further investigation of interior drainage is recommended during PED.

<u>Gate Sizing</u>

Gates are placed along the alignment where main waterways and existing drainage paths are intersected. To model this, culvert openings are placed along the 2D area connection in locations that intersect waterways and drainage paths. Initial opening widths and heights were selected to fit within the existing channel dimensions visualized in the terrain dataset. It should be noted channel surveys were not collected for this study, and old surveys were burned into the terrain dataset for reaches that had this available data. This is important to note as it directly impacts the initial estimates of gate widths and elevations. Gate heights were determined such that the top of the gate would be above the water surface during the design event to allow gravity flow through the gate. Iterative runs were made to identify the minimum gated opening widths to keep interior inducements at 0.5 feet or less in locations of identified structures for the 10-year 2032 intermediate SLR scenario. The 10-year frequency event was selected because it is the design standard for interior drainage features in St. Tammany Parish. Table 14-1 represents the final minimum gate openings widths and heights meeting these criteria. It should be noted that gate openings were modeled in the connection data editor as culverts and not gates to stabilize and mitigate against fluctuating WSEs during the simulation. Additionally, these estimates are not considered a highly detailed interior drainage design, and that effort will need to be conducted during PED.

Pump Sizing

Pumps are placed along the alignment where main waterways are intersected. To model this, pumps are placed within the 2D area mesh and pass flow from a receiving cell on the protected side of the alignment to a depository cell on the flood side of the alignment. All pumping facilities were modeled as a single pump with a single on and off elevation. Without-project peak flows were used as a guide for initial estimates of pumping capacities. Iterative runs were made to identify the appropriate pumping capacity of the waterways to keep the interior inducements at 0.5 feet or less in locations of identified structures for the 10-year 2032 intermediate SLR scenario. The 10-year frequency event was selected because it is the design standard for interior drainage features in St. Tammany Parish. Table E:14-1 depicts the minimum pumping capacities identified meeting these criteria. It should be noted that a bug has been identified in the HEC-RAS release 6.2 where the pump efficiency curve set in the Pump Station Data Editor doubles the pumped flow. This is addressed by halving the pump efficiency curve in the geometry so that the results portray the necessary pumping capacity. Additionally, these estimates are not considered a highly detailed interior drainage design, and that effort will need to be conducted prior to construction during PED. Further investigation and design are required.

Table E:14-1. Summary of Minimum Hydraulic Drainage Features for the South Slidell and West Slidell Levee and Floodwall System. For gate type designations, refer to the Engineering Division Project Descriptions.

Description	Width of Drainage Gate (ft)	Ground/Sill Elev.	Hydraulic Height Opening of Drainage Gate (ft)	Area (s.f)	Pumping Capacity (cfs)
Gate near Shannon Dr	4	15.5	2	8	
Tammany Trace Gate	15	12	2	30	
Sluice Gate #7 (Near CC Rd)	25	8.6	2	50	
Sluice Gate #6 (Bayou Paquet North Tributary)	75	0.8	3.5	262.5	300
Nav. Gate #3 (Bayou Paquet Navigable Gate)	90	-0.5	4	360	500
Bayou Liberty Nav. Gate	80	-6.8	14	1120	1800
Bayou Bonfouca Nav. Gate	110	-9	14	1540	2000
Sluice Gate #2 (Bayou Bonfouca Sluice Gate)	50	0.4	3	150	
W14 Nav. Gate	90	0.1	8.5	765	1000
Sluice Gate #8 (Kingspoint East)	90	4.4	1.5	135	200
Sluice Gate #10 (Near Eastern Terminus)	20	10.5	2	40	
Reine Canal	30	7.5	8	240	200
French Branch at I-10	25	8.3	10	250	450

14.1.7 South Slidell and West Slidell Levee and Floodwall System Modeling Results

As stated above, the final pumping capacities and gate dimensions depicted in Table E:14-1 maintain with-project maximum WSEs of 0.5 feet or less than without-project maximum WSEs on the interior of the alignment at locations of structures for the 10-year baseline (2032) event. Additionally, two sets of simulations were completed to consider flood risk with and without coincident Pearl River flooding. When modeling the Pearl River flood frequencies coincident with rainfall flooding, any impact to WSEs near the project location for each rate of SLR is masked by the higher stages from the Pearl River flood. This results in compounded flood impacts near the downstream region of the model domain, where Slidell, LA is located.

To evaluate the changes in maximum WSEs on the exterior of the alignment, the PDT ran two different sets of runs with varying inflows on the Pearl River and Bogue Chitto boundary conditions. The first set of runs used a historic mean value for the Pearl River and Bogue Chitto River. This allowed the PDT to evaluate the inducements and not mask the rainfall

WSE changes between with and without project more clearly. The historic mean inflow for the Bogue Chitto River using gage 2492000 near Bush, LA is 2,010 cfs. The historic mean inflow for the Pearl River using gage 2489500 near Bogalusa, LA is 10,100 cfs. The second set of runs used the calculated frequency flows discussed in the boundary condition section of this Appendix.

Difference maps are generated for the historic mean inflow runs to illustrate the changes in WSE with the project. The maps can be reviewed in Annex 3 for the Slidell levee. Figure E:14-6 depicts the 10-year 2032 difference map denoting the change in WSE with the project in place for the intermediate rate of SLR. Discussion of results for the mean inflow runs are grouped into three regions, and delineations of these regions are depicted in Figure E:14-6.

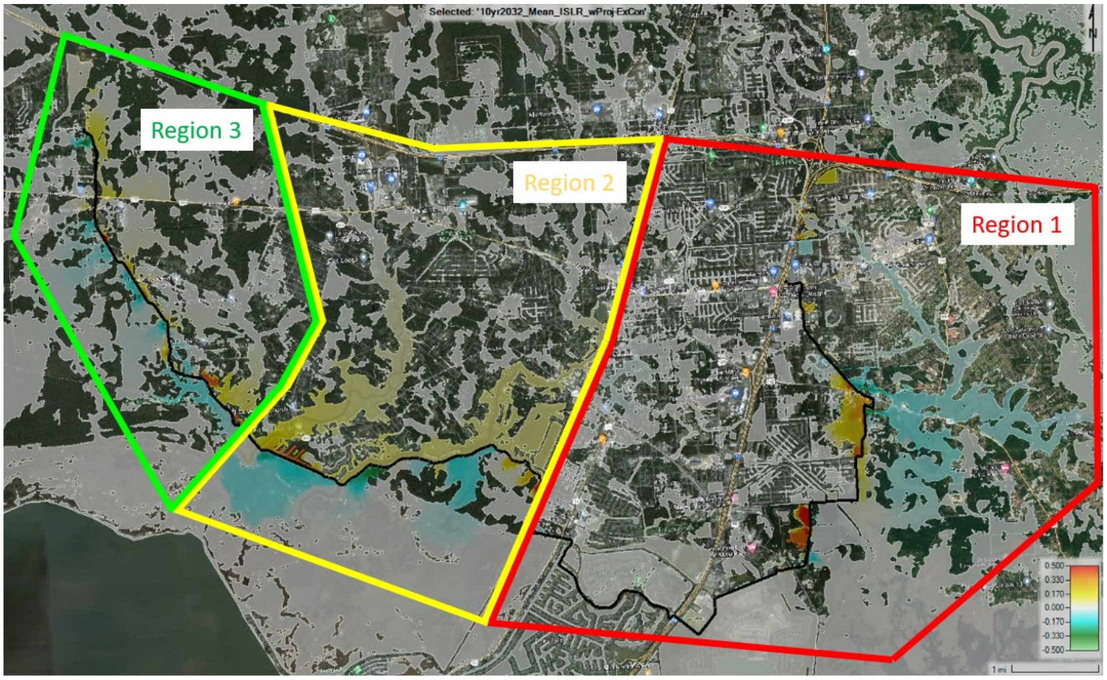


Figure E:14-6. 10-year 2032 event difference map depicting WSE increases and lowering's for the intermediate rate of SLR and mean inflows on the Bogue Chitto River and Pearl River. Regions correlate to areas discussed in the following results section. For a comprehensive description of difference maps refer to Annex 3 of this appendix.

The first results region encompasses the eastern extent of the levee, from Norfolk Southern Railroad to the Pearl River floodplain, and Figure E: 14- 6 outlines this area in red and will be referred herein as Region 1. On the eastern side of the levee, reductions can be seen on the flood side for each rainfall event, specifically concentrated around Doubloon Bayou and the W-14 canal. Reduction in WSE for each frequency remains 0.05 feet - 0.25 feet directly along the flood side of the levee for the 10-year 2032 and 2082 runs. Reductions for the 100-year baseline and future runs on the flood side of the levee in this same location remain in the range of 0.15 feet - 0.75 feet. For both the 10-year and 100-year events, the magnitude of reductions gradually reduces further east of the levee. Reductions remain concentrated in the Doubloon Bayou channel and floodplain. This is occurring because the drainage path east of I-10, which generally drains from northwest to southeast, is being obstructed by the proposed alignment. In turn, there are also inducements on the protected side of the levee for each event. Inducements in Region 1 on the protected side north of Kingspoint levee range between 0.20 feet - 0.40 feet for the 10-year event, 2032 and 2082 runs. In this same location on the protected side for the 100-year 2032 and 2082 events, the range of inducements are between 0.40 feet - 0.88 feet. There is also a small detention pond located directly south of the Kingspoint levee that has increased WSE with the project in place. This inducement is partially due to terrain data not capturing the bathymetry of this detention area and is exaggerating the inducement. For the 10-year event 2032 and 2082 runs, the inducement remains below 0.5 feet. For the 100-year event, the inducement remains below 1.4 feet.

The second results region is along the central reaches of the levee alignment, between Bayou Liberty and the Norfolk Southern Railroad. Figure E:14-6 outlines this area in yellow and will be referred herein as Region 2. Within Region 2, the levee alignment crosses two major waterways in the parish: Bayou Liberty and Bayou Bonfouca. The alignment crosses these two waterways and their floodplains perpendicularly. As can be seen in Figure E:14-6 along with the other difference maps in Annex 3, inducements are evident on the protected side along this extent of the levee. This is occurring because the drainage paths and floodplains for these two waterways are being obstructed. Inducements for the 10-year events (baseline and future) range between 0.1 - 0.4 feet on the protected side. Approximately 0.75 miles upstream of the levee crossing with Bayou Liberty, the inducements within the channel reduce to a negligible range (below a tenth of a foot). Approximately 0.25 miles upstream of the levee crossing with Bayou Bonfouca, the inducements within the channel on the protected side reduce to a negligible range (below a tenth of a foot). For the 100-year baseline and future events, the floodplain of these two waterways converge in the low lying terrain between them. Inducements on the protected side for the 100-year events range between 0.1 feet – 0.9 feet. Highest inducements are closest to the levee alignment and decrease further upstream from the crossing in both waterways. Inducements decrease to a negligible range (below a tenth of a foot) approximately 1.70 miles upstream of the Bayou Liberty crossing. Approximately 1.95 miles upstream of the Bayou Bonfouca crossing inducements reduce to a negligible range. As would be anticipated, WSE reductions are seen on the flood side of the levee in Region 2. Reductions are concentrated in two locations on the flood side of the levee: the floodplain of Bayou Bonfouca, and the floodplain between the two waterways. Reductions to WSE for the Bayou Bonfouca floodplain range between 0.1 feet - 0.3 feet for the 10-year and 0.2 feet - 0.7 feet for the 100-year baseline and future events. The second location of reductions to WSE on the flood side of the alignment between the two waterways has a lower magnitude of reductions. For the 10-year 2032 and 2082 runs, the range of WSE reductions remains between 0.1 feet - 0.25 feet. For the 100-year baseline and future events, the reductions in WSE range between 0.1 feet - 0.2 feet.

The western portion of the alignment, west of the Bayou Liberty crossing, is the final results region outlined in green on Figure E:14-6 and will be referred to Region 3 herein. Reductions occur along the flood side of the levee ranging from 0.1 feet - 0.3 feet for the baseline and future 10-year events. The 100-year 2032 and 2082 runs have reductions on the flood side that range from 0.10-feet - 0.40 feet. One main drainage path in Region 3 that is obstructed is Bayou Paquet. In this location on the protected side, the 10-year baseline and future events exhibit a range of inducements between 0.1 feet - 0.2 feet and the 100-year events exhibit inducements between 0.1 feet - 0.30 feet. Other locations of protected side inducements are in low lying terrain, and for the 10-year events remain below 0.5 feet. The ranges of these inducements can be evaluated further reviewing the difference maps in Annex 3.

Difference maps are generated for the coincident frequency inflow runs to illustrate the changes in WSE with the project during a coincident precipitation and Pearl River basin flood event. The maps can be reviewed in Annex 3 for the Slidell levee. Figure E:14-7 depicts the 10-year 2032 difference map denoting the change in WSE with the project in place for the intermediate rate of SLR. Discussion of results for the coincident frequency inflow runs are grouped into three regions, and delineations of these regions are depicted in Figure E:14-7.

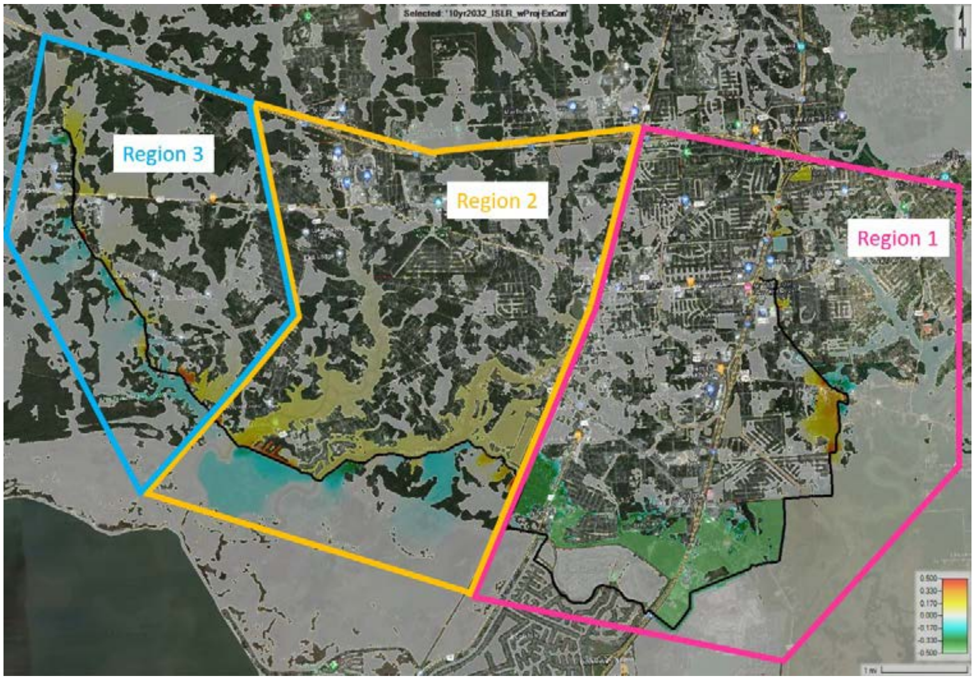


Figure E:14-7. 10-year 2032 event difference map depicting WSE increases and lowering's for the intermediate rate of SLR and coincident Frequency inflows on the Bogue Chitto River and Pearl River. Regions correlate to areas discussed in the following results section. For a comprehensive description of difference maps refer to Annex 3 of this appendix.

The first results region discussed for the coincident frequency inflow runs will be the eastern extent of the levee, from Norfolk Southern Railroad to the Pearl River floodplain, and Figure E:14- 7 outlines this area in pink and will be referred herein as Region 1. During the 10-year event, both baseline and future runs for the protected side of the levee show inducements localized around the identified locations for pump and gate complexes and are consistent with the mean inflow maximum WSE increases. Inducements for the baseline and future 10-year runs remain between 0.2 feet - 0.4 feet and are focused just north of the Kingspoint levee. This indicates that for the 10-year event, regardless of the Pearl River basin flood wave, the hydraulic performance on the protected side of the alignment is consistent with the mean inflow runs. One location that performs differently with the coincident flooding is the region east of the railroad and south of Kingspoint levee. There is an evident reduction in WSE, up to half a foot for the 10-year baseline and future runs, that is not exhibited in the runs with a historic mean Pearl River basin flood wave. This is occurring because the flood wave from the Pearl is being obstructed from entering the low-lying terrain on the protected side of the levee. These observations are consistent between each frequency run. Within Region 1, for the 100-year event runs, the hydraulics on the flood side and protected side of the levee perform differently than the 10-year event runs. The flood wave comes down from the Pearl River basin and propagates westward toward the Slidell area causing inducements on the flood side of the alignment. The flood side inducement ranges from 0.1 feet - 0.2 feet for the 100-year event. The magnitude of the inducement dissipates while traveling eastward and southward, away from the proposed levee alignment and toward Lake Pontchartrain. Similar to the 10-year baseline and future runs, the 100-year runs also exhibits substantial WSE decreases on the interior of the alignment South of Kingspoint levee because the Pear River flood wave is blocked. However, unlike the 10-year runs, the region north of Kingspoint levee experiences a reduction of WSE up to 0.5 feet on the protected side. This is occurring because the 100-year flood wave from the Pearl River is far larger in volume and propagates further west than the 10-year, therefore the levee is obstructing a larger volume of water.

The second results region for the coincident frequency inflow runs is along the central reaches of the levee alignment, between Bayou Liberty and the Norfolk Southern Railroad. Figure E:14-7 outlines this area in orange and will be referred herein as Region 2. For the 10-year events, this area performs the same hydraulically as the mean inflow runs. Similar hydraulic behavior is occurring because the Pearl River basin flood wave does not propagate west far enough to impact this area for the coincident 10-year flood event in the Pearl River. The 100-year, 2032 and 2082 runs perform differently in this region as compared to the mean inflow runs. For both 100-year events, there are reductions on the protected side of the levee, which were not exhibited in the mean inflow runs. The WSE lowering’s on the protected side of the alignment range from 0.5 feet to 2 feet. The locations of lowering’s in Region 2 are hydraulically connected to locations east of the Norfolk Southern Railroad. This indicates that the Pearl River basin flood wave propagates west of the Norfolk Southern Railroad during existing conditions and is obstructed with the project in place. Locations of inducements on the protected side of the alignment are consistent with those seen in the mean inflow runs for the 100-year baseline and future runs.

The Western portion of the alignment, west of Bayou Liberty is the final region results, which will be discussed for the coincident frequency inflow runs and is outlined in blue on Figure

E:14-7 and will be referred to Region 3 herein. For the 10-year and 100-year events, 2032 and 2082 runs, this area performs hydraulically the same as the mean inflow runs. This is occurring because the Pearl River basin flood wave is unable to propagate west far enough to impact Region 3 for the coincident 10-year or 100-year flood event in the Pearl River. It is evident that for the 10-year event during current conditions, the flood wave does not propagate west of the Norfolk Southern railroad. For the 100-year event during current conditions, the flood wave from the Pear River basin does not propagate further west than Bayou Liberty. Refer above to the mean inflow results section for inducements and reductions described for the 10-year and 100-year events in Region 3.

14.1.8 HEC-RAS Modeling – Coincident Rainfall and Sea Level Rise Analysis

As discussed in the Climate Assessment Section 11 of this appendix, the low, intermediate, and high rates of SLR were all modeled in conjunction with the frequency inflows to ensure impacts of SLR and coincident flood impacts of rainfall and riverine flooding can be evaluated. The downstream boundary stages used in the SLR analysis for low, intermediate and high can be reviewed in Table E:12-2 of this appendix. The impacts of the various rates of SLR will be evaluated by dividing the RAS model domain into two regions: East of Lacombe, LA and West of Lacombe, LA.

<u>East of Lacombe, LA</u>

The eastern portion of the study area contains the Pearl River basin, along with other large waterways, including Bayou Bonfouca, Bayou Liberty, and W-14 canal. To evaluate the extent that SLR impacts the region, a difference grid is generated comparing the high and low rates of SLR for the 10-year and 100-year, baseline and future events for the with- and without-project conditions. Figures in Annex 3 take the high sea level rise (HSLR) WSE output minus the low sea level rise (LSLR) WSE output, resulting in a map layer displaying the WSE difference between the two SLR conditions. These difference grids are generated for both the coincident frequency and the mean inflow runs for the two upstream boundary conditions (Pearl River and Bogue Chitto).

The impacts of SLR with coincident frequency inflows on the Eastern side of the parish are exhibited from the coastline of Lake Pontchartrain inland approximately 4-6 miles and varies along the extent of the coastline. In general, the impact zone of SLR remains south of I-12 along the Eastern side of the parish coastline for the 10-year and 100-year runs. Impacts of varying rates of SLR can also be seen further inland in locations of major waterways listed above, which act as a conduit for fluctuating WSEs in Lake Pontchartrain. For example, upstream on Bayou Liberty at the Hwy 190 crossing (approximately 4.5 miles inland), there is a 0.15ft difference in maximum WSE between LSLR and HSLR for the 100-year 2082 event. For the 10-year event, the impacts of SLR will be felt further inland; this can be seen in Figure E:14-8, which depicts the existing condition SLR difference map for the 10-year event. WSEs will be impacted for the 10-year event from the coastline to I-12 crossing along Bayou Liberty and Bayou Bonfouca.

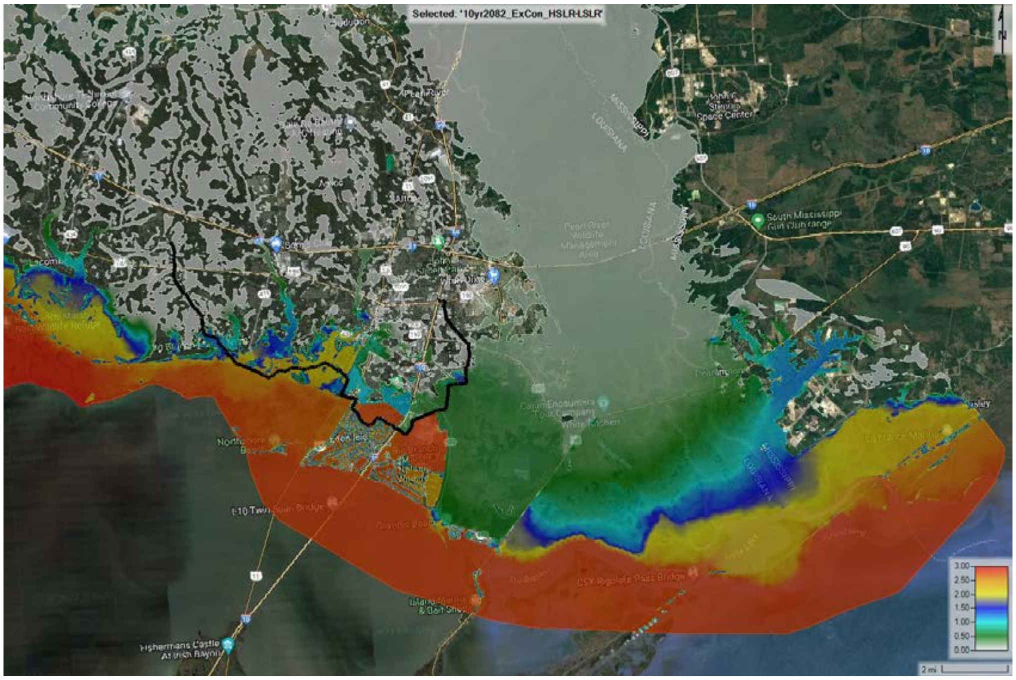


Figure E:14-8. 10-year 2082 event Existing Condition HSLR-LSLR with coincident frequency inflows on Pearl River and Bogue Chitto River

The differences in performance of the 2032 (baseline) runs compared to the 2082 (future) runs are also assessed. It is found that for the 10-year event, baseline runs where the model domain is over solid land, the WSE difference between the HSLR and LSLR scenario ranges from 0 feet - 0.4 feet (refer to Annex 3 for visual aid). For the corresponding 10-year future runs where the model domain is over solid land, the WSE difference between the HSLR and LSLR scenario ranges between 0 feet - 3 feet. It should be noted this is consistent between existing conditions and with-project runs, and that relationship will be discussed further below. For the 2082 runs, a larger area of the Pearl River basin floodplain exhibits impact from varying levels of SLR in comparison to the 2032 runs. Overall, it is concluded that the 2032 runs are not as sensitive to varying rates of SLR as compared to the 2082 runs. This indicates that the backwater effects of higher downstream boundaries for the future condition will cause greater impact to WSEs further inland.

An evaluation is also performed on the comparison of SLR impacts with respect to the with-project and existing conditions runs. Figure E:14-9 depicts the 10-year 2082 event with-project simulation and can be compared to Figure E:14-8 to evaluate the differences between with-project and existing conditions simulations. It is found that with the project in place, the impacts of SLR are exhibited the same extent inland (from the shoreline to the I-12 crossing) as the existing conditions runs and the magnitude of WSEs are the same. This indicates that the sizing of the gate structures along the alignment at locations of waterway crossings and low-lying terrain maintains the existing conditions hydraulics in the area well. This also indicates that the presence of the levee will not aid in mitigating impacts caused by rising sea levels over time for more frequent precipitation events, such as the 10-year recurrence interval.

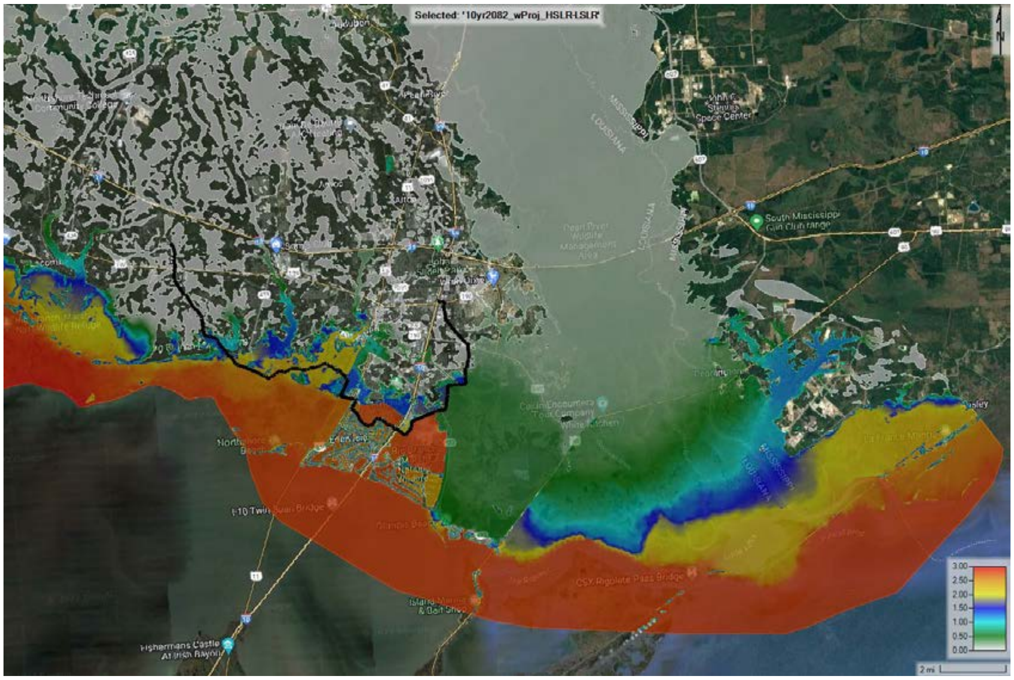


Figure E:14-9. 10-year 2082 event With-Project HSLR-LSLR with coincident frequency inflows on Pearl River and Bogue Chitto River

Hydraulically, the study area performs differently to the various rates of SLR with a historic mean inflow from the Pearl River and Bogue Chitto River as compared to the coincident frequency inflows. Figure E:14-10 and Figure E:14-11 depict the difference in WSE between LSLR and HSLR for the 10-year future event, existing conditions and with-project simulations, respectively. When compared to Figure E:14- 8 and Figure E:14-9, it is evident that the mean inflow runs exhibit impacts from varying rates of SLR further inland than the coincident frequency inflow runs. For example, in the Pearl River basin, WSEs will be impacted as far as 15 miles inland with a mean Pearl River flood. Additionally, in the Slidell area east of Norfolk Southern Railroad, WSE vary by higher magnitudes between the HSLR and LSLR simulations for the mean inflow runs. For the 10-year 2082 event mean inflow runs near the project area, WSE differences between the HSLR and LSLR simulations range between 0.5 feet-2.75 feet. This indicates that the Pearl River flood masks the impact of SLR to the area in the simulations. It also shows this area is more susceptible to SLR with historically mean inflows from the Pearl and Bogue Chitto. West of the Norfolk Southern Railroad, WSEs vary from the coastline to the I-12 crossing for the 10-year 2082 event with mean Pearl River basin inflows. This is the same distance inland as the coincident frequency inflow runs.

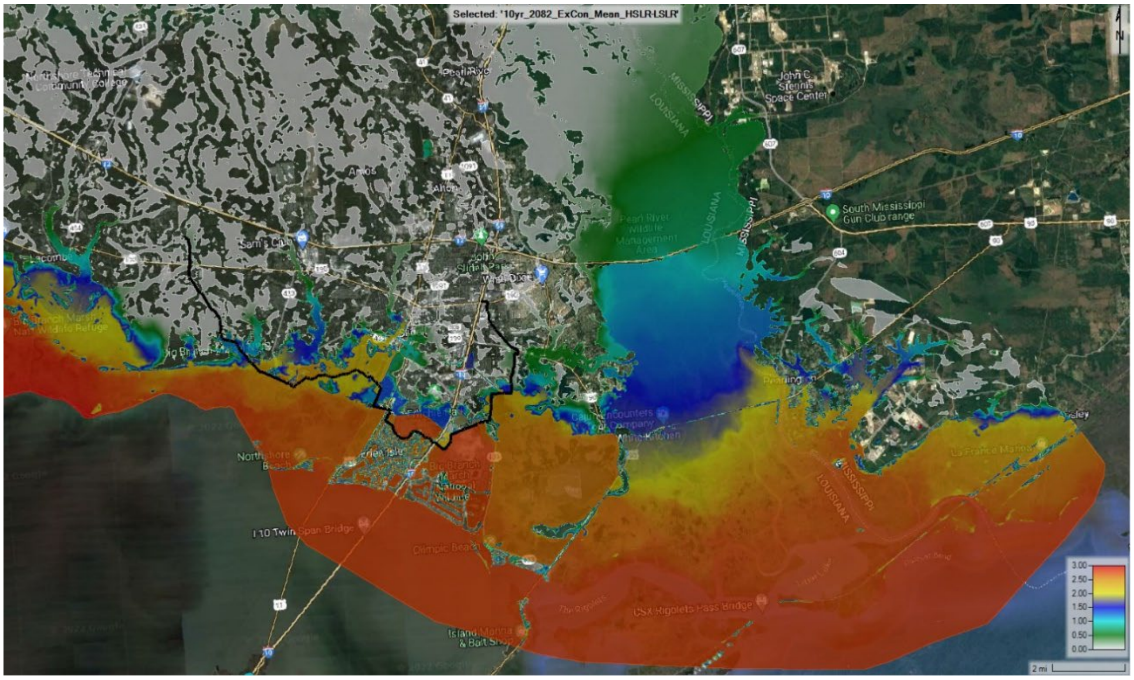


Figure E:14-10. 10-year 2082 event existing conditions HSLR-LSLR with mean inflows on the Pearl River and Bogue Chitto River

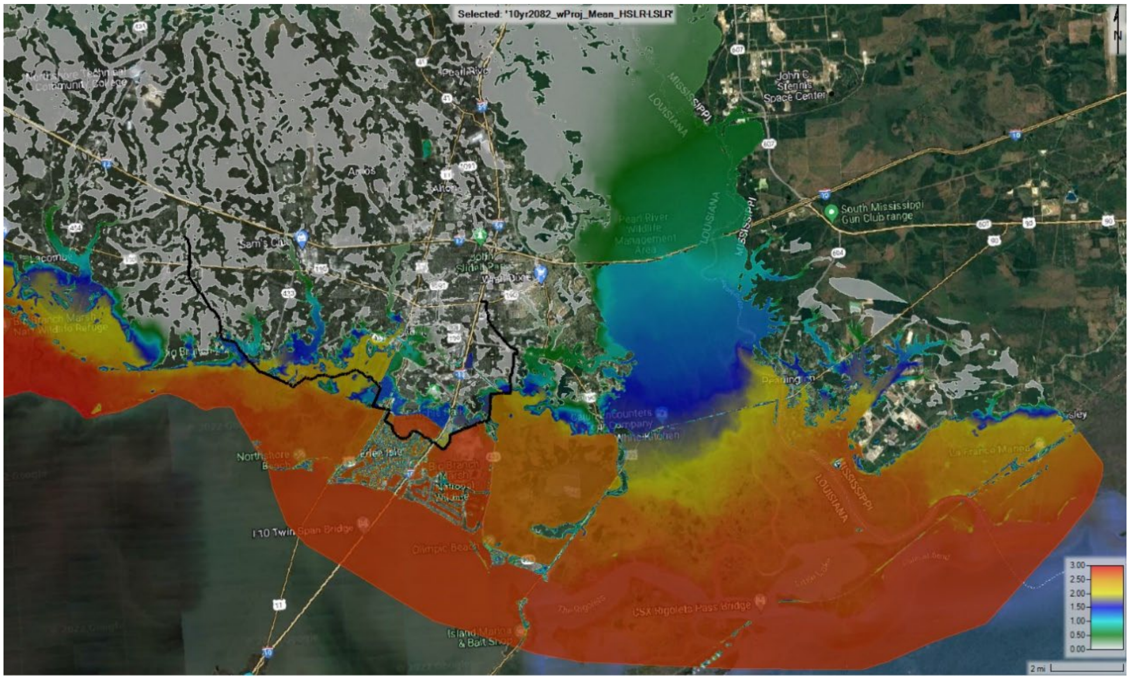


Figure E:14-11. 10-year 2082 event with-project HSLR-LSLR with mean inflows on the Pearl River and Bogue Chitto River

Upon reviewing the 100-year future runs, the same conclusion may be drawn that the mean frequency inflow runs are more susceptible to SLR as compared to the coincident frequency inflow runs. Figure E:14-12 and Figure E:14-13 show the 100-year 2082 with-project runs with mean and frequency inflows, respectively. It is evident that during the higher frequency events, the mean inflow runs have greater varying SLR impacts as compared to the coincident frequency inflows. The differences between the mean and coincident frequency inflows remain on the flood side of the levee alignment. Therefore, it can be concluded that unlike for the coincident frequency inflow runs, the levee does in fact aid in abating the impacts from SLR for the higher frequency events when there is a historic mean Pearl River basin flood. This also indicates that the Pearl River flood masks the impact of SLR to the area in the simulation east of the Norfolk Southern Railroad. West of the Norfolk Southern Railroad, SLR WSE differences are similar magnitude between the frequency inflow and historic mean inflow runs.

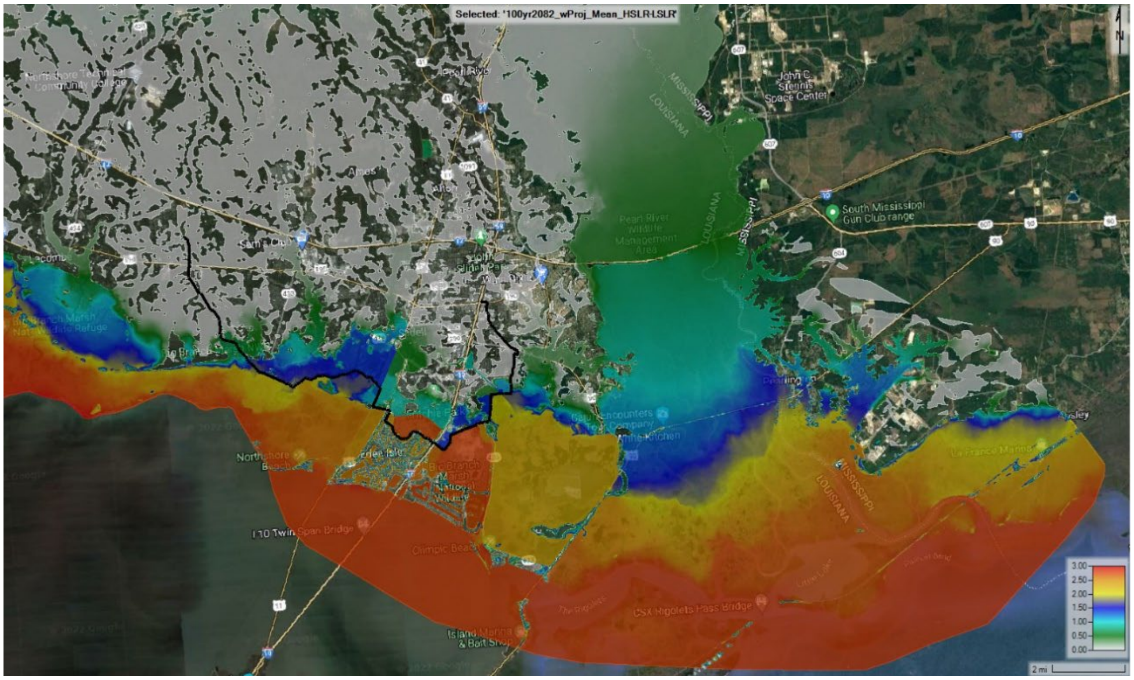


Figure E:14-12. 100-year 2082 event with-project HSLR-LSLR with mean inflows on the Pearl River and Bogue Chitto River

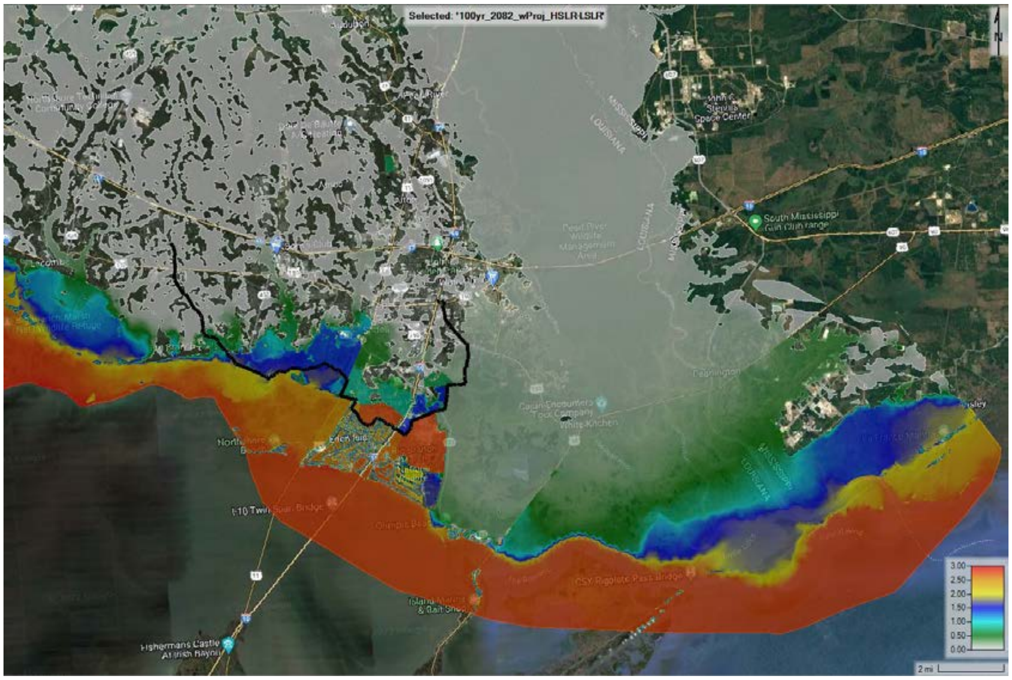


Figure E:14-13. 100-year 2082 event with-project HSLR-LSLR with frequency inflows on the Pearl River and Bogue Chitto River

In conclusion, the Slidell area will be impacted in different ways when considering the various rates of SLR in conjunction with varying precipitation and Pearl River basin flooding scenarios. This area experiences greater backwater effects and flooding for more frequent precipitation events, such as the 10 year. These backwater effects are exaggerated for the future (2082) runs as compared to the baseline (2032). This is the case for both the Pearl River basin frequency inflows and the mean historic inflows. It is also concluded that with a mean historic Pearl River flood, the impacts to WSEs from varying rates of SLR are more exaggerated than when there are coincident frequency floods in the Pearl River basin. Another finding for the region east of Lacombe, LA is that waterways hydraulically connected to Lake Pontchartrain act as a conduit for fluctuating WSEs in the lake and propagate impacts from SLR further inland. Additionally, the WSE differences between the HSLR and LSLR scenarios for the with-project runs are not substantially different compared to the existing conditions runs. This indicates that the proposed levee system will not be effective at reducing risk associated with future rising sea levels.

West of Lacombe, LA

The western region of the study area contains the Tchefuncte River and its large tributaries, including but not limited to the Abita River and the Bogue Falaya. Difference grids denoting the change in maximum WSE between the HSLR and LSLR scenarios for the 10-year and 100-year, 2032 and 2082, existing condition and with-project runs for the western region of the parish are also in Annex 3 for review. As stated above, the difference maps for both Pearl River coincident frequency and mean runs are in Annex 3.

The impacts of SLR with coincident frequency inflows on the western region of the parish are seen from the coastline of Lake Pontchartrain inland approximately 1-7 miles and varies along the extent of the coastline. As stated in the East of Lacombe section, the impact of SLR is viewed further inland along waterways hydraulically connected to Lake Pontchartrain. Between Lacombe and the western boundary of Mandeville, the SLR impact zone reaches a maximum of 1.8 miles inland along waterways Bayou Castine and Bayou Chinchuba. Further west, from the Tchefuncte River estuary north to the city of Covington, the impacts of SLR are seen as far as 7 miles from the coast for the 100-year events and 8.3 miles for the 10-year events along the Tchefuncte River floodplain. This is approximately 2-3 miles north of I-12, which was the upper boundary for the impact zone of SLR on the eastern side of the parish. These findings indicate that the Tchefuncte River poses a threat regarding rising sea levels for communities in the center of the parish, miles inland from the coast.

Like the eastern half of the parish, this region also exhibits impacts from SLR due to the backwater effects of Lake Pontchartrain. For example, Figure E:14-14 and Figure E:14-15 depict the existing condition future simulation difference between HSLR and LSLR, for the 10-year and 100-year precipitation events, respectively. The impact of SLR for the 10-year event is exhibited inland to the extent of Abita Springs, LA and well into Covington, LA. For the 100-year, the impacts from SLR do not make it into Covington, LA. This shows that more frequent and smaller storms, such as the 10-year, are more susceptible to impacts from SLR due to backwater effects of higher stages in Lake Pontchartrain as compared to larger precipitation events.

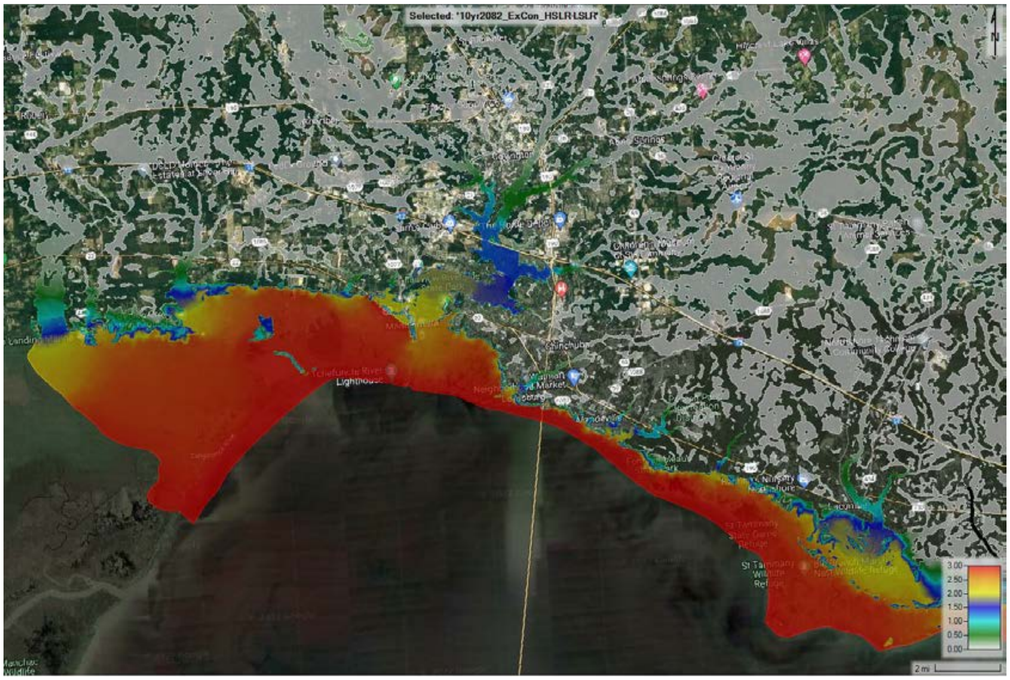


Figure E:14-14. 10-year 2082 event Existing Condition HSLR-LSLR with frequency inflows on the Pearl River and Bogue Chitto River

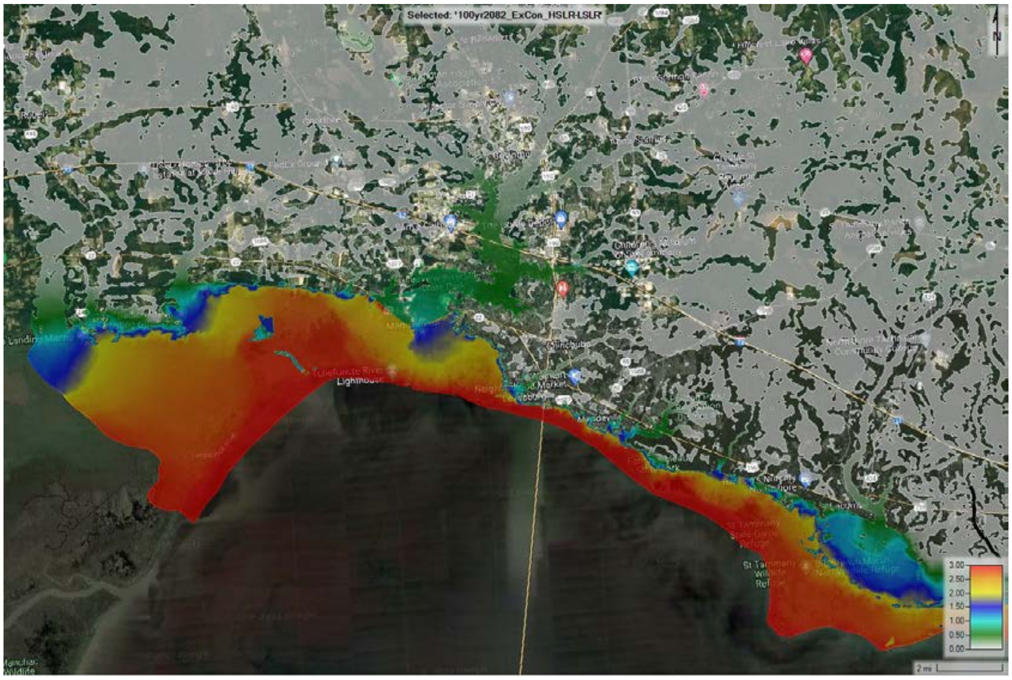


Figure E:14-15. 100-year 2082 event Existing Condition HSLR-LSLR with frequency inflows on the Pearl River and Bogue Chitto River

Further investigation on how SLR impacts the RP at Mile Branch was also conducted. Mile Branch was removed from the Recommended Plan and would not be implemented. Figure E:14- 16 depicts the change in WSE with respect to high and low SLR for the 10-year 2082 events, the existing conditions and with-project runs, using mean inflows on the Pearl River and Bogue Chitto River. Figure E:14- 17 shows the same simulations but with coincident frequency inflows on the Pearl River and Bogue Chitto. As can be seen for both the mean inflow and frequency inflow runs, Mile Branch exhibits a change of less than 0.2 feet for both the existing conditions channel and with-project simulations. The changes to WSE with respect to SLR remain near the confluence of Mile Branch and the Tchefuncte River and propagate up the channel until the W 11th Avenue crossing for the existing condition. For the with-project condition, WSE changes propagate slightly further up the channel past the W 11th Avenue crossing, approximately 200 feet upstream of that crossing. Changes in WSE remain at or below 0.2 feet in this small reach of the Mile Branch channel. It can be concluded that the historic mean inflows and coincident frequency inflows do not have an impact on the hydraulics on the project area at Mile Branch. Furthermore, upon reviewing difference maps in Annex 3 for the West of Lacombe, LA region, the differences between the mean inflow runs and frequency inflow runs are not significant in the central portion of the parish. This indicates that the Pearl River basin flooding impacts do not propagate west of Lacombe, LA.

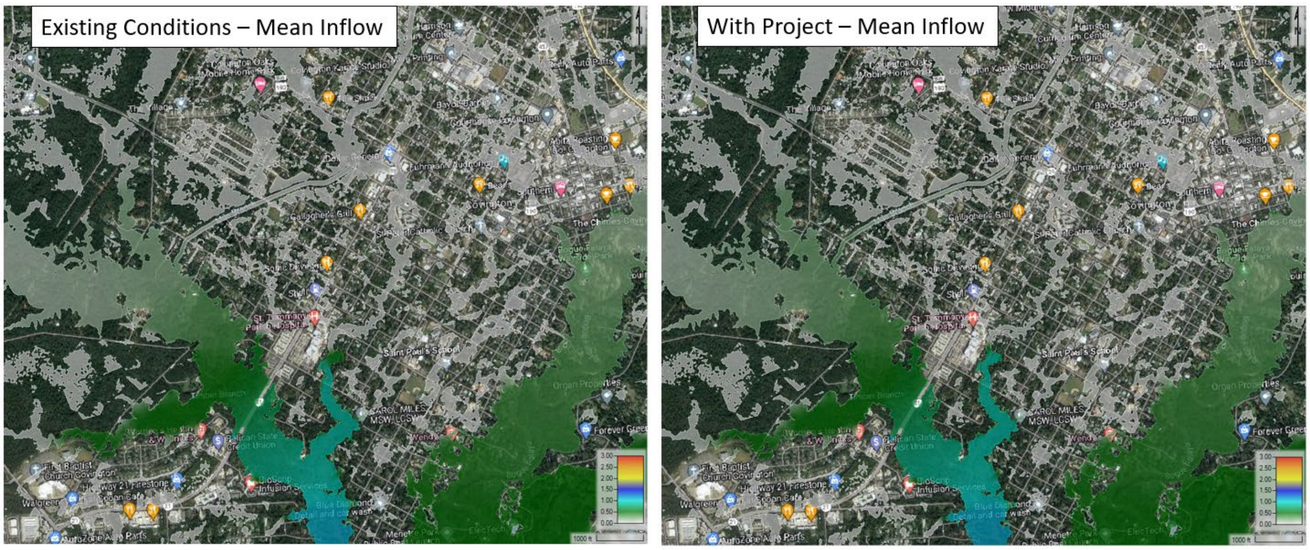


Figure E:14-16. 10-year 2082 event, Existing Condition (left) and With Project (right), depicting the change in WSE between the HSLR-LSLR simulations with mean inflows on the Pearl River and Bogue Chitto River; zoomed into Mile Branch project area

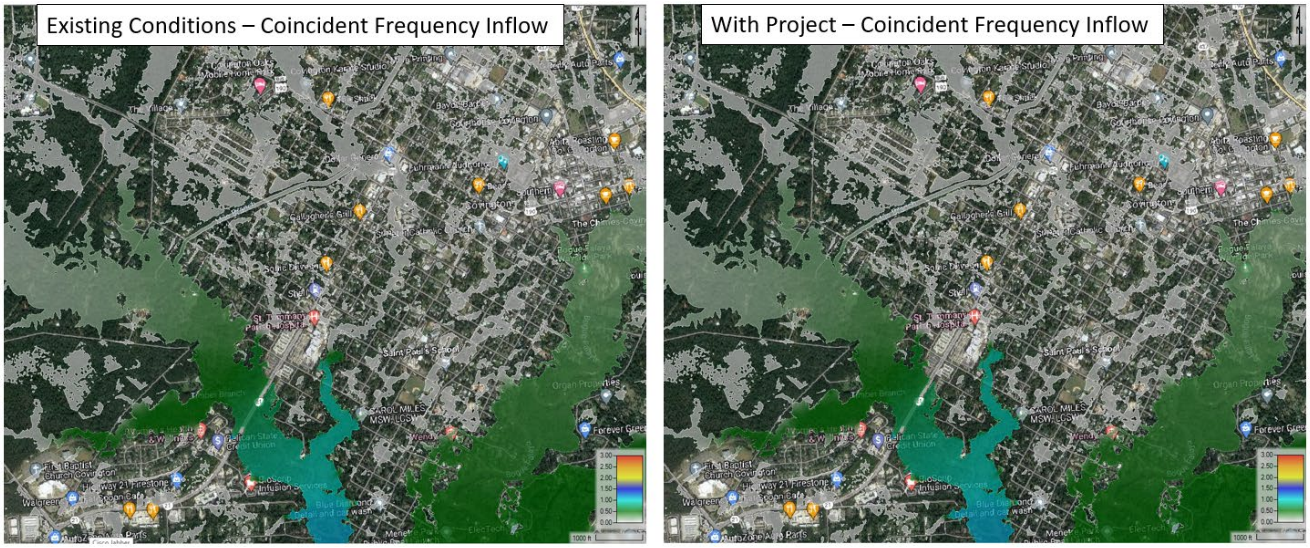


Figure E:14-17. 10-year 2082 event, Existing Condition (left) and With Project (right), depicting the change in WSE between the HSLR-LSLR simulations with coincident frequency inflows on the Pearl River and Bogue Chitto River; zoomed into Mile Branch project area

14.2 HEC-RAS MODELING HH&C PRODUCTS

Various products were generated from the hydraulic modeling results to aid other disciplines in their analyses of the RP. One generated product is a compilation of screenshots depicting the change to hydraulic flow paths using Particle Tracing in RAS Mapper. This product was requested by the Environmental Office to aid in writing to the change in flow direction around the proposed levee system and how that would impact existing habitat. The particle tracing screenshots can be reviewed in Annex 5.

The Environmental team also requested a product to assist in their evaluation of indirect impacts. Hydrographs were plotted for the 2-year 2032 condition comparing the existing conditions with the with-project run using the intermediate rate of SLR at specific locations of interest the Environmental team provided. The main purpose of these hydrographs is for Environmental to evaluate the length of time specific locations of interest took to drain and return to baseline water levels. This product may be reviewed in Annex 6.

Another product developed for the PDT to perform their analysis are point locations throughout the parish that denote the location on waterways that exceed 800 cfs on waterways. This product was developed to assist with Economic analysis. Additionally, another product shared with the PDT for assistance with Economic analysis are inundation boundaries of the 10-year and 100-year floodplains and are used to assist in the nonstructural aggregation process.

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List of Acronyms

ADCIRC – Advanced Circulation model

AEP – Annual Exceedance Probability

CHAT – Climate Hydrology Assessment Tool

CFS – Cubic Feet Per Second

CoNED – Coastal National Elevation Database

CPRA – Coastal Protection and Restoration Authority

CSRM – Coastal Storm Risk Management

CSTORM – Costal Storm Modeling System

ECB – Engineering and Construction Bulletin

ER – Engineer Regulation

ERDC – Engineer Research and Development Center

FIS – Flood Insurance Studies

FRM – Flood Risk Management

HEC – Hydrologic Engineering Center

HH&C – Hydrology, Hydraulics, and Coastal

HMS – Hydrologic Modeling System

HSDRRS – Hurricane and Storm Damage Risk Reduction System

HSLR – High Sea Level Rise

HUC – Hydrologic Unit Code

IPCC - Intergovernmental Panel on Climate Change

ISLR – Intermediate Sea Level Rise

JPM-OS – Joint Probability Method-Optimal Sampling

LaDOTD – Louisiana Department of Transportation

LSLR – Low Sea Level Rise

MATLAB – Matrix Laboratory

MVD – Mississippi Valley Division

MVK – Vicksburg District

MVN – New Orleans District

NEXRAD – Next Generation Weather Radar

NLCD – National Land Cover Database

NOAA – National Oceanic and Atmospheric Administration

NRC – National Research Council

PED – Pre Construction Engineering and Design

PDT – Project Delivery Team

RAS – River Analysis System

RP – Recommended Plan

RSL – Relative Sea Level Rise

RSLC – Relative Sea Level Change

SLaMM – Southeast Louisiana Master Model

SLC – Sea Level Change

SLR – Sea Level Rise

STPFS – St. Tammany Parish Feasibility Study

SWAN - Simulating WAves Nearshore

TSP – Tentatively Selected Plan

2D – Two-Dimensional

USACE – United States Army Corps of Engineers

USGS – United States Geological Survey

VA – Vulnerability Assessment

WOWA – Weighted Order Weighted Average

WSE – Water Surface Elevation

Annex E-1-With-Project Difference Maps for Alternative Analysis Phase

Depicted in this section of the annex are difference maps for the 10-year and 200-year, 2032 (baseline) runs for the ISLR around each alternative investigated during the alternative analysis phase. The difference map takes the maximum WSE for the with-project run and subtracts the maximum WSE for the corresponding existing condition run.

Light blue translucent areas denote no change in WSE with the project in place. Red, orange, and warm toned colors denote a reduction in WSE (negative value on scale) with the project in place. Green tones denote an increase in WSE (positive value on scale) with the project in place.

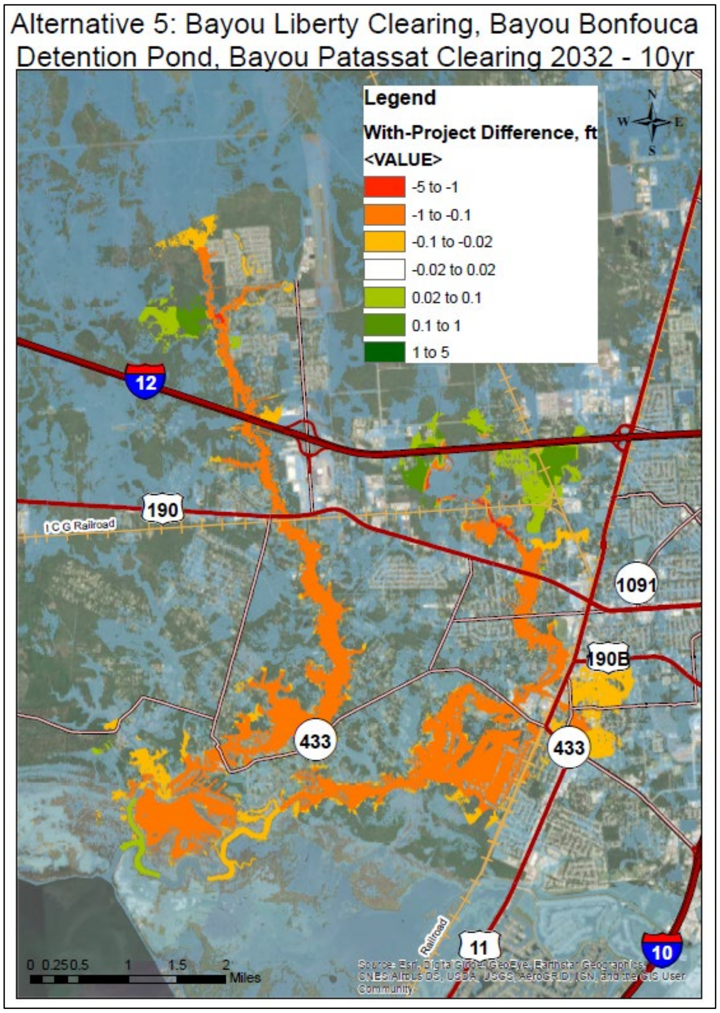


Figure E1:1: Baseline Conditions (year 2032) 10yr frequency event for Bayou Liberty Clearing and Snagging, Bayou Bonfouca Detention Pond, and Bayou Patassat Clearing and Snagging

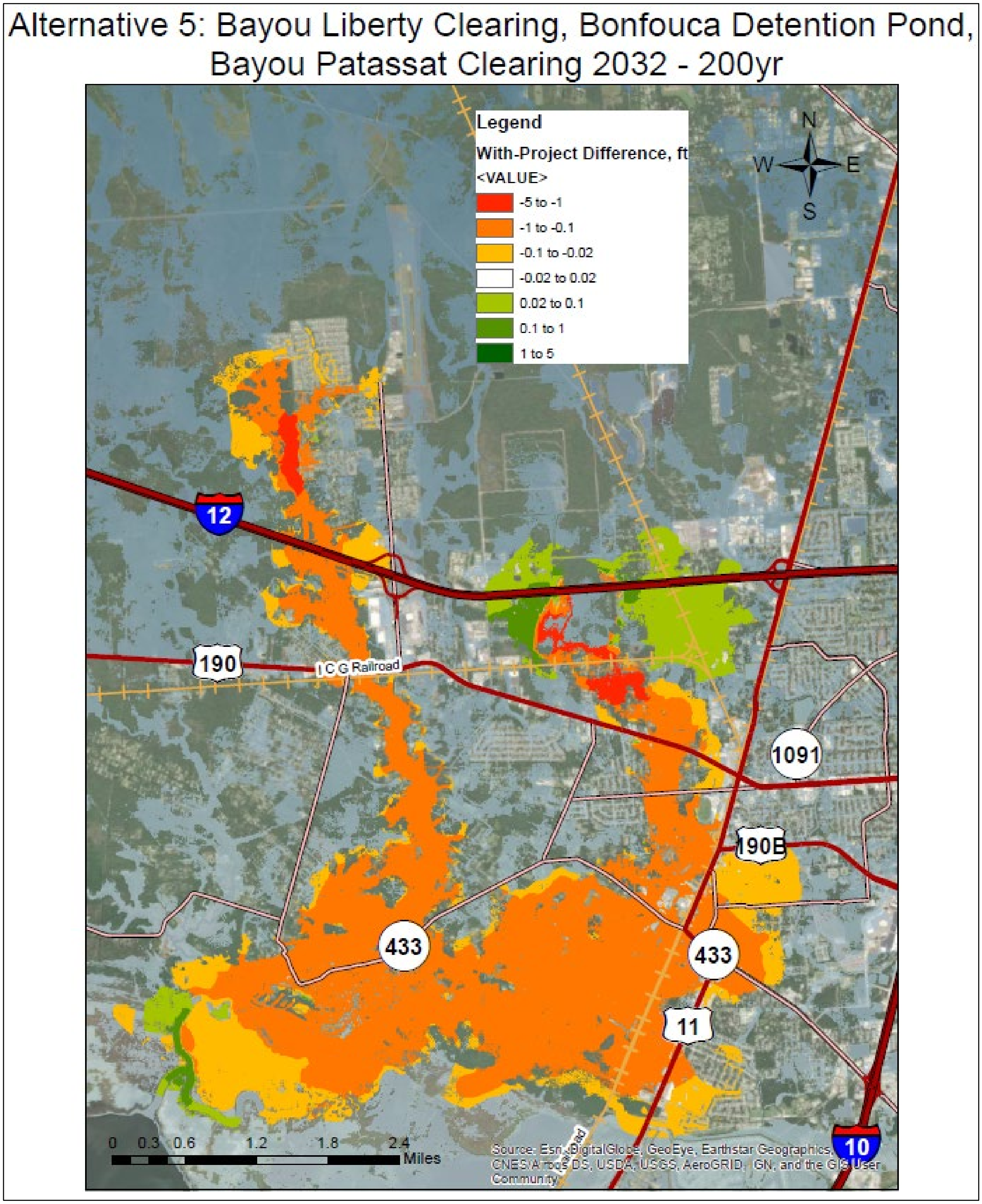


Figure E1:2. Baseline Conditions (year 2032) 200yr frequency event for Bayou Liberty Clearing and Snagging, Bayou Bonfouca Detention Pond, and Bayou Patassat Clearing and Snagging

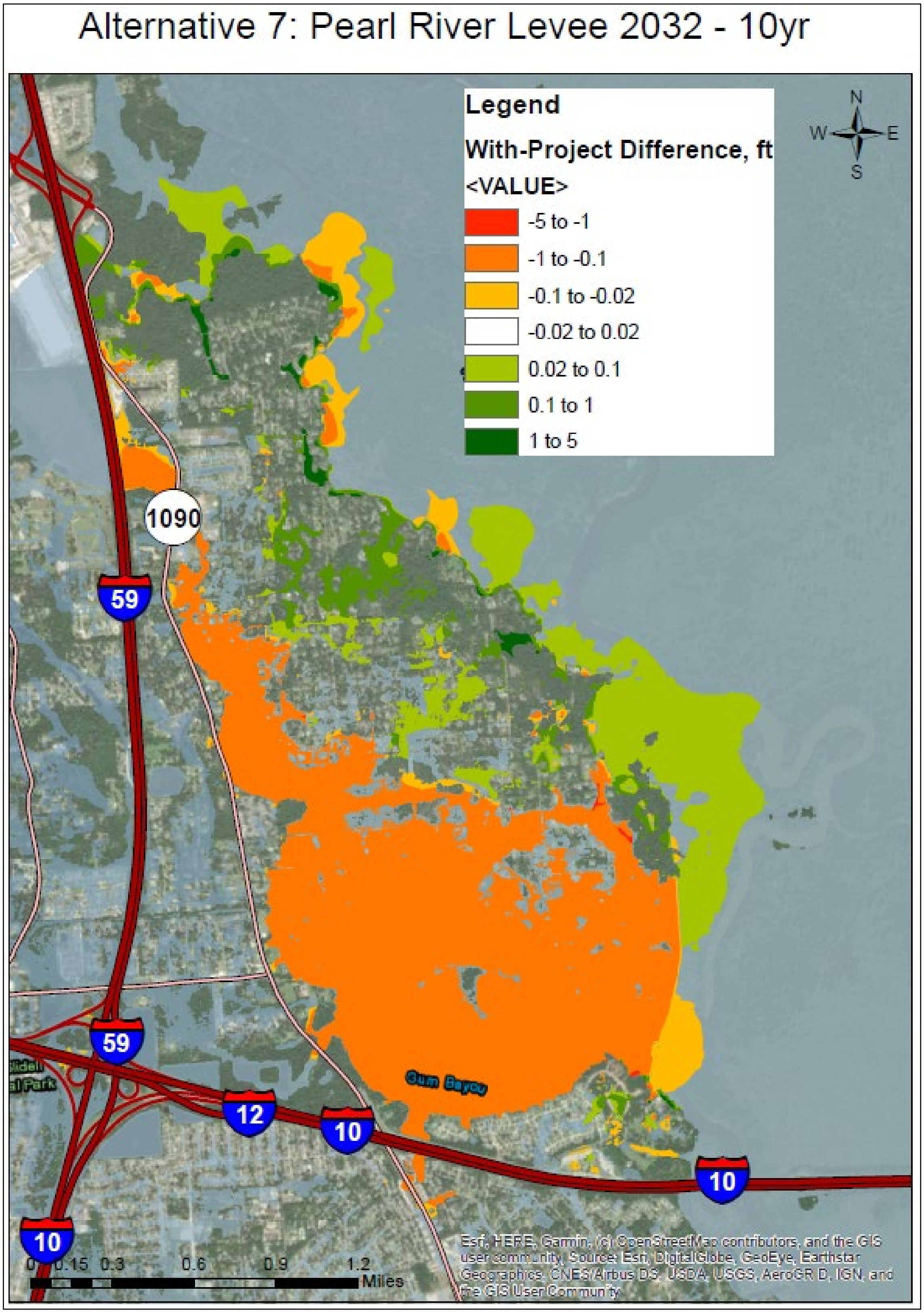


Figure E1:3. Baseline Conditions (year 2032) 10yr frequency event for Pearl River Levee

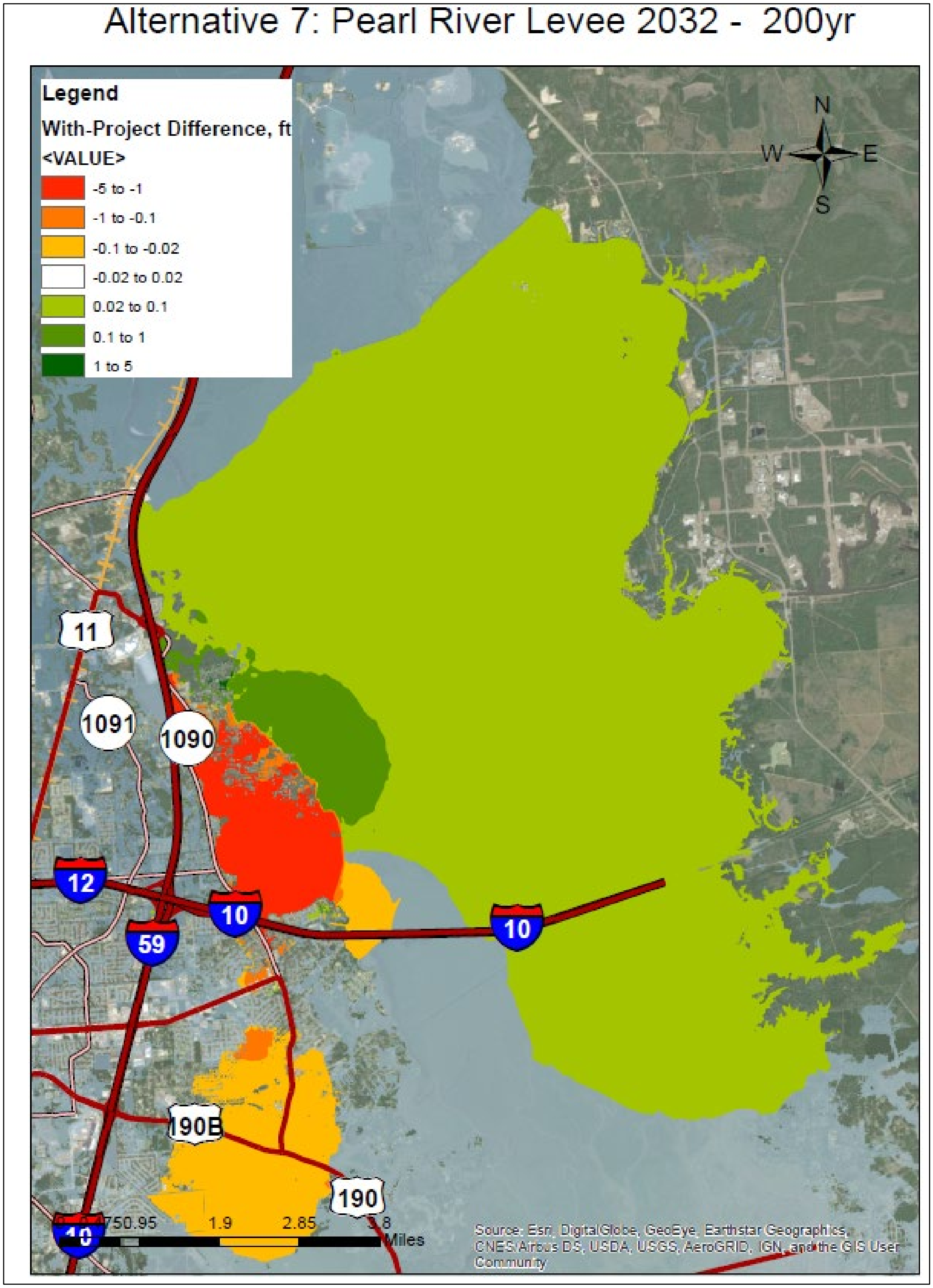


Figure E1:4. Baseline Conditions (year 2032) 200yr frequency event for Pearl River Levee

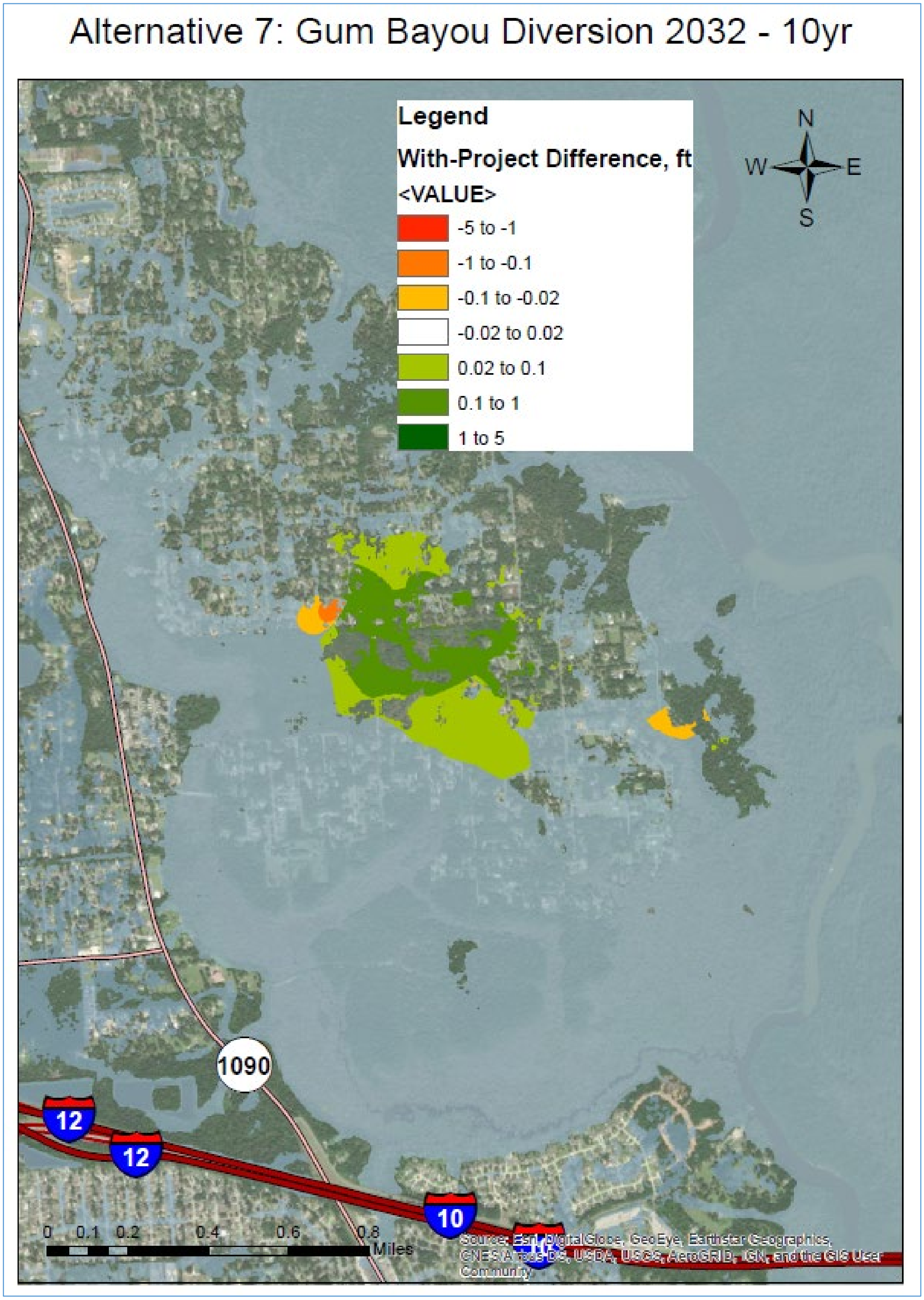


Figure E1:5. Baseline Conditions (year 2032) 10yr frequency event for Gum Bayou Diversion

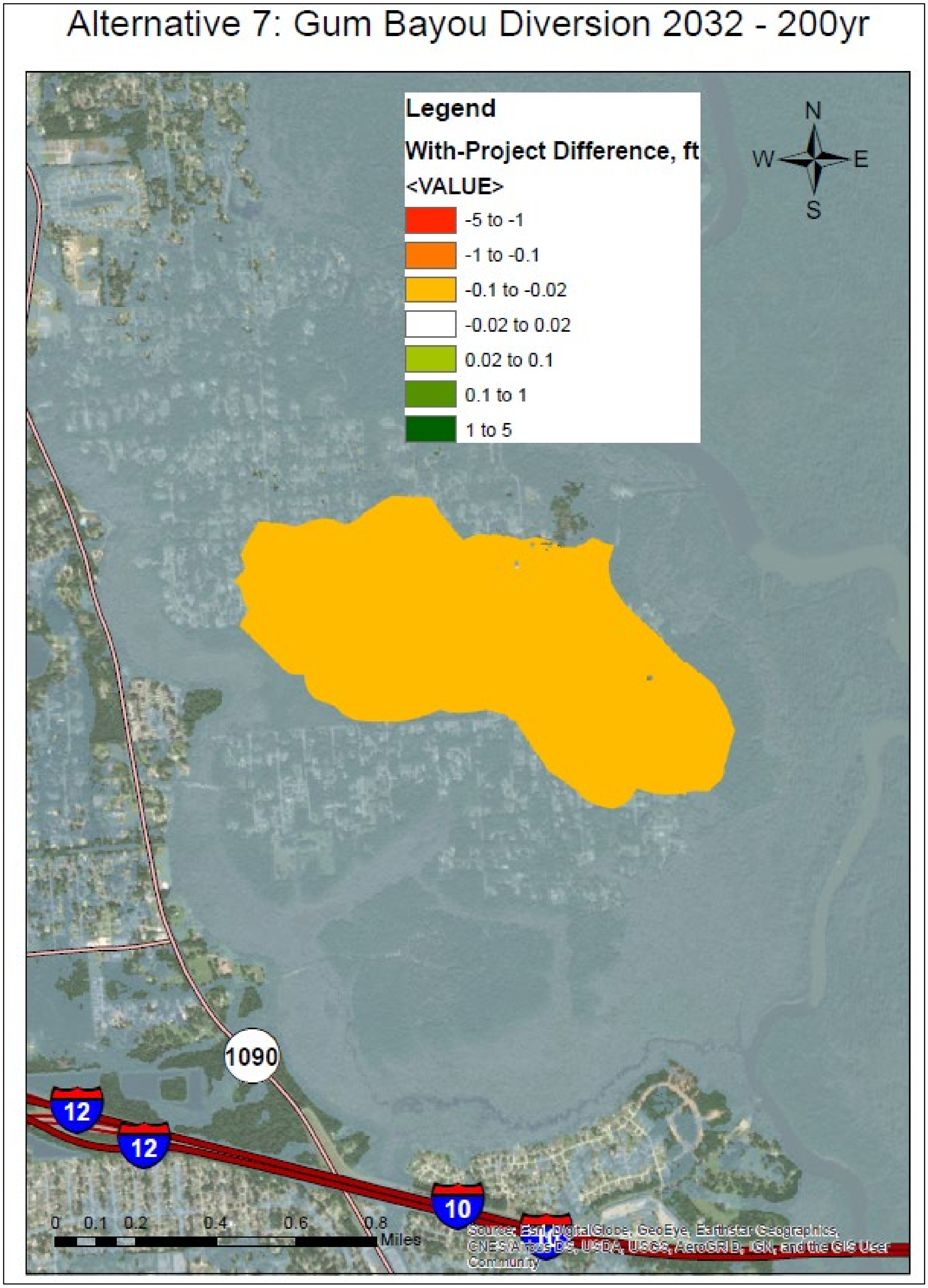


Figure E1:6. Baseline Conditions (year 2032) 200yr frequency event for Gum Bayou Diversion

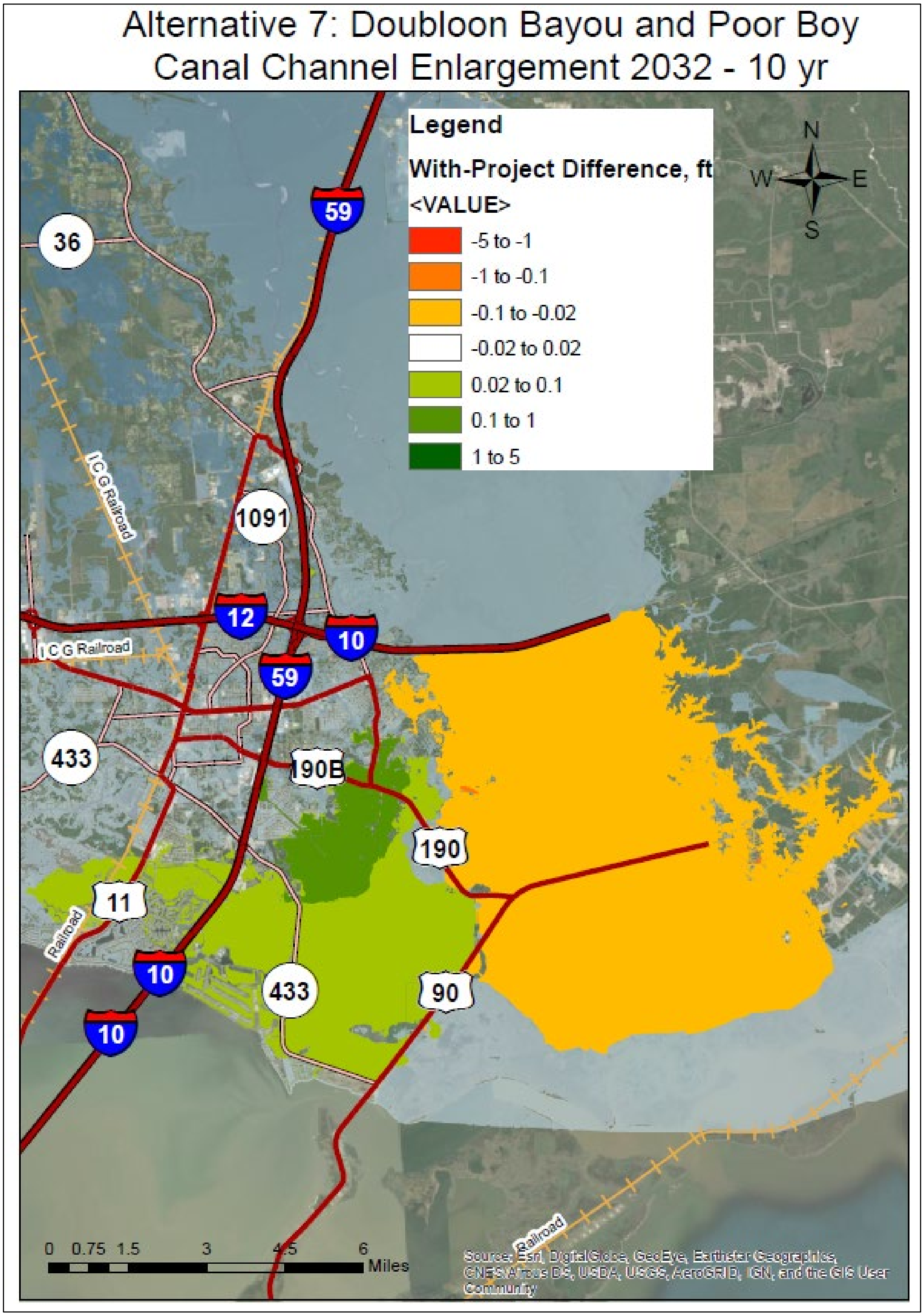


Figure E1:7. Baseline Conditions (year 2032) 10yr frequency event for Doubloon Bayou and Poor Boy Canal Channel Enlargements

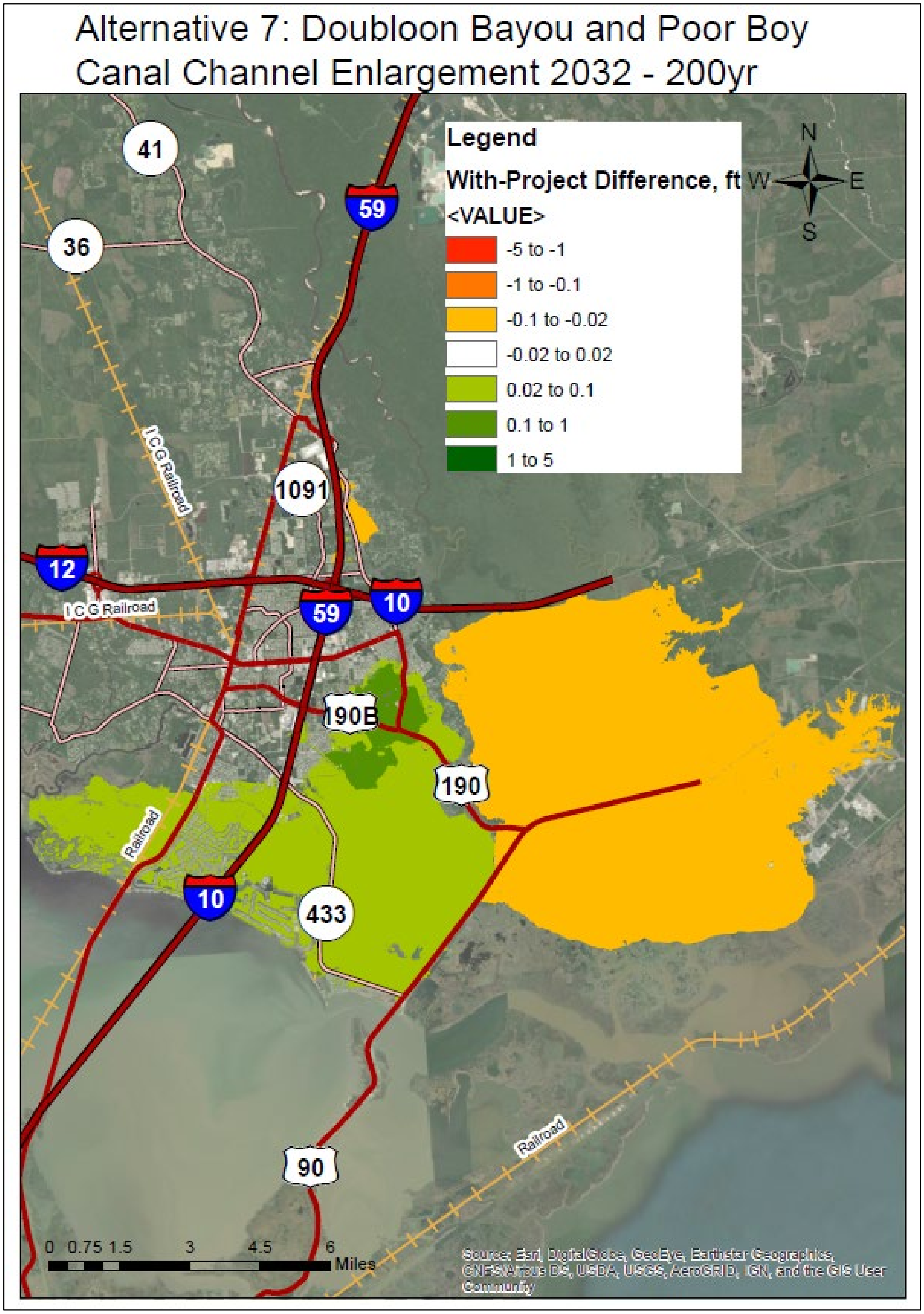


Figure E1:8. Baseline Conditions (year 2032) 200yr frequency event for Doubloon Bayou and Poor Boy Canal Channel Enlargements

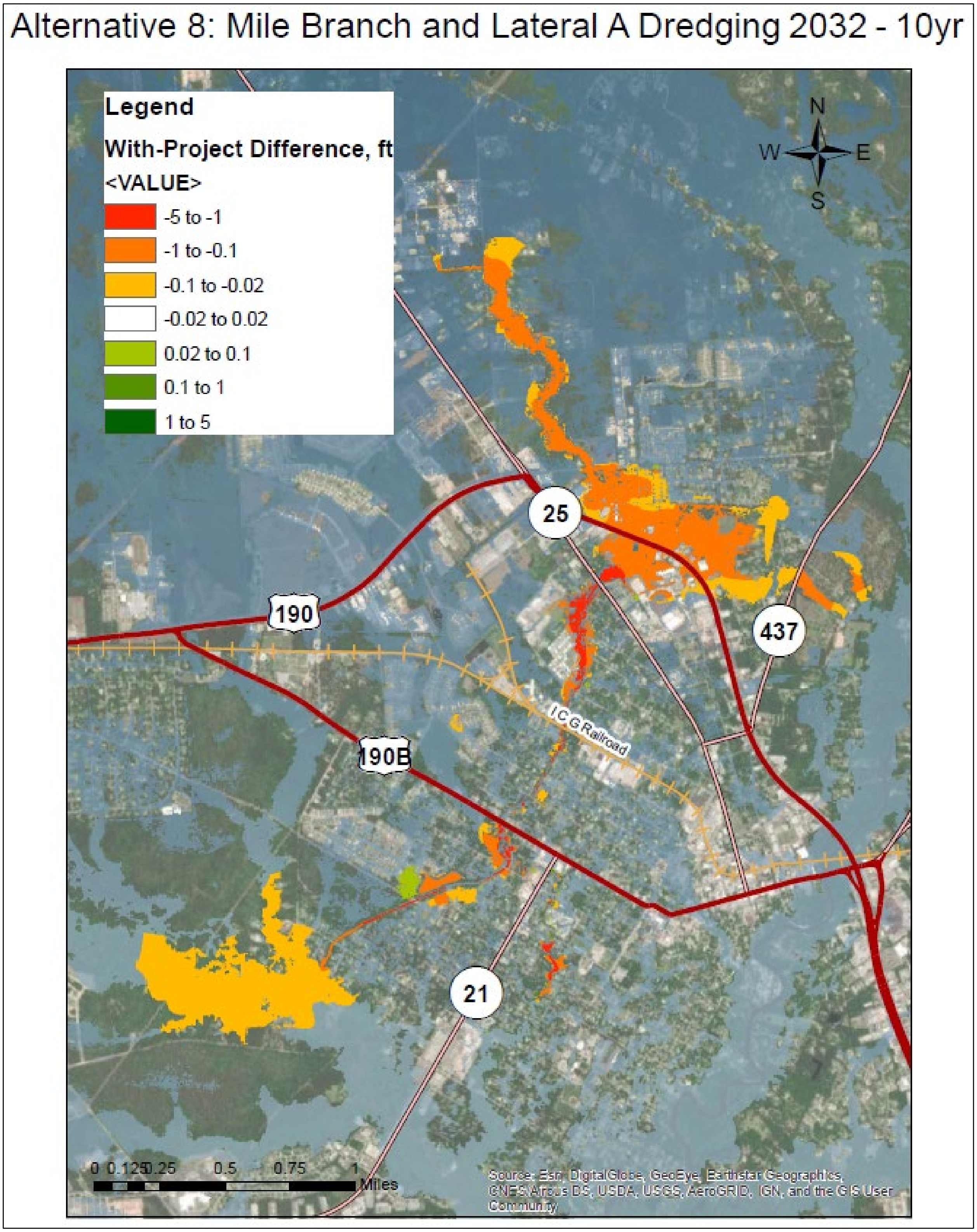


Figure E1:9. Baseline Conditions (year 2032) 10yr frequency event for Mile Branch and Lateral A Dredging

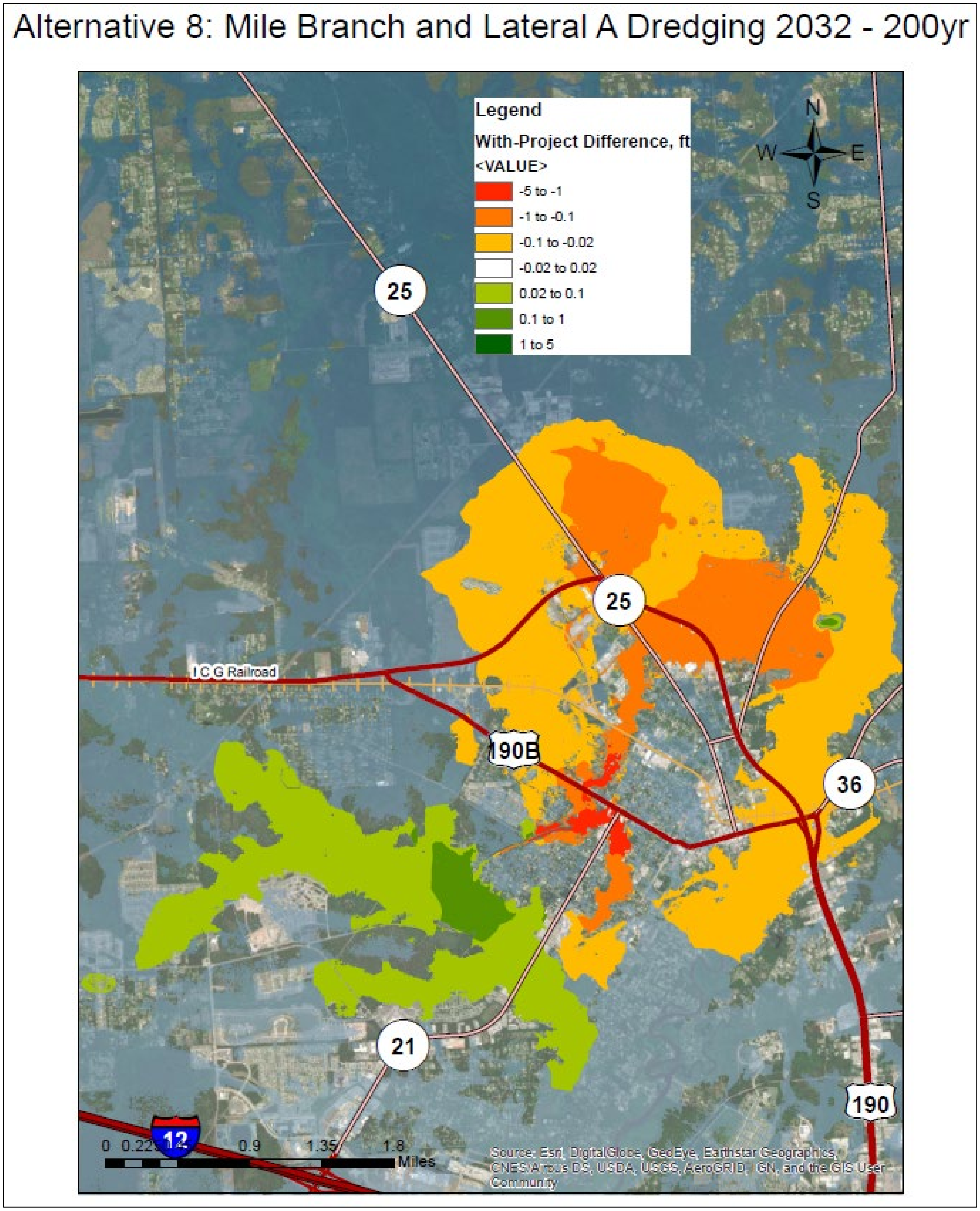


Figure E1:10 . Baseline Conditions (year 2032) 200yr frequency event for Mile Branch and Lateral A Dredging

Annex E-2-Calibration Plots for the Alternative Analysis Phase

March 2016 Calibration

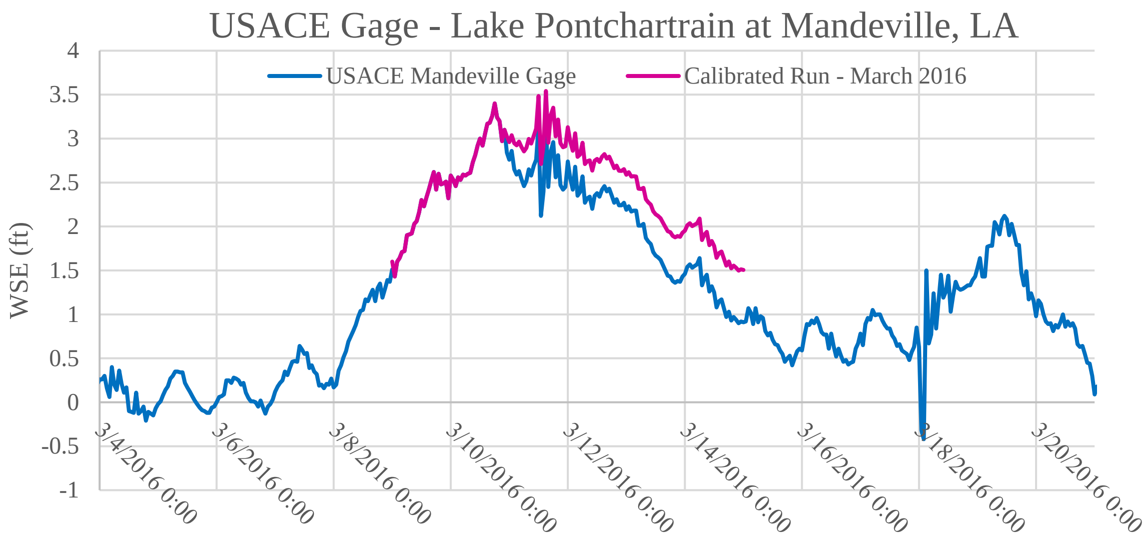


Figure E2:1. March 2016 calibration event plot for USACE Gage -Lake Pontchartrain at Mandeville, LA

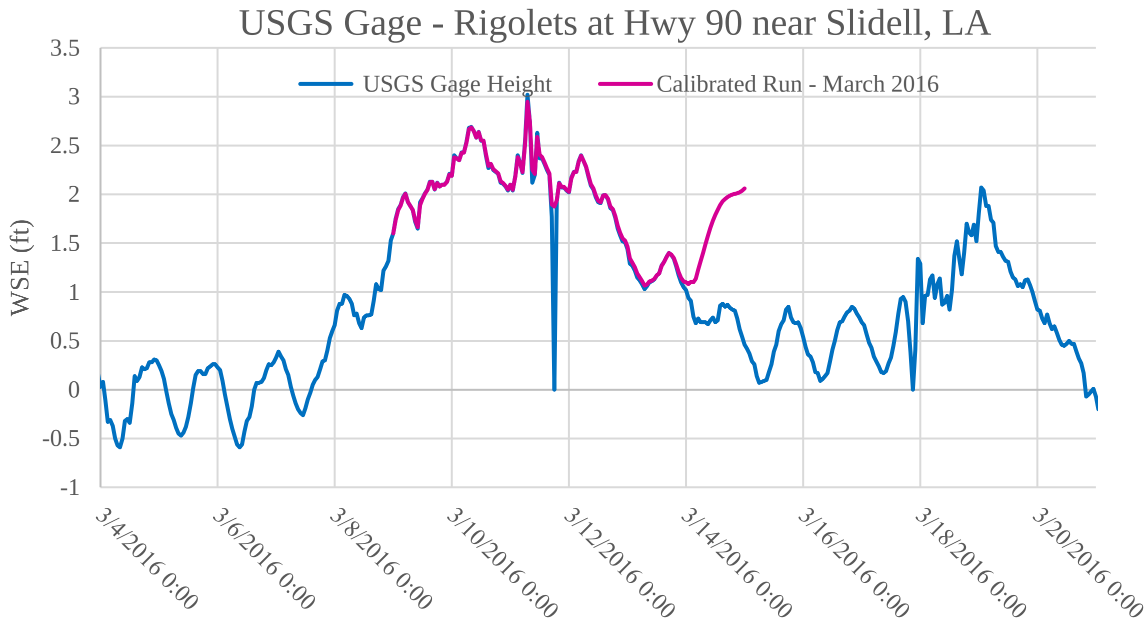


Figure E2:2. March 2016 calibration event plot for USGS Gage -Rigolets at Hwy 90 near Slidell, LA

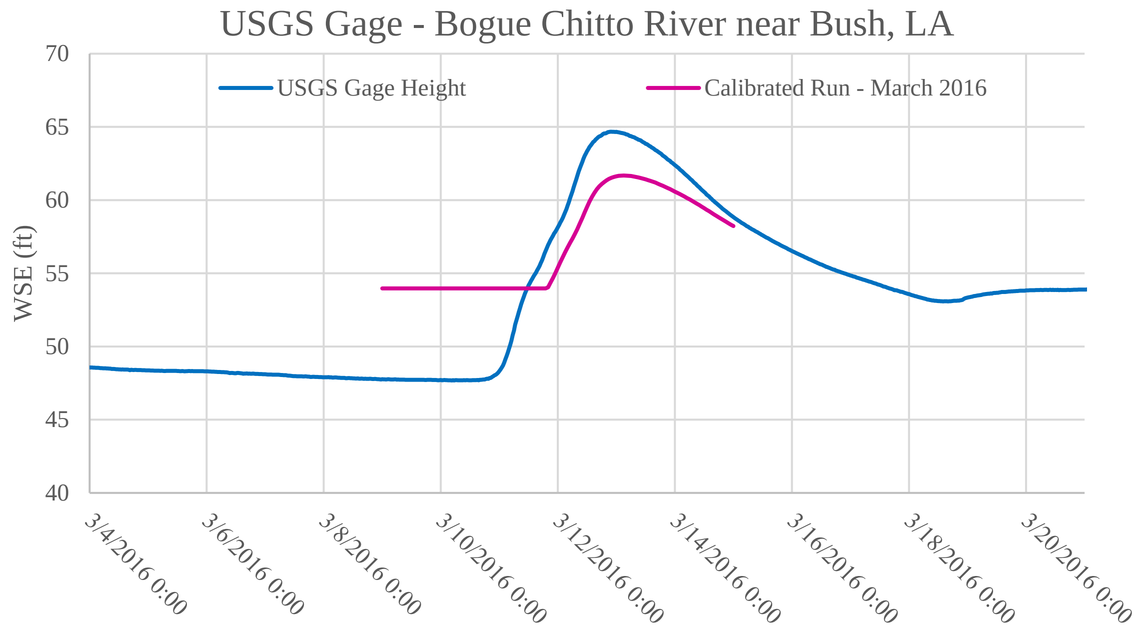


Figure E2:3. March 2016 calibration event plot for USGS Gage -Bogue Chitto River near Bush, LA

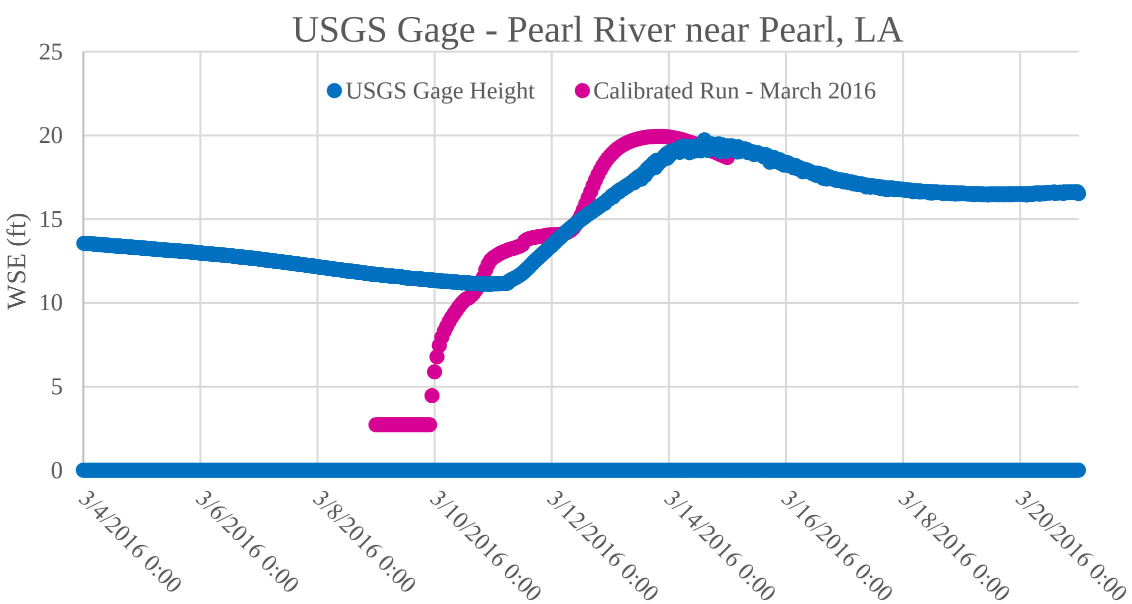


Figure E2:4. March 2016 calibration event plot for USGS Gage -Pearl River near Pearl, LA

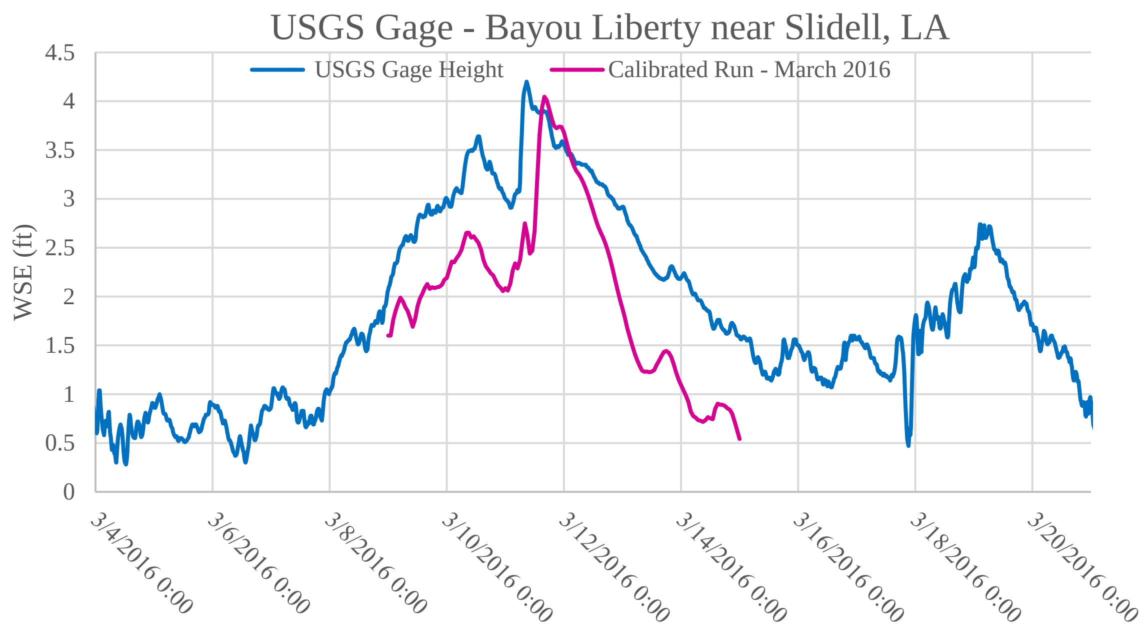
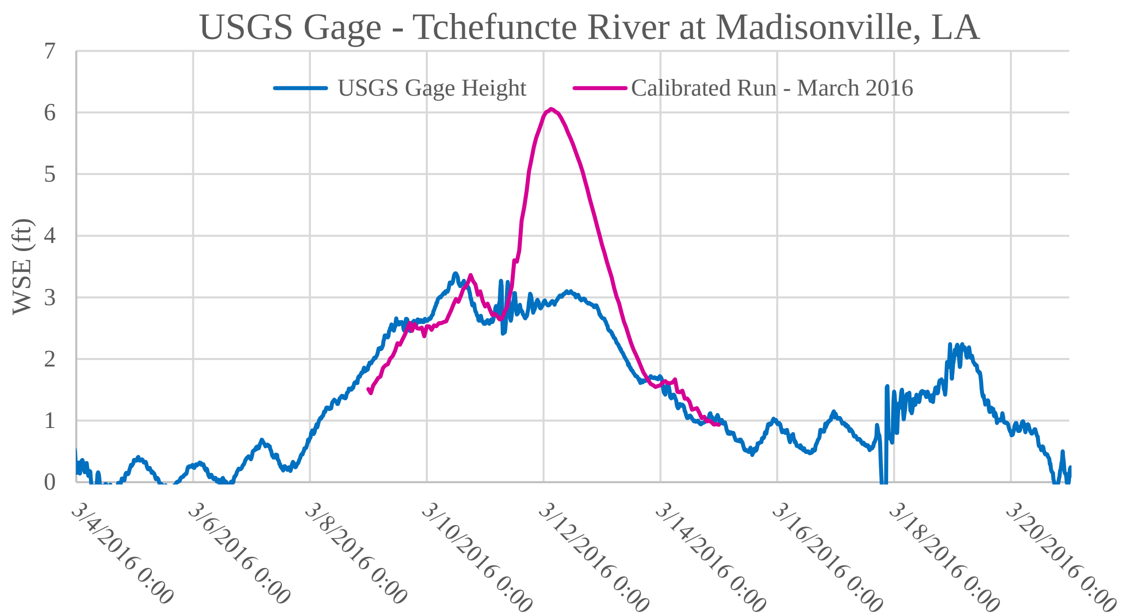


Figure E2:5. March 2016 calibration event plot for USGS Gage-Bayou Liberty near Slidell, LA



*The location of the USGS Gage – Tchefuncte River at Madisonville, LA has poorly defined channel bathymetry in the model domain which is causing the large discrepancy between the gage data and calibrated run results.

Figure E2:6. March 2016 calibration event plot for USGS Gage -Tchefuncte River at Madisonville, LA

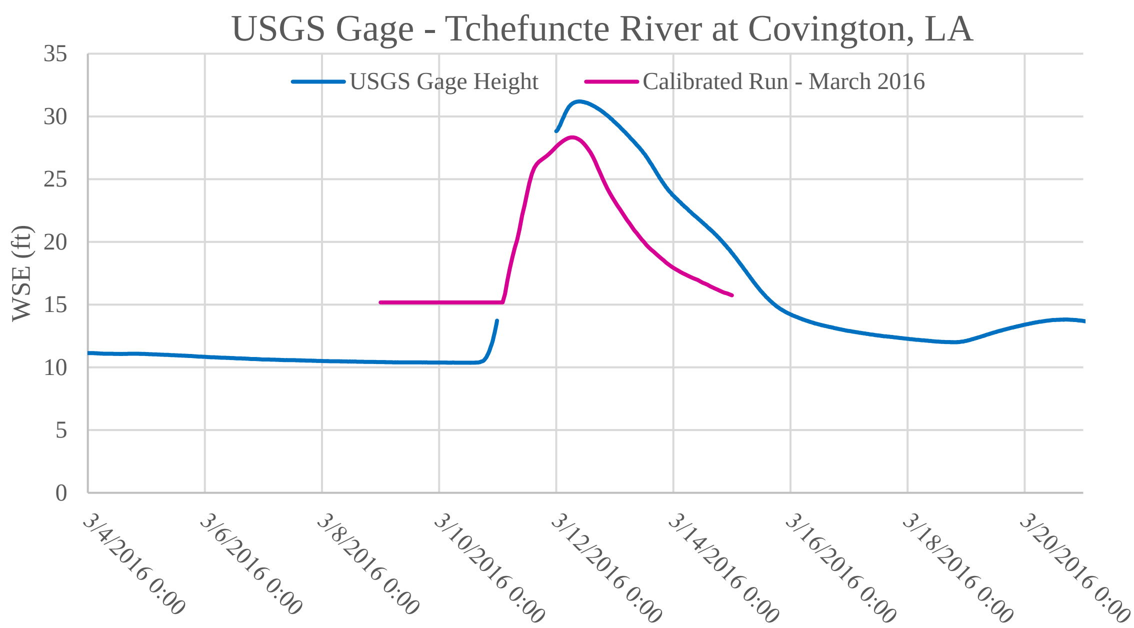


Figure E2:7. March 2016 calibration event plot for USGS Gage -Tchefuncte River at Covington, LA

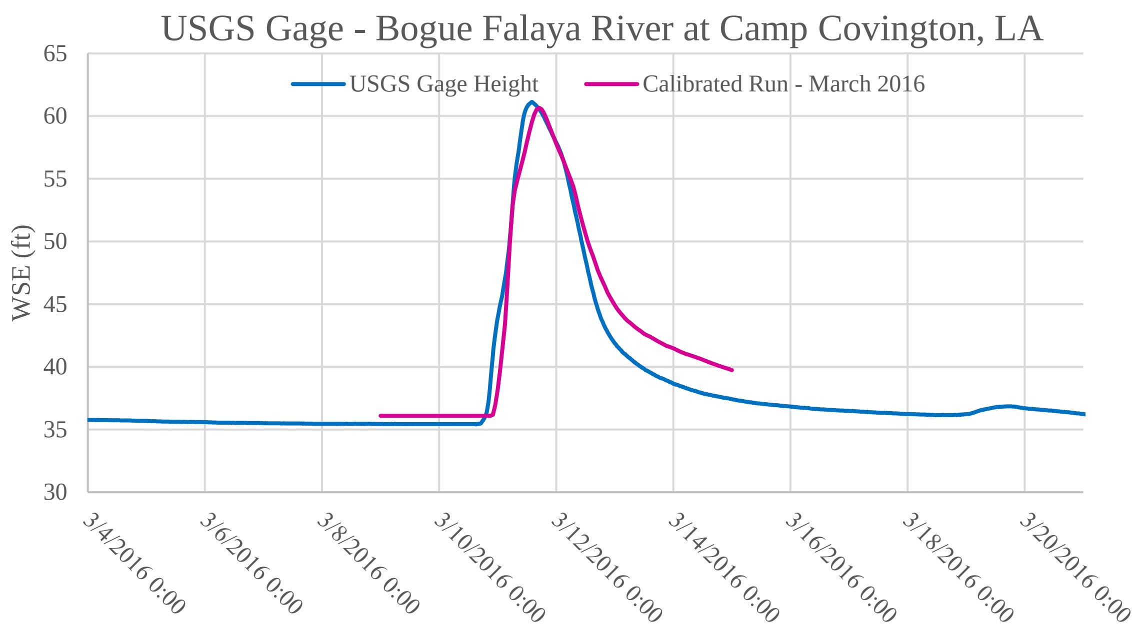


Figure E2:8. March 2016 calibration event plot for USGS Gage -Bogue Falaya River at Camp Covington, LA

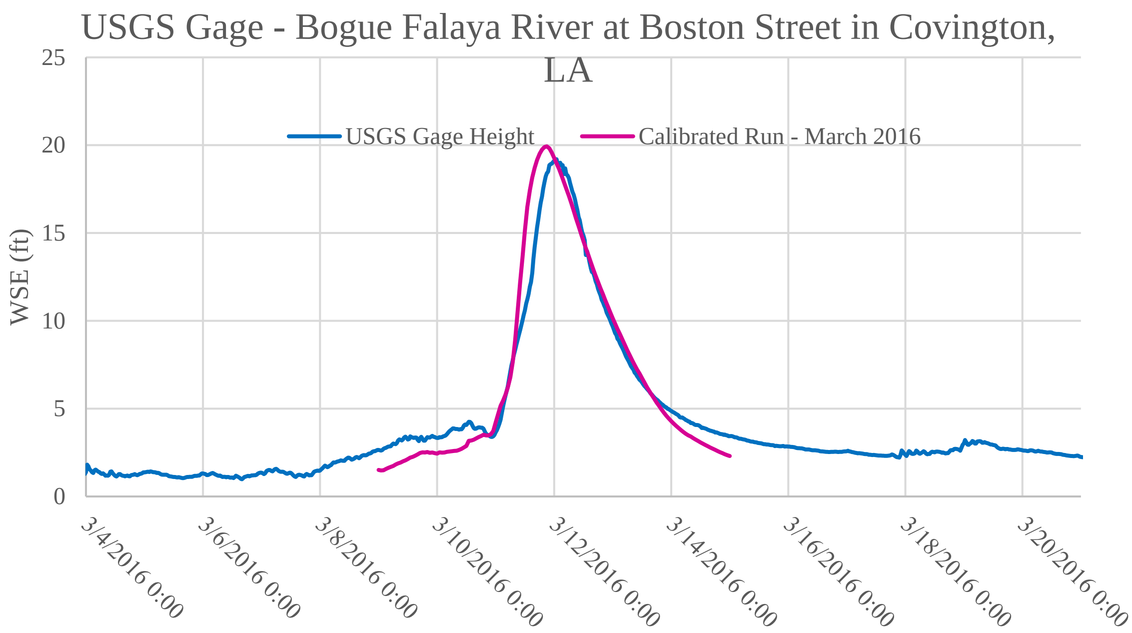


Figure E2:9. March 2016 calibration event plot for USGS Gage -Bogue Falaya River at Boston Street in Covington, LA

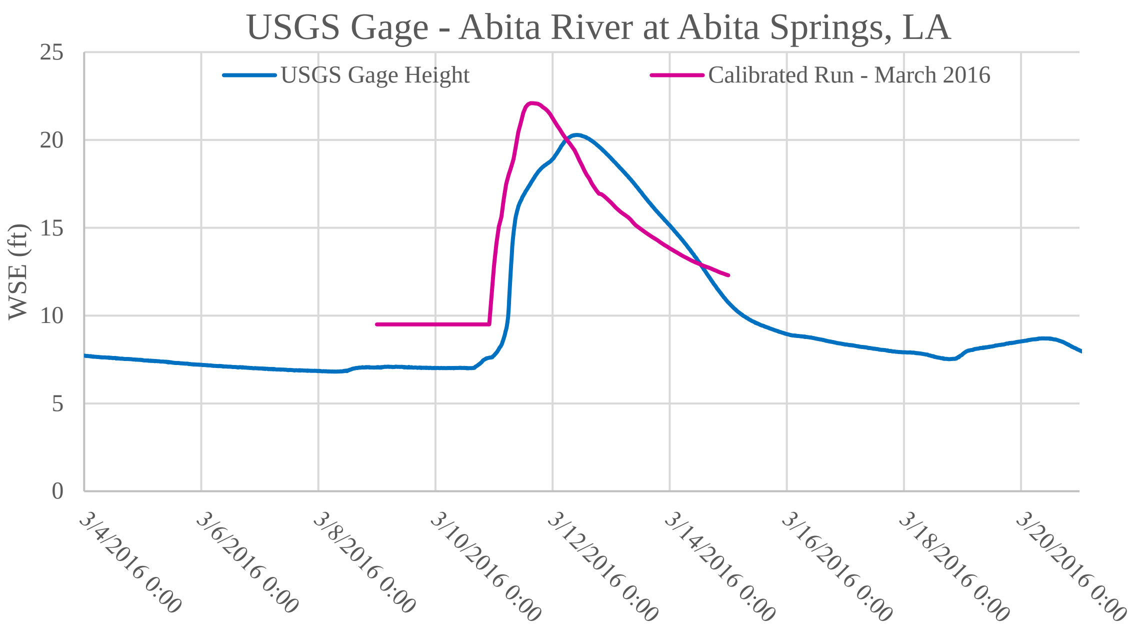


Figure E2:10. March 2016 calibration event plot for USGS Gage -Abita River at Abita Springs, LA

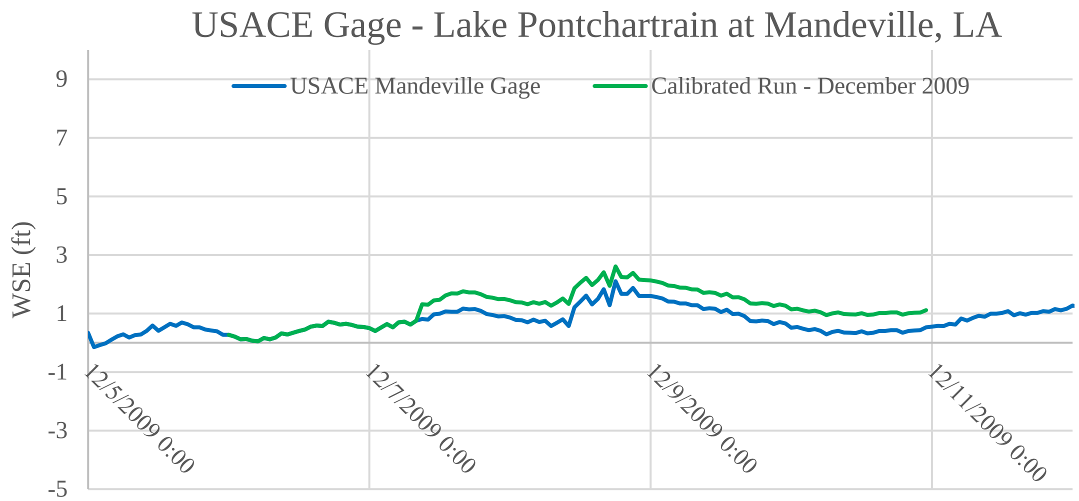


Figure E2:11. December 2009 calibration event plot for USACE Gage -Lake Pontchartrain at Mandeville, LA

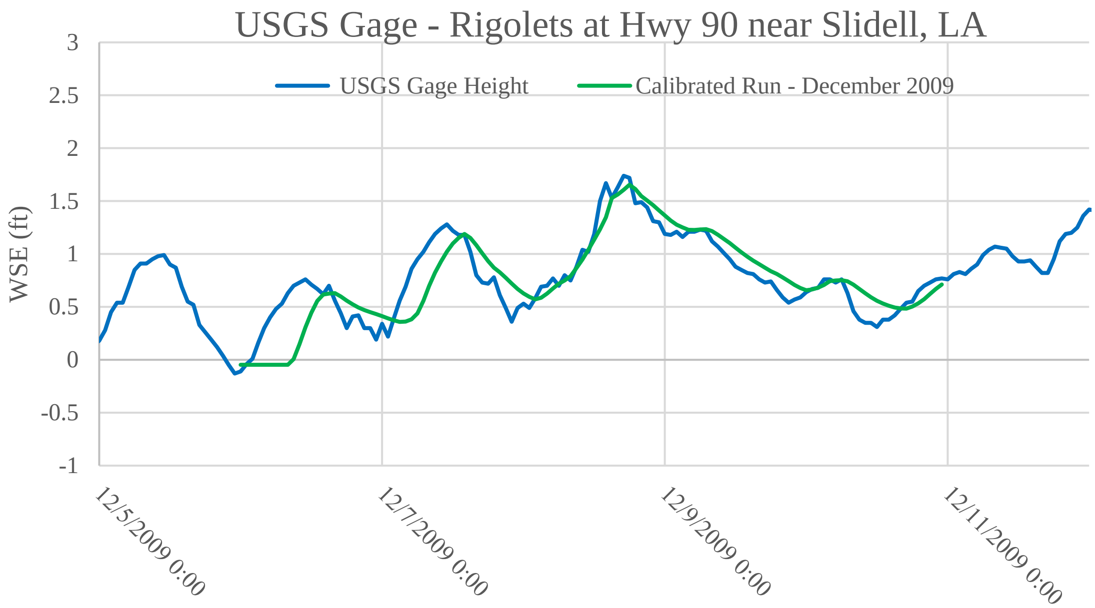


Figure E2:12. December 2009 calibration event plot for USGS Gage -Rigolets at HWY 90 *near Slidell, LA*

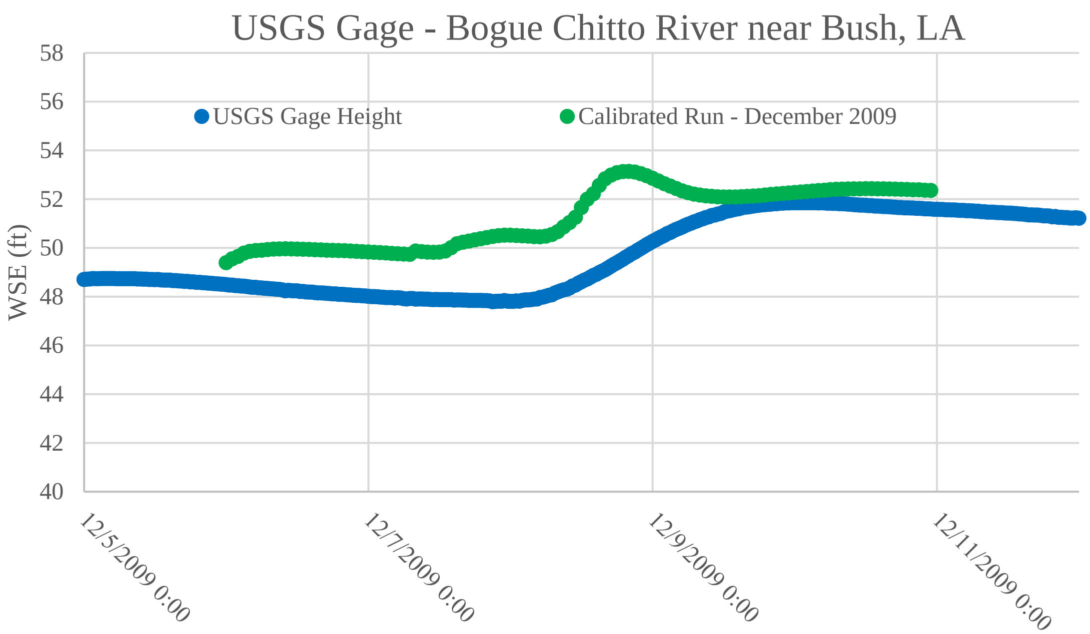


Figure E2:13. December 2009 calibration event plot for USGS Gage -Bogue Chitto River near Bush, LA

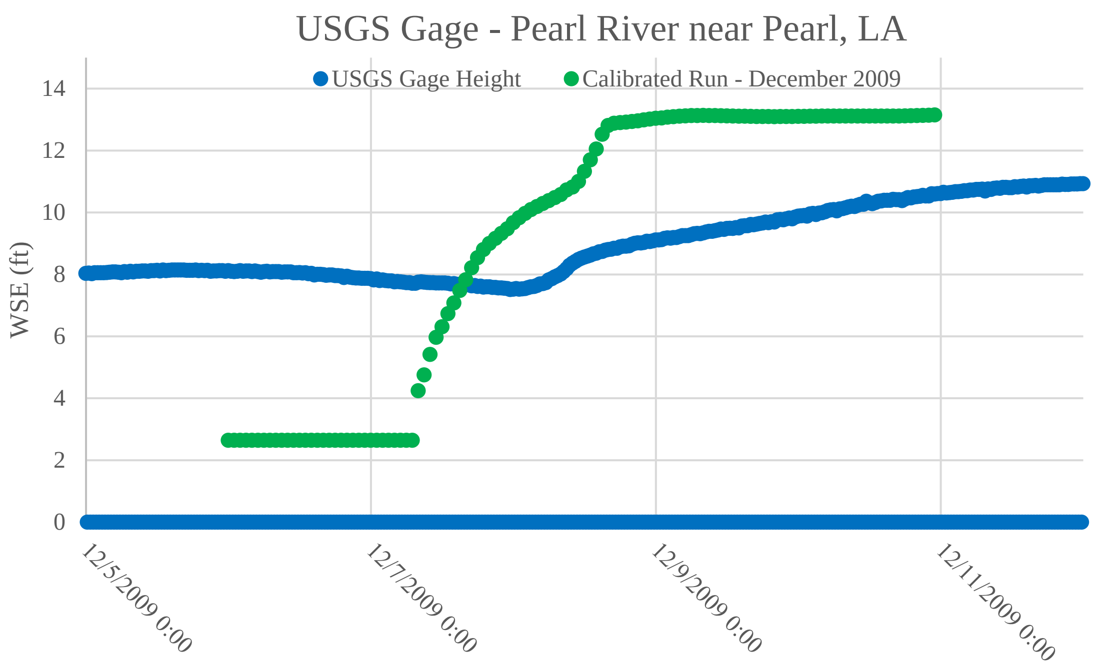


Figure E2:14. December 2009 calibration event plot for USGS Gage -Pearl River near Pearl, LA

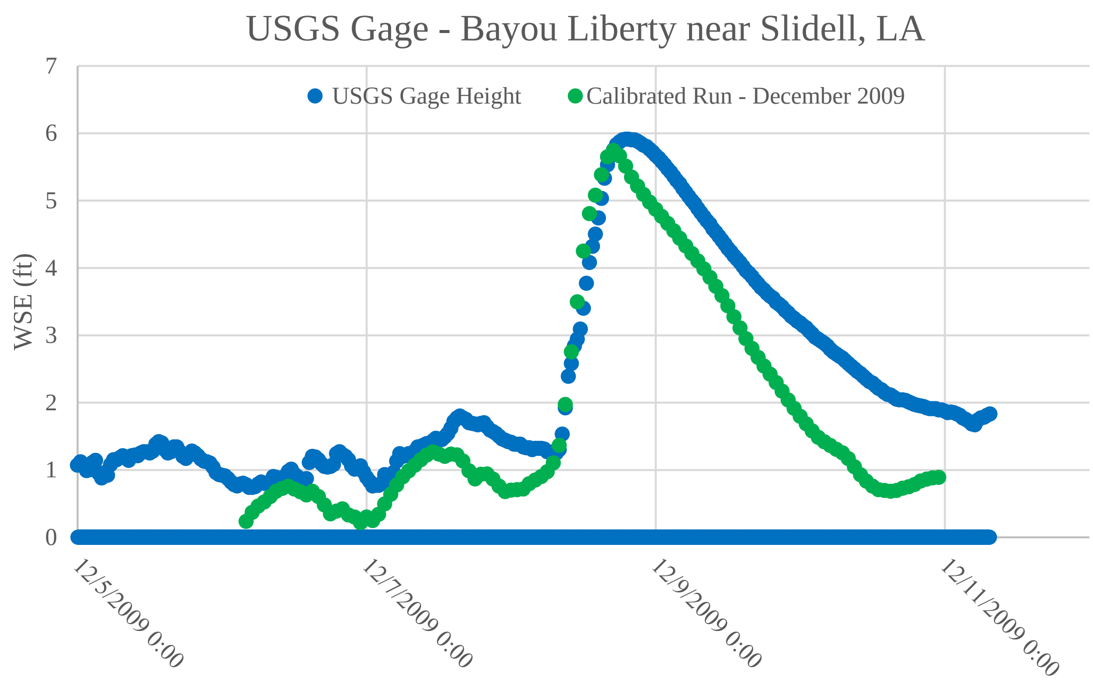


Figure E2:15. December 2009 calibration event plot for USGS Gage -Bayou Liberty near Slidell, LA

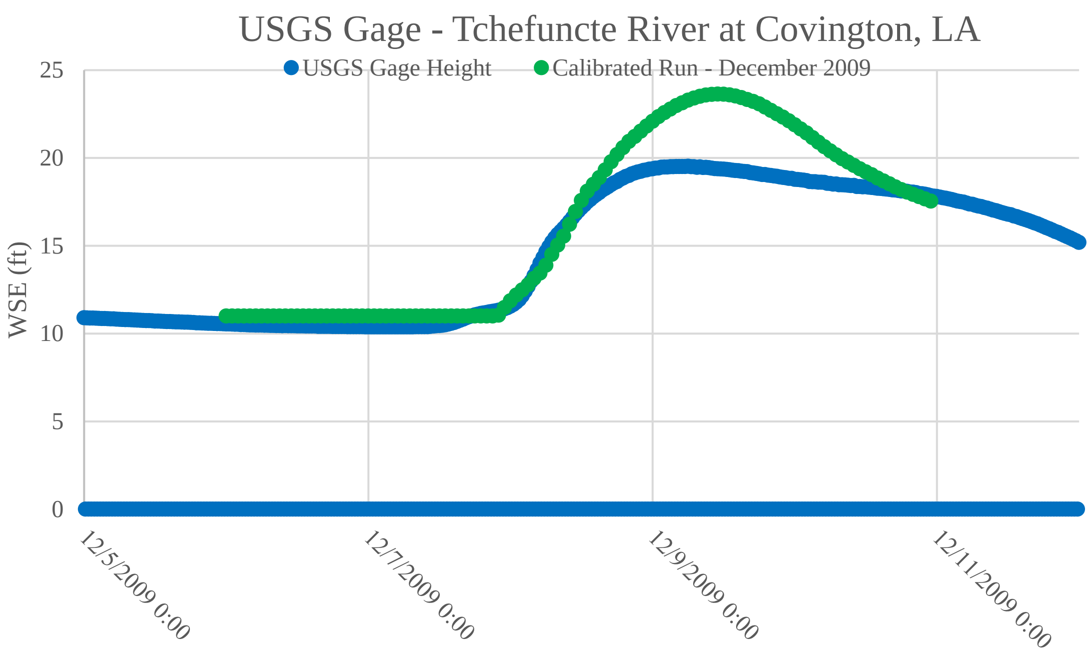


Figure E2:16. December 2009 calibration event plot for USGS Gage -Tchefuncte River at Covington, LA

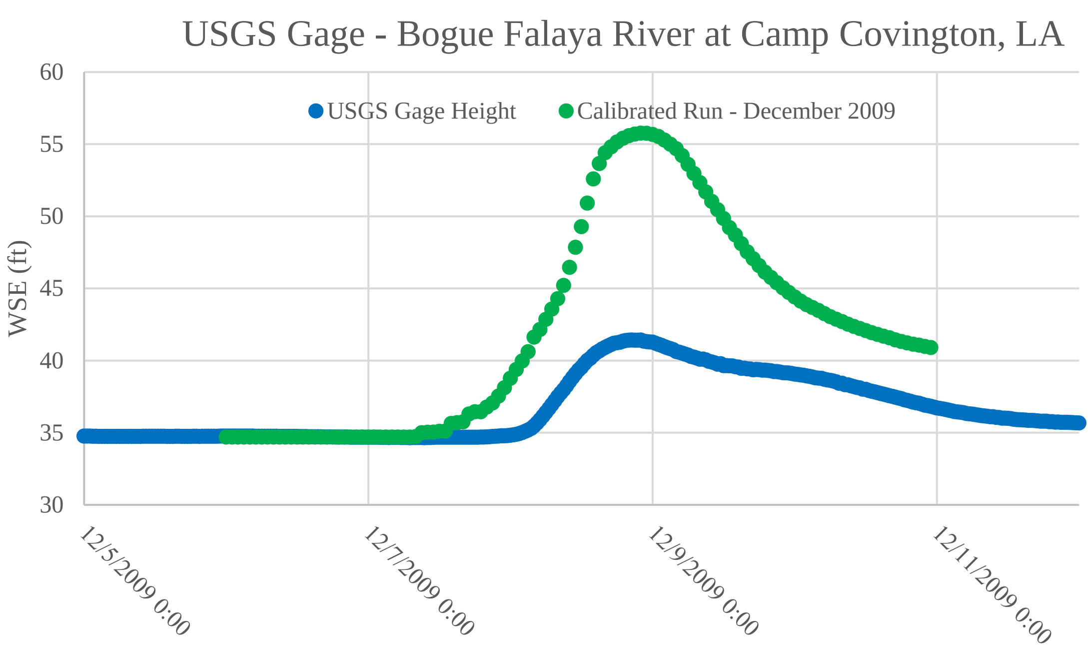


Figure E2:17. December 2009 calibration event plot for USGS Gage -Bogue Falaya River at Camp Covington, LA

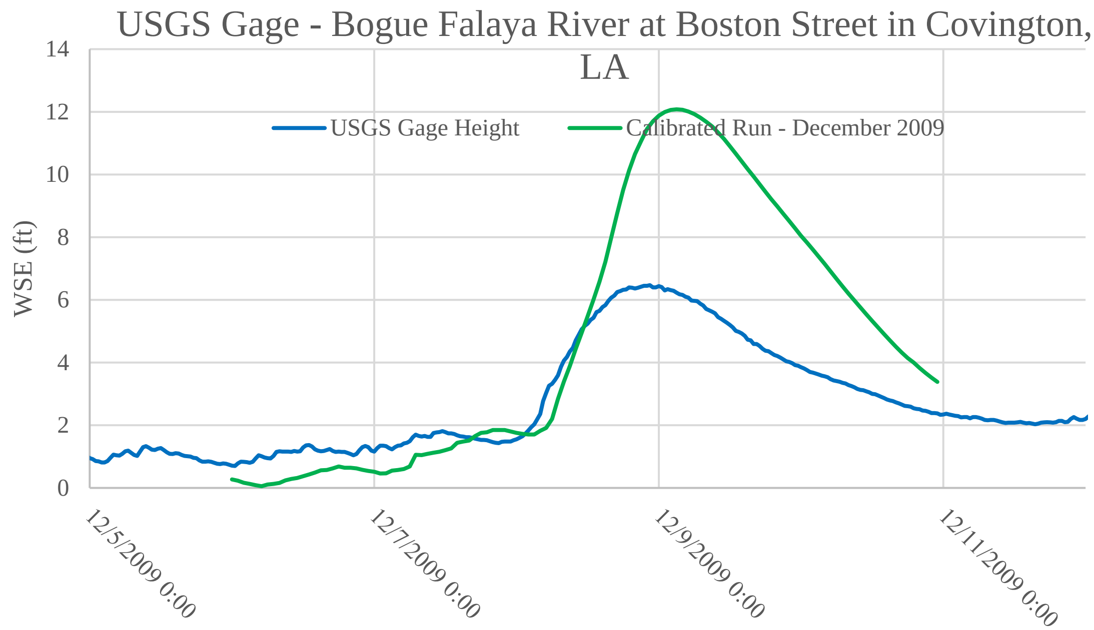


Figure E2:18. December 2009 calibration event plot for USGS Gage -Bogue Falaya River at Boston Street in Covington, LA

Annex E-3-TSP Phase Difference Maps

With Project Difference Maps with Coincident Frequency Inflows – RP Slidell Levee

Depicted in this section of the annex are difference maps for the 10-year and 100-year, 2032 (baseline) and 2082 (future) runs for the LSLR, ISLR, and HSLR rates around the ________ RP Slidell levee alignment. Each run has coincident frequency precipitation and inflows from the Bogue Chitto and Pearl River. The difference grid takes the maximum WSE for the with-project run and subtracts the maximum WSE for the corresponding existing condition run.

Gray areas denote no change in WSE with the project in place. Red, orange, and warm toned colors denote an inducement (positive value on scale) to WSE with the project in place. Green, blue, and cool toned colors denote a reduction (negative value on scale) in WSE with the project in place.

Figure E3:1. 10-year 2032 LSLR difference in WSE with project

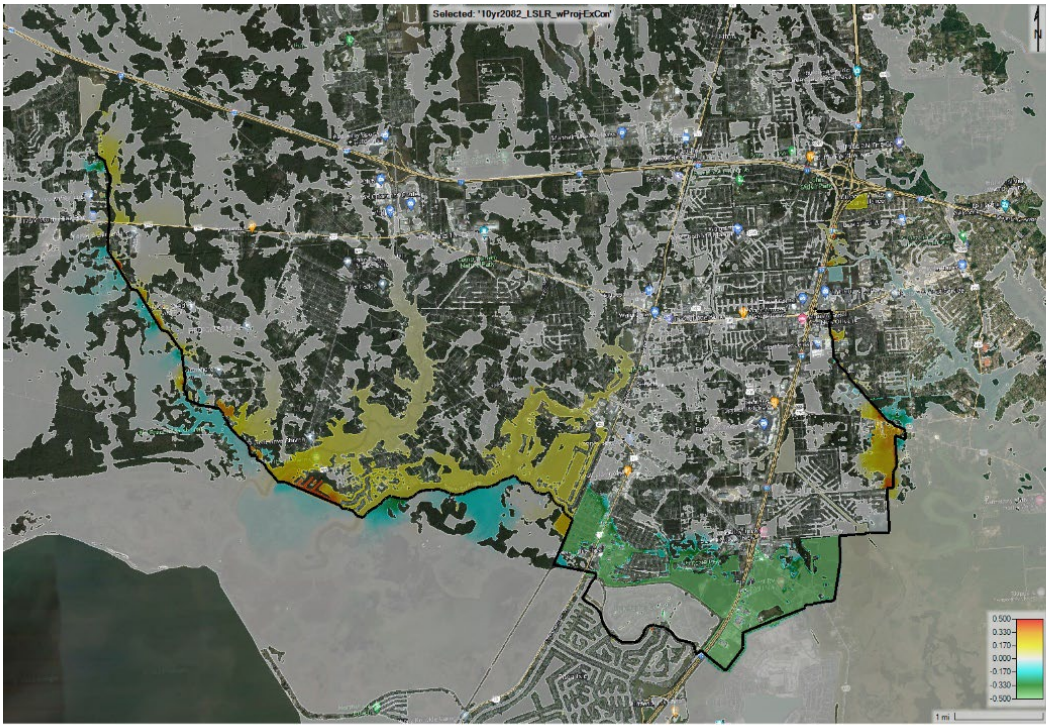


Figure E3:2. 10-year 2082 LSLR difference in WSE with project

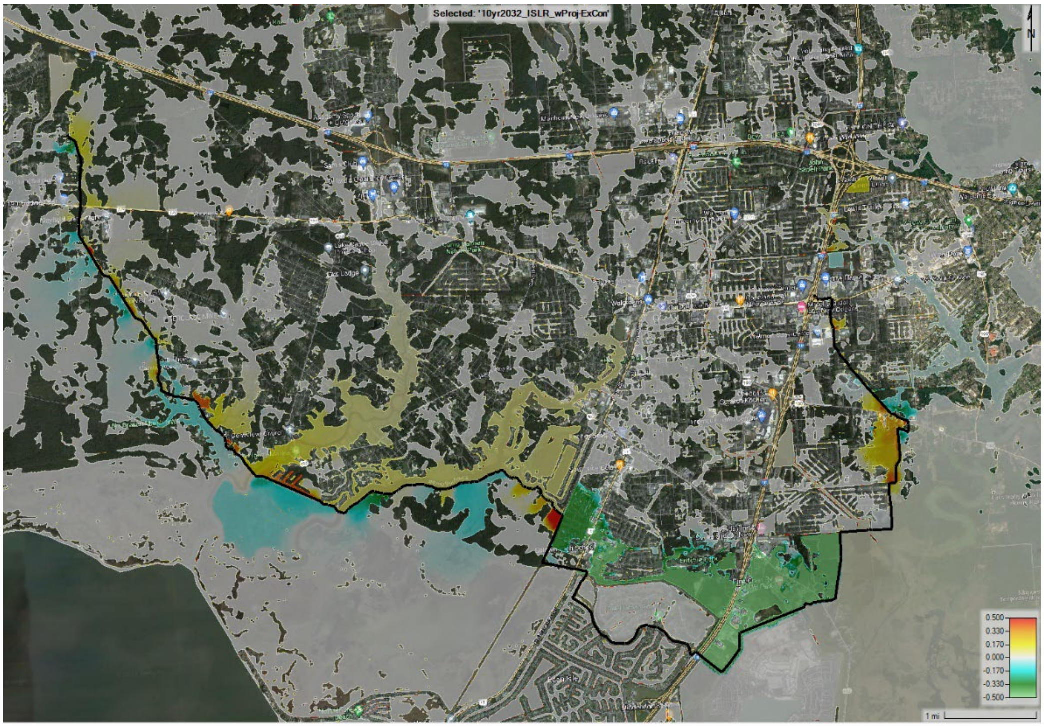


Figure E3:3. 10-year 2032 ISLR difference in WSE with project

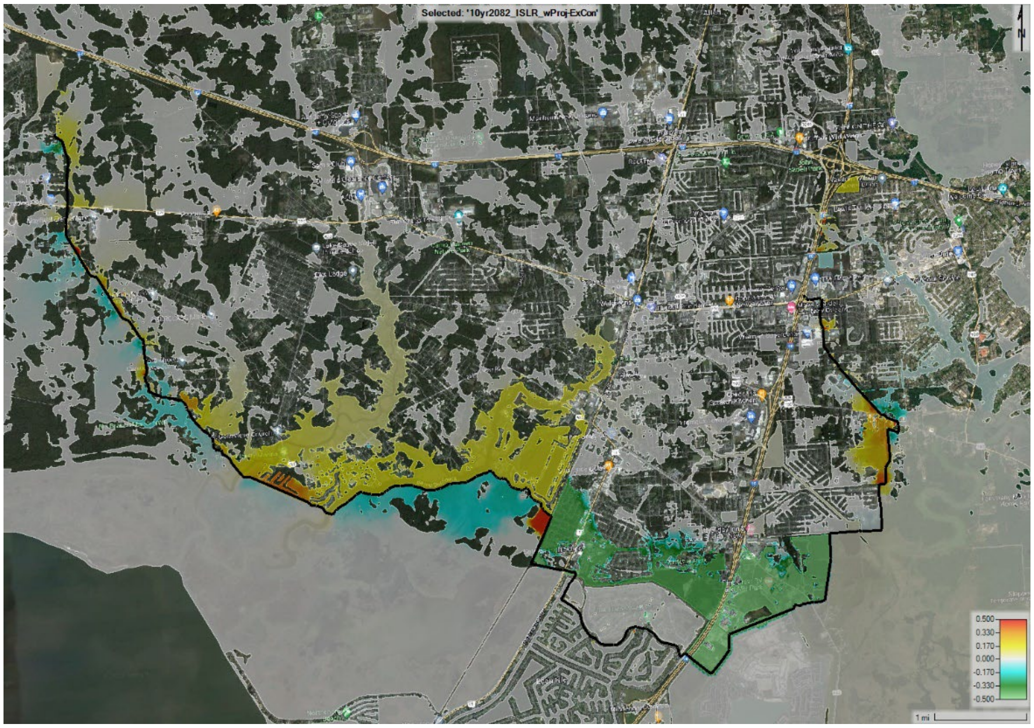


Figure E3:4. 10-year 2082 ISLR difference in WSE with project

Figure E3:5. 10-year 2032 HSLR difference in WSE with project

Figure E3:6. 10-year 2082 HSLR difference in WSE with project

Figure E3:7. 100-year 2032 LSLR difference in WSE with project

Figure E3:8. 100-year 2082 LSLR difference in WSE with project

Figure E3:9. 100-year 2032 ISLR difference in WSE with project

Figure E3:10. 100-year 2082 ISLR difference in WSE with project

Figure E3:11. 100-year 2032 HSLR difference in WSE with project

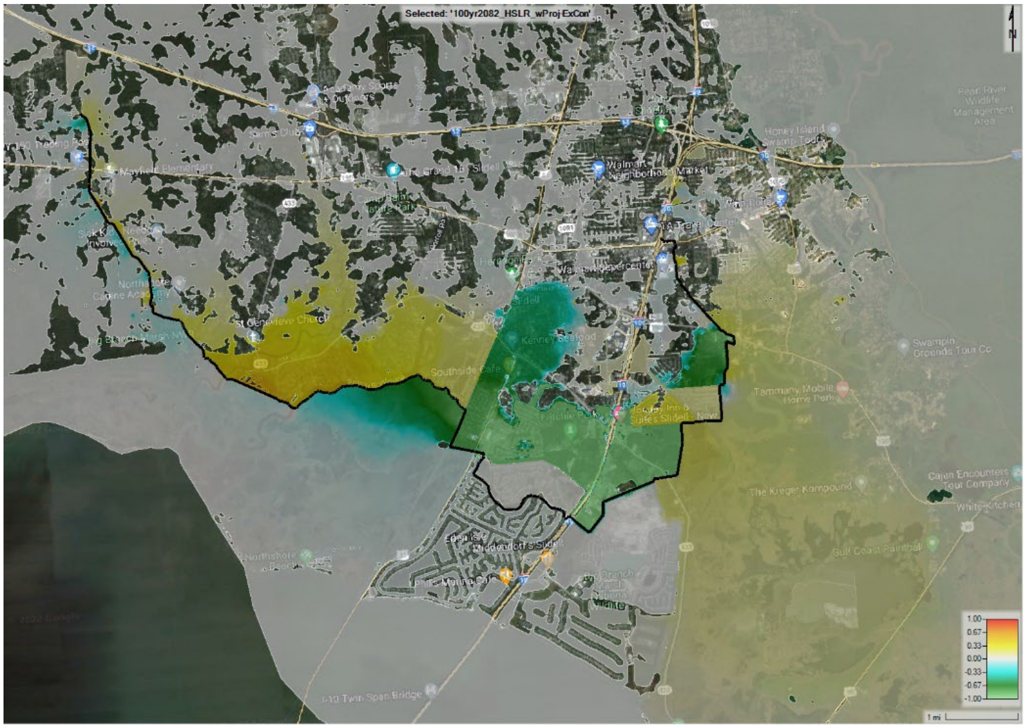


Figure E3:12. 100-year 2082 HSLR difference in WSE with project

With Project Difference Maps with Coincident Frequency Inflows – Mile Branch

Depicted in this section of the annex are difference maps for the 10-year and 100-year, 2032 (baseline) and 2082 (future) runs for the LSLR, ISLR, and HSLR rates around the Mile Branch alignment. Each run has coincident frequency precipitation and inflows from the Bogue Chitto and Pearl River. The difference grid takes the maximum WSE for the with-project run and subtracts the maximum WSE for the corresponding existing condition run.

Gray areas denote no change in WSE with the RP in place. Red, orange, and warm toned colors denote an inducement (positive value on scale) to WSE with the project in place. Green, blue, and cool toned colors denote a reduction (negative value on scale) in WSE with the project in place.

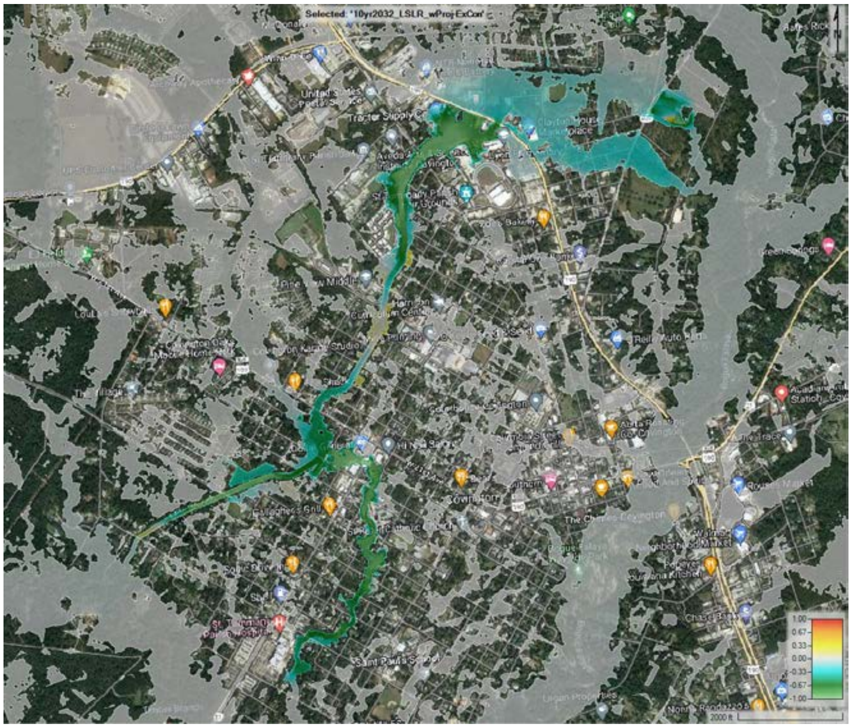


Figure E3:13. 10-year 2032 LSLR difference in WSE with project

Figure E3:14. 10-year 2082 LSLR difference in WSE with project

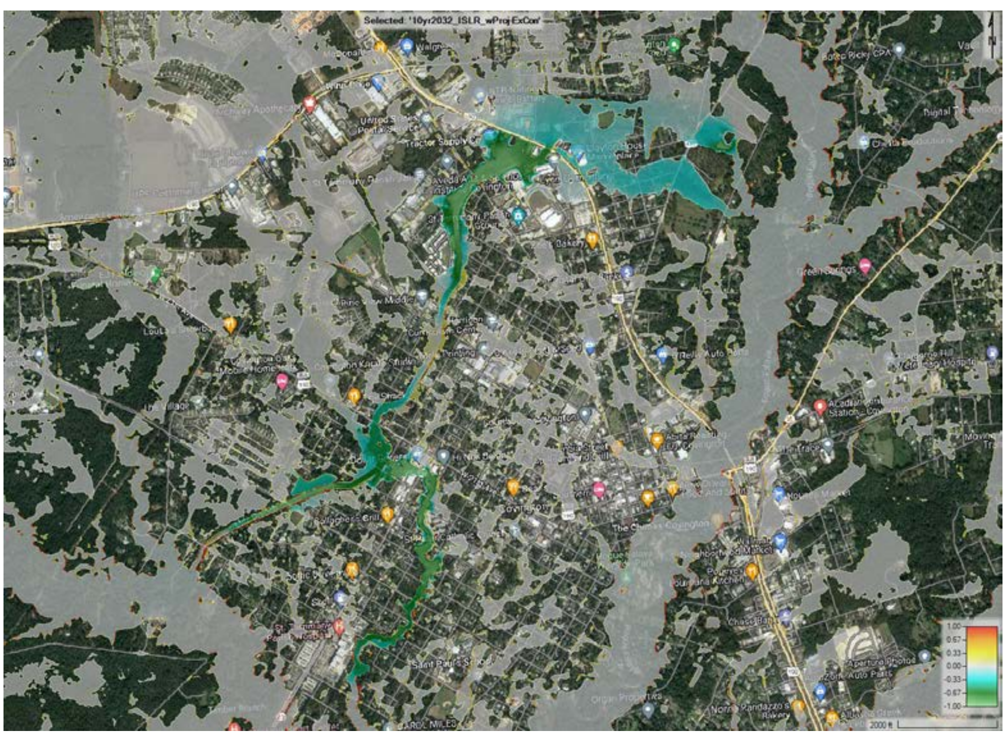


Figure E3:15: 10-year 2032 ISLR difference in WSE with project

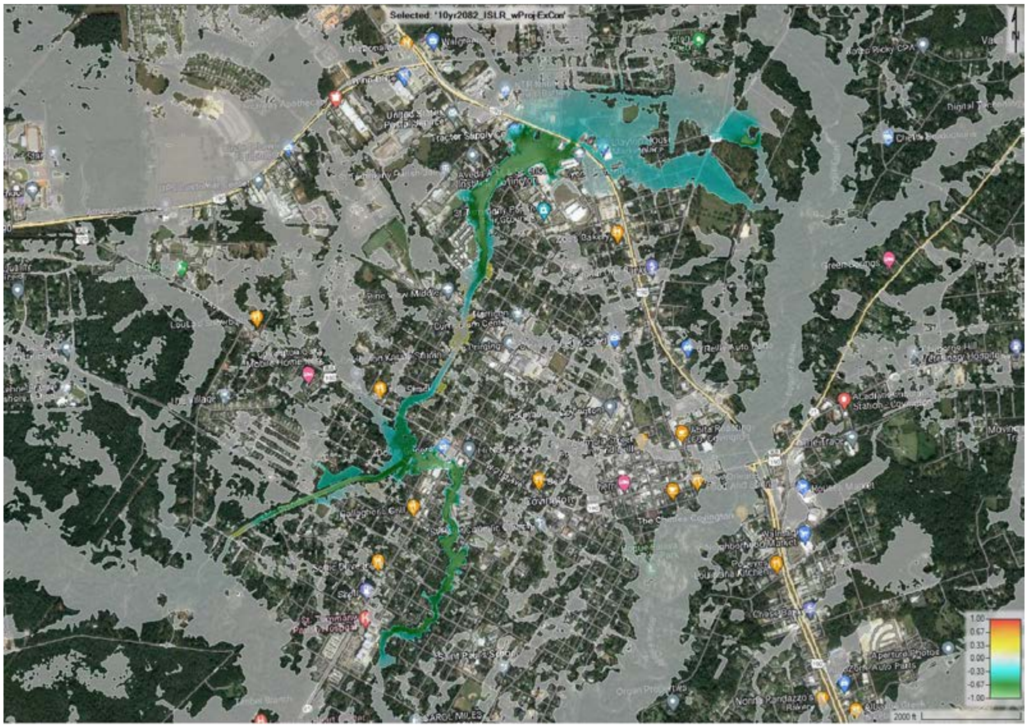


Figure E3:16. 10-year 2082 ISLR Difference in WSE with project

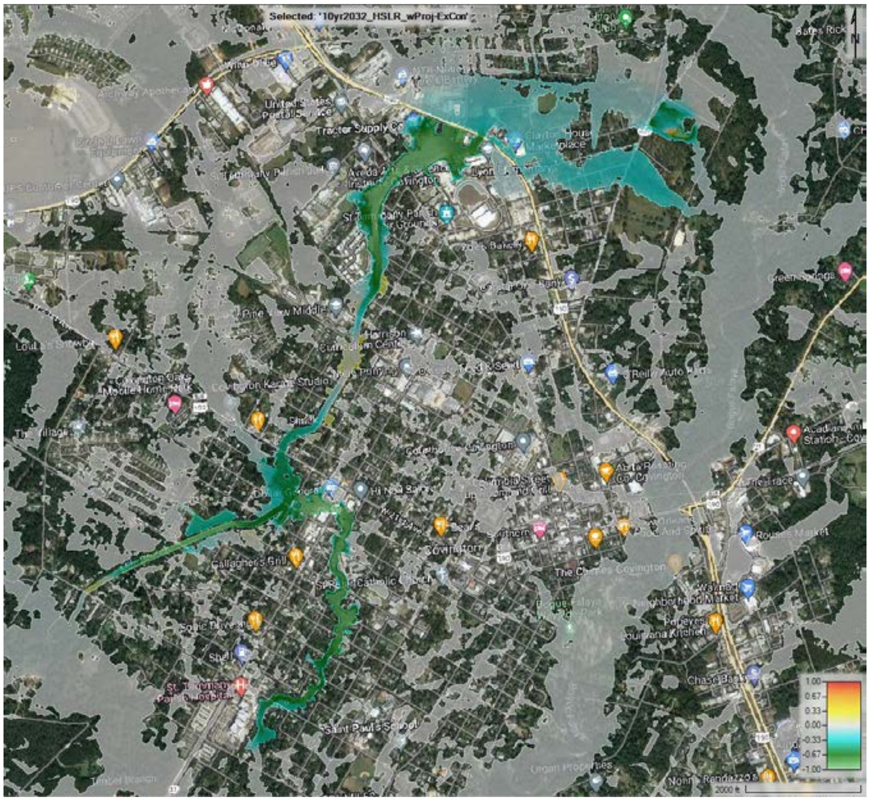


Figure E3:17. 10-year 2032 HSLR Difference in WSE with project

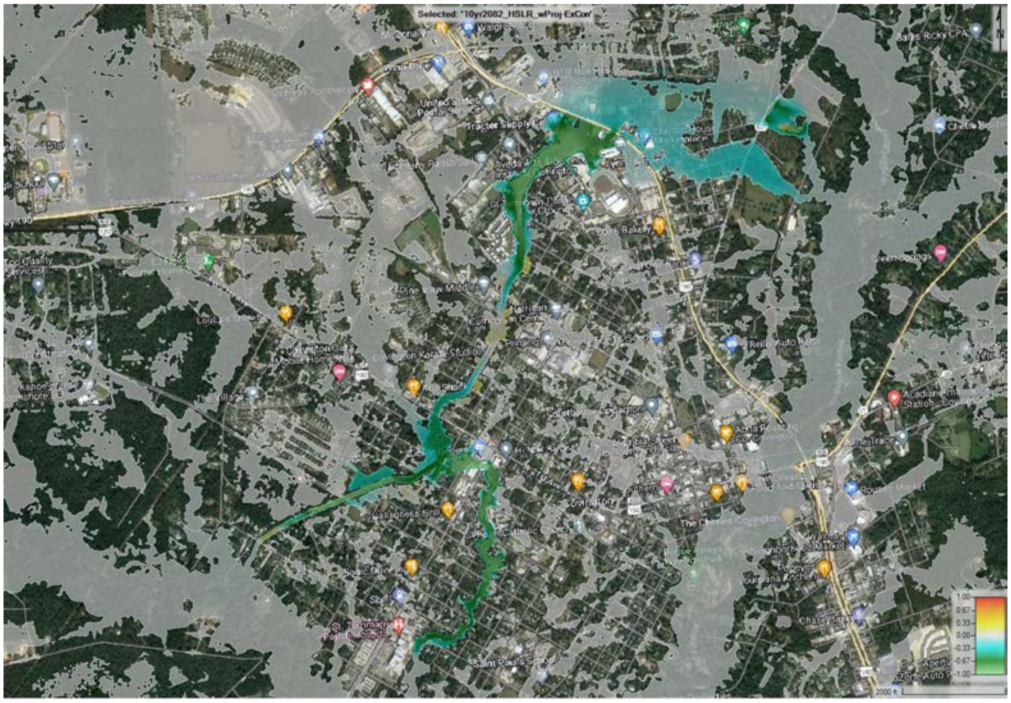


Figure E3:18. 10-year 2082 HSLR difference in WSE with project

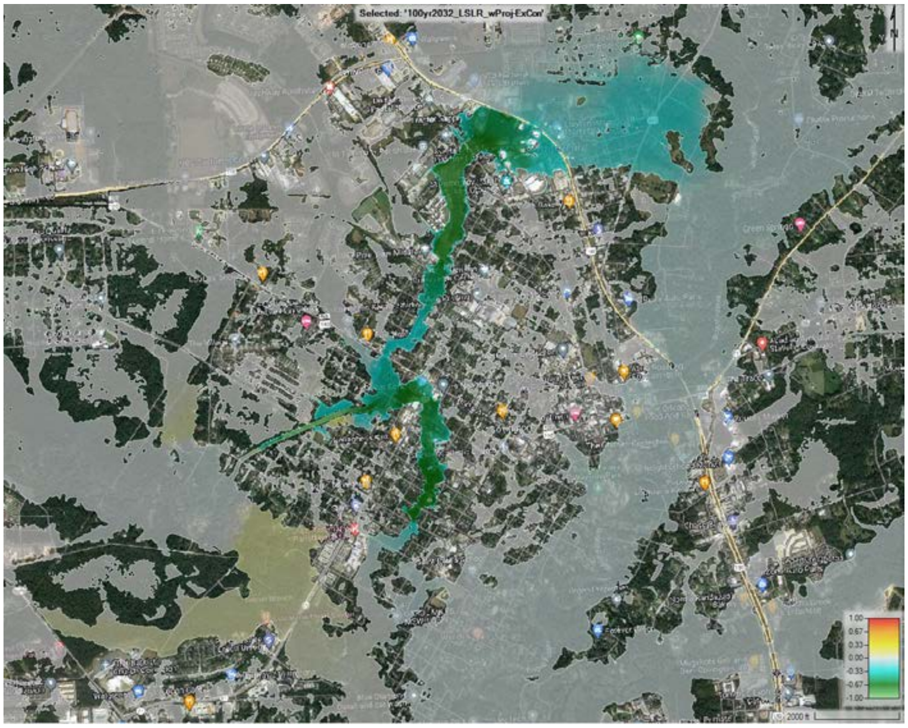


Figure E3:19. 100-year 2032 LSLR difference in WSE with project

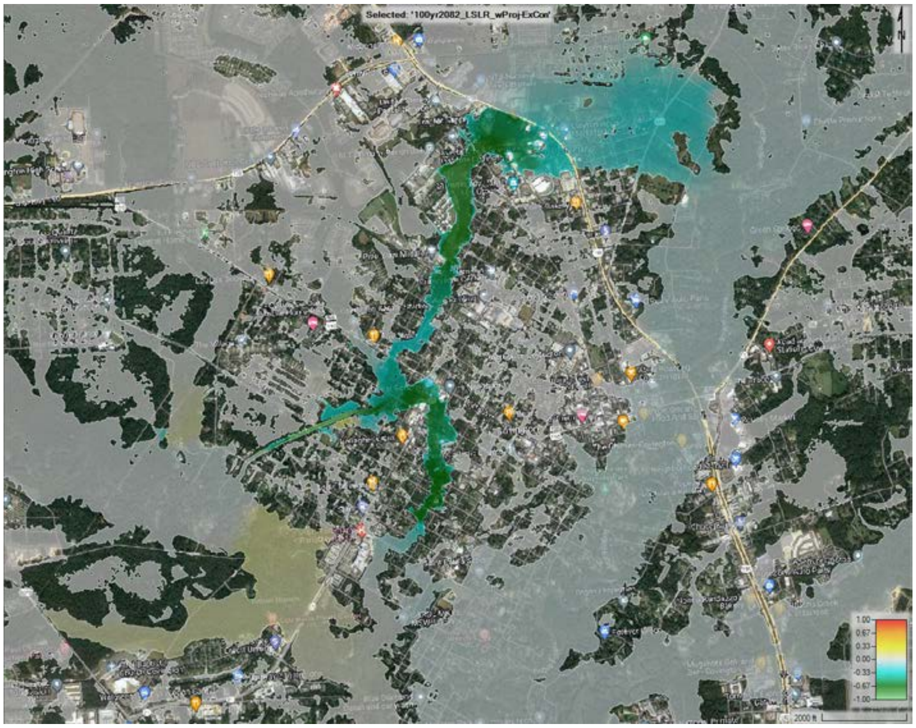


Figure E3:20. 100-year 2082 LSLR Difference in WSE with project

Figure E3:21. 100-year 2032 ISLR difference in WSE with project

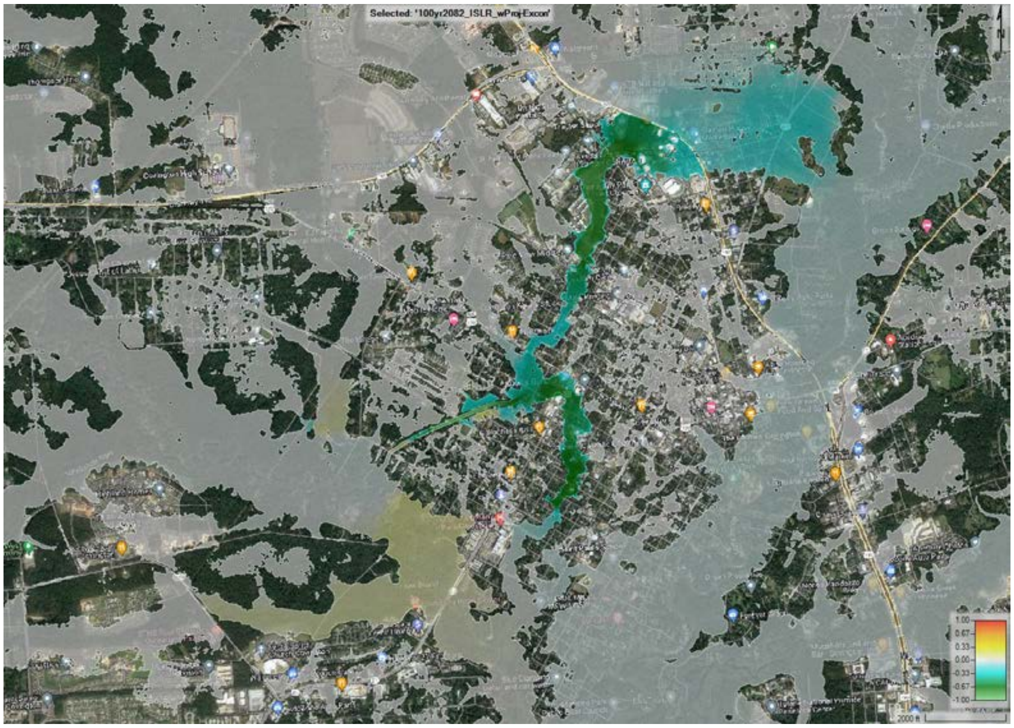


Figure E3:22. 100-year 2082 ISLR difference in WSE with project

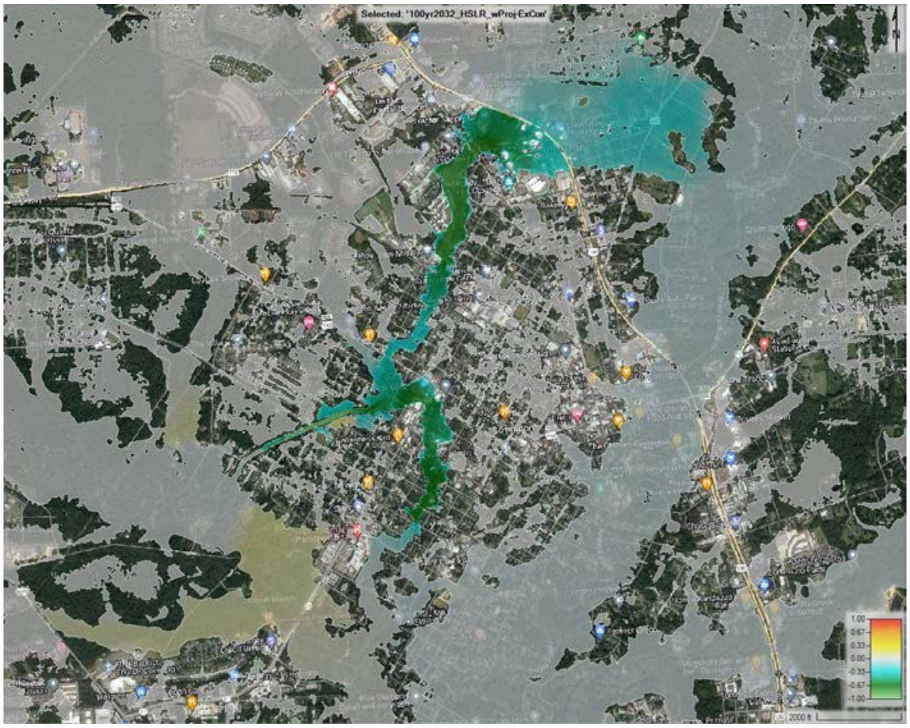


Figure E3:23. 100-year 2032 HSLR difference in WSE with project

Figure E3:24. 100-year 2082 HSLR difference in WSE with project

With Project Difference Maps with Mean Inflows – RP Slidell Levee

Depicted in this section of the annex are difference maps for the 10-year and 100-year, 2032 (baseline) and 2082 (future) runs for the LSLR, ISLR, and HSLR rates around the Optimzied Slidell levee alignment. Each run has mean historic inflows from the Bogue Chitto and Pearl River. The difference grid takes the maximum WSE for the with-project run and subtracts the maximum WSE for the corresponding existing condition run.

Gray areas denote no change in WSE with the project in place. Red, orange, and warm toned colors denote an inducement (positive value on scale) to WSE with the project in place. Green, blue, and cool toned colors denote a reduction (negative value on scale) in WSE with the project in place.

Figure E3:25. 10-year 2032 LSLR difference in WSE with project

Figure E3:26. 10-year 2082 LSLR difference in WSE with project

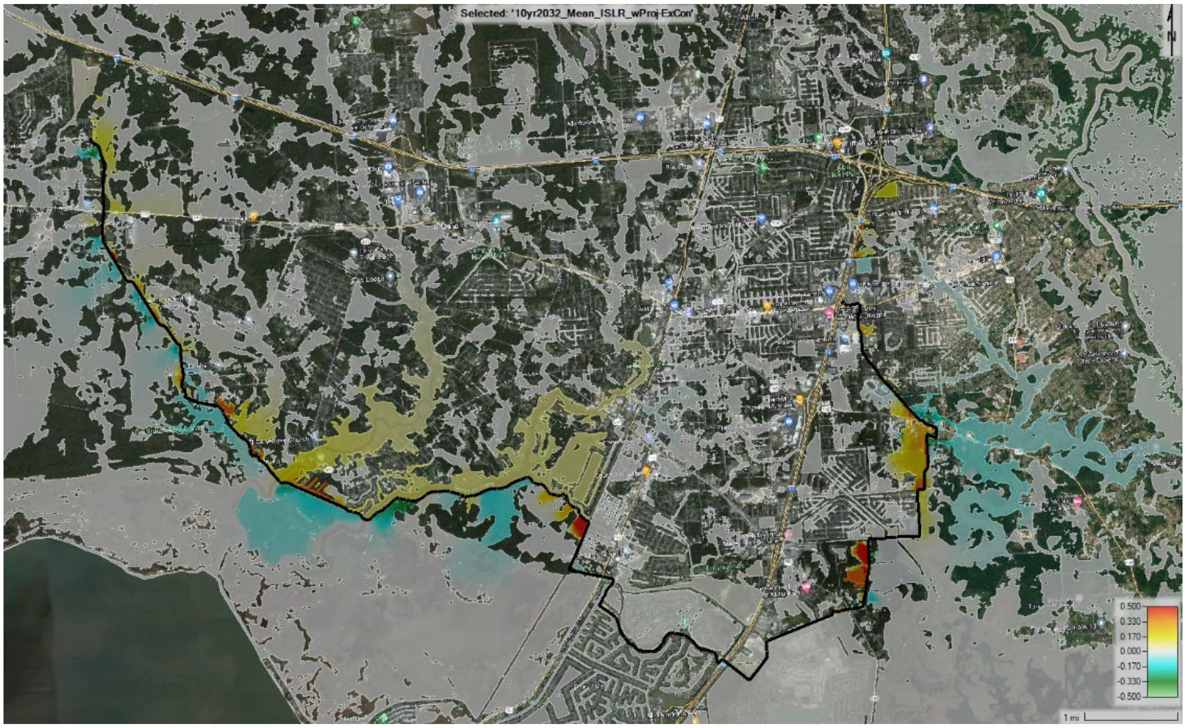


Figure E3:27. 10yr 2032 ISLR difference in WSE with project

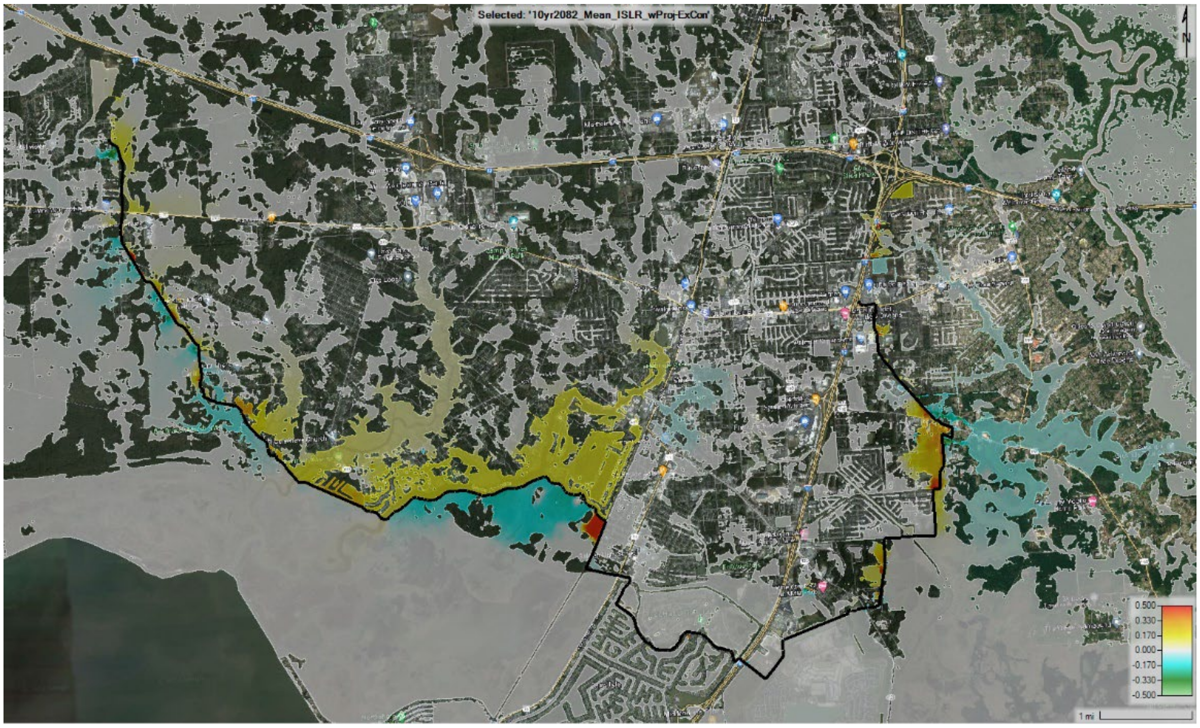


Figure E3:28. 10-year 2082 ISLR difference in WSE with project

Figure E3:29. 10-year 2032 HSLR difference in WSE with project

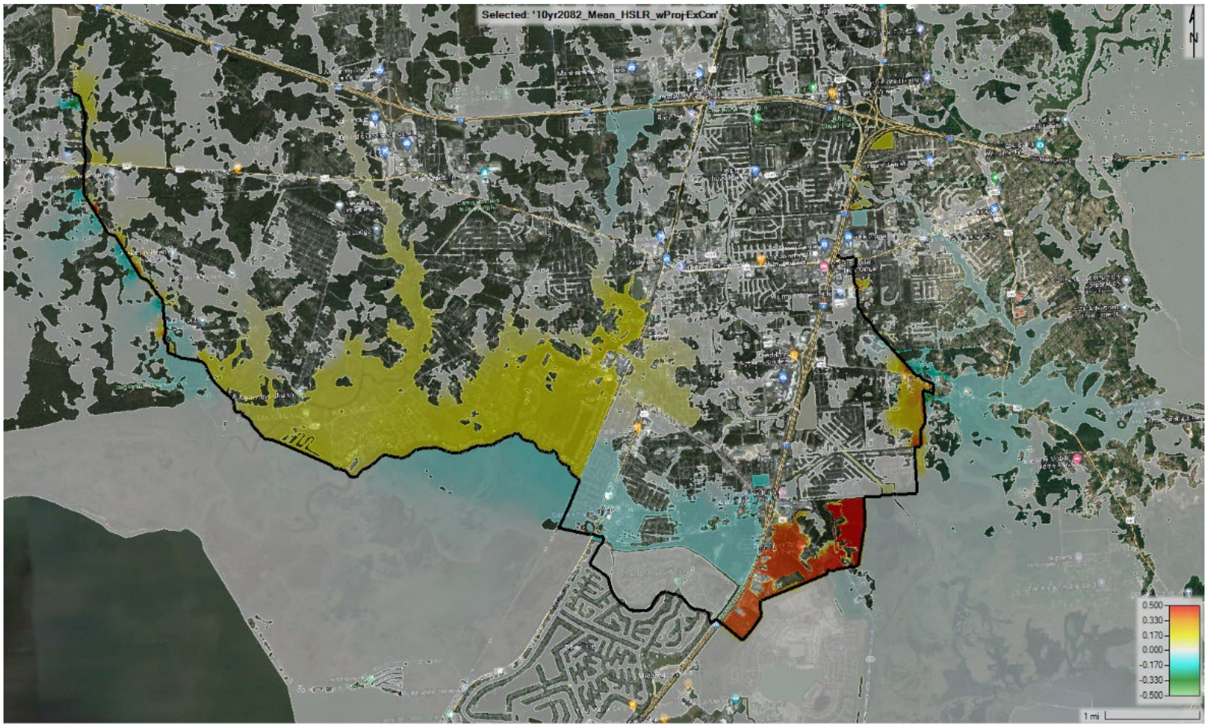


Figure E3-30. 10-year 2082 HSLR difference in WSE with project

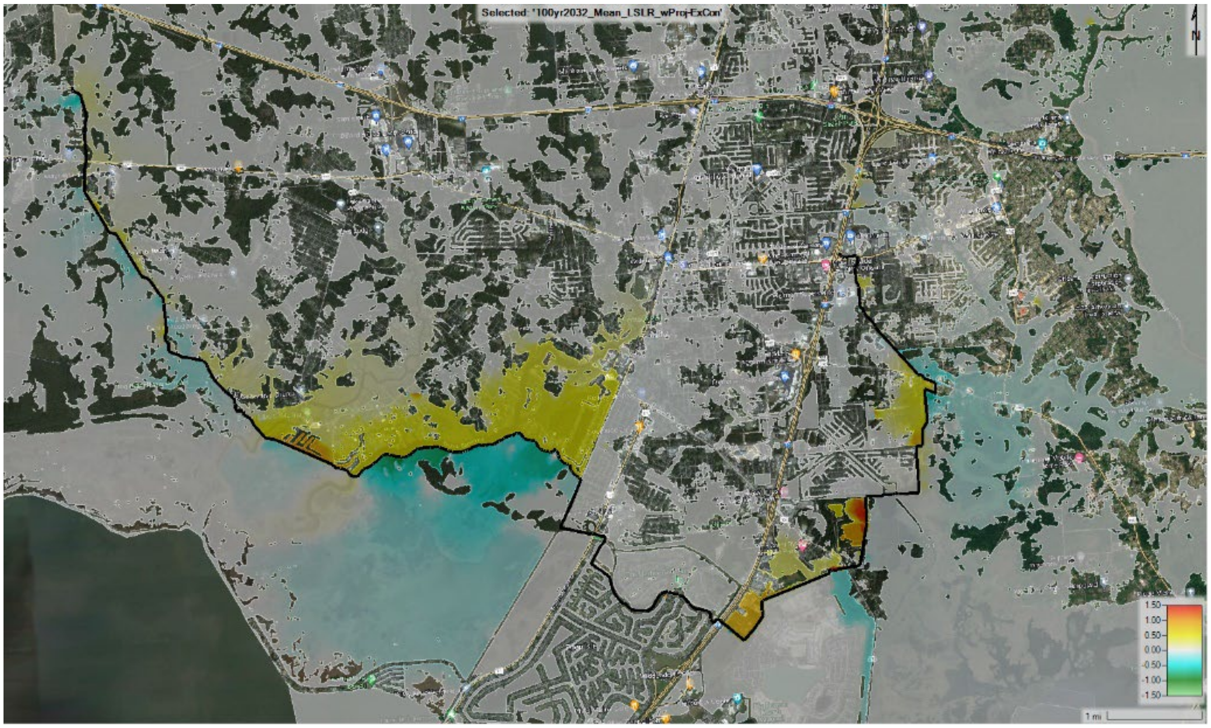


Figure E3:31. 100-year 2032 LSLR difference in WSE with project

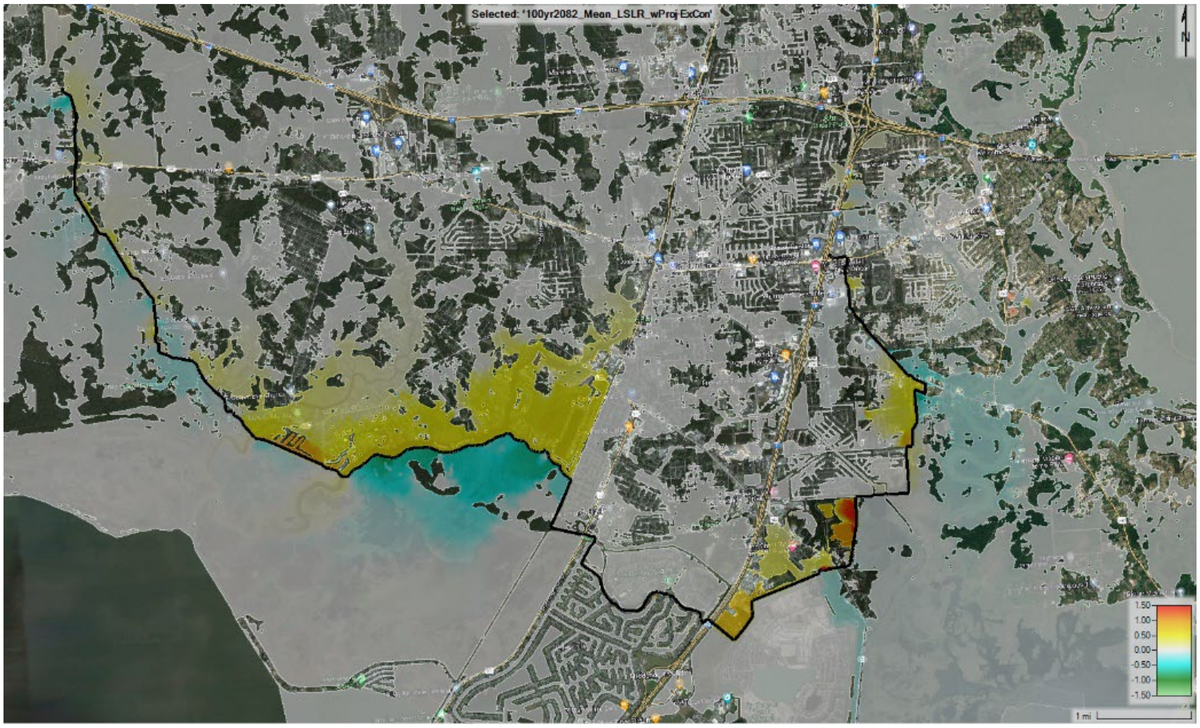


Figure E3:32. 100-year 2082 LSLR difference in WSE with project

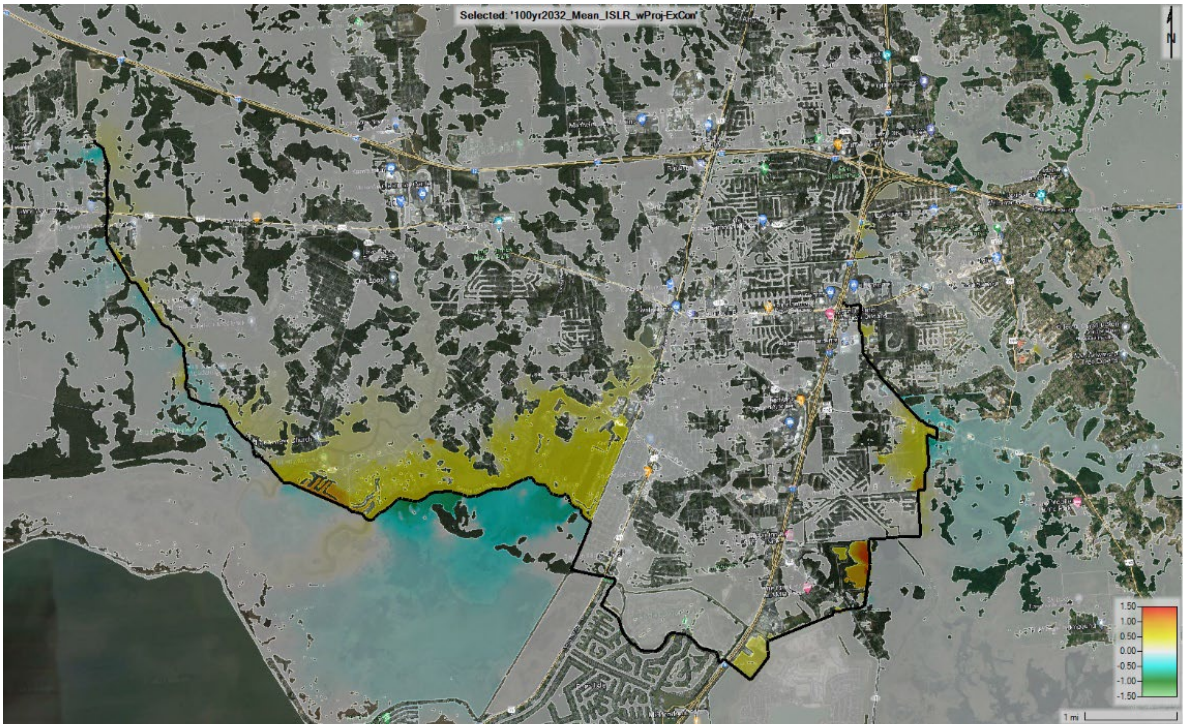


Figure E3:33. 100-year 2032 ISLR difference in WSE with project

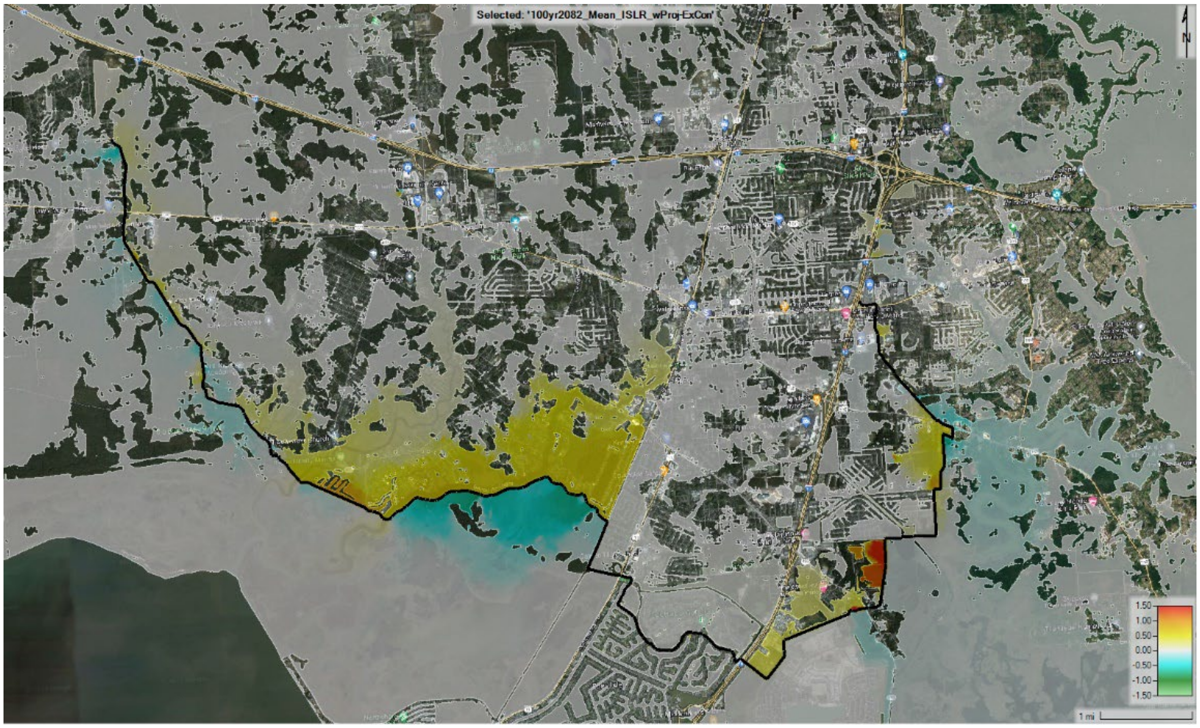


Figure E3:34. 100-year 2082 ISLR difference in WSE with project

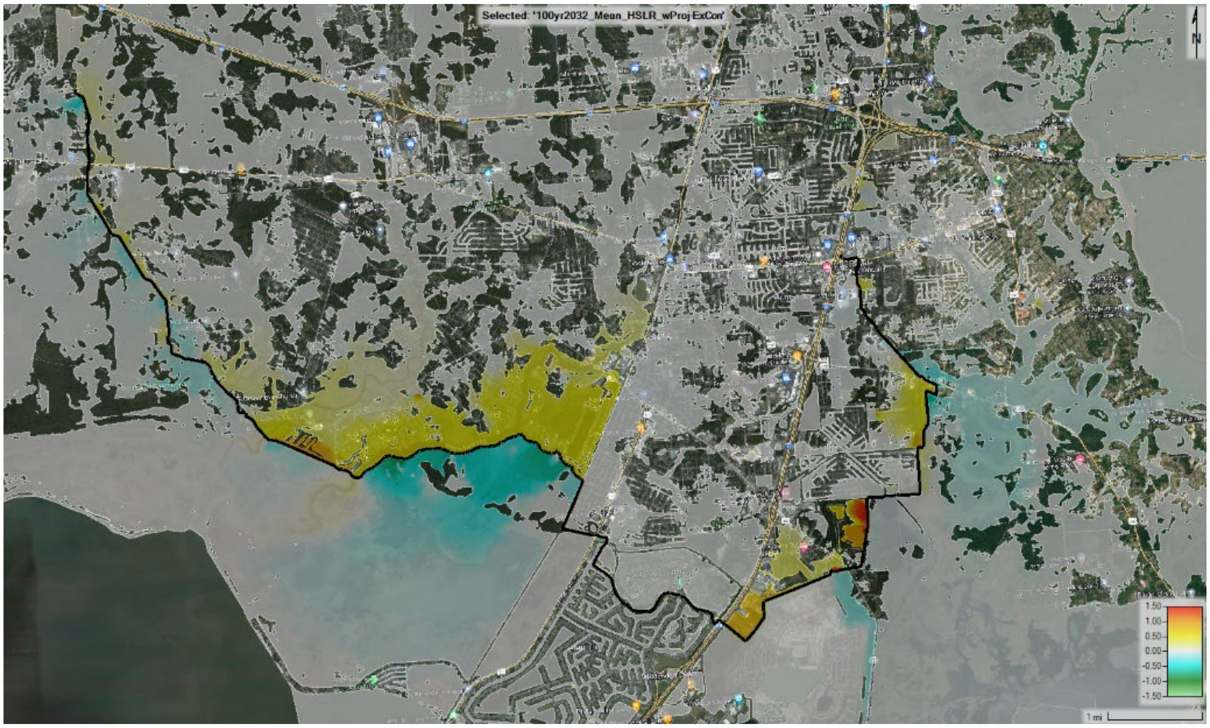


Figure E3:35. 100-year 2032 HSLR difference in WSE with project

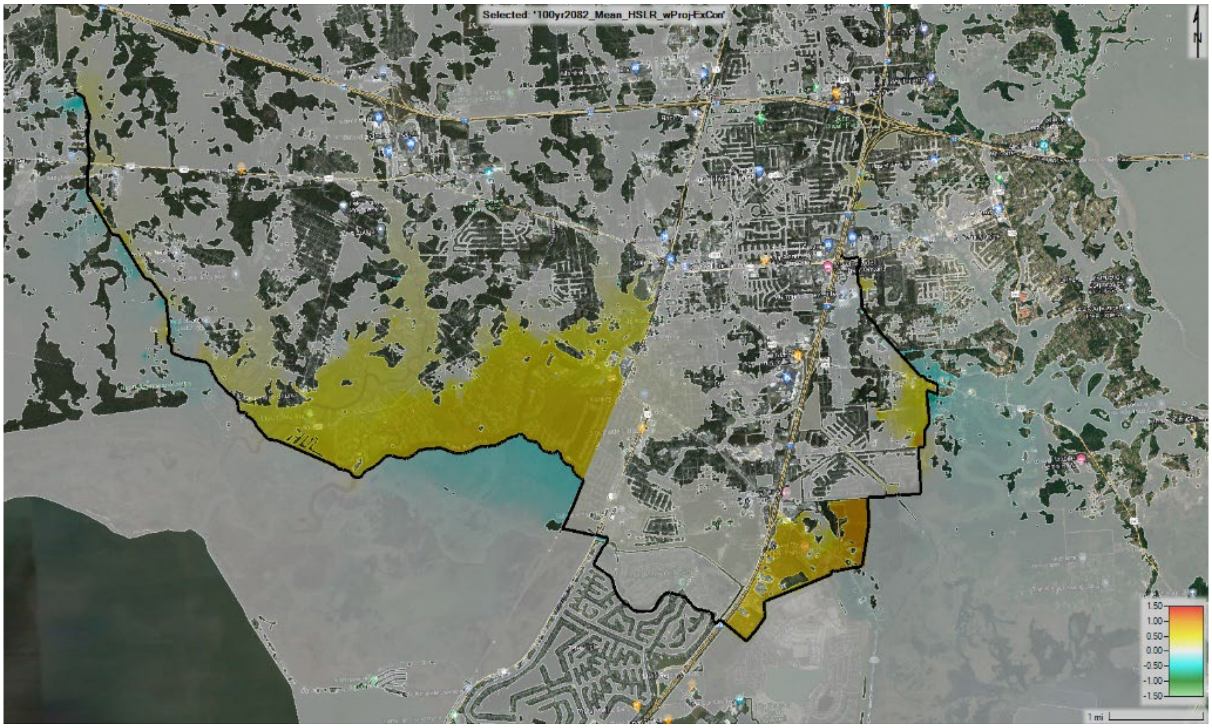


Figure E3:36. 100-yr 2082 HSLR difference in WSE with project

With Project Difference Maps with Mean Inflows – Mile Branch

Depicted in this section of the annex are difference maps for the 10-year and 100-year, 2032 (baseline) and 2082 (future) runs for the LSLR, ISLR, and HSLR rates of sea level rise around the Mile Branch alignment of the RP. Each run has mean historic inflows from the Bogue Chitto and Pearl River. The difference grid takes the maximum WSE for the with-project run and subtracts the maximum WSE for the corresponding existing condition run.

Gray areas denote no change in WSE with the project in place. Red, orange, and warm toned colors denote an inducement (positive value on scale) to WSE with the project in place. Green, blue, and cool toned colors denote a reduction (negative value on scale) in WSE with the project in place.

Figure E3:37. 10-year 2032 LSLR difference in WSE with project

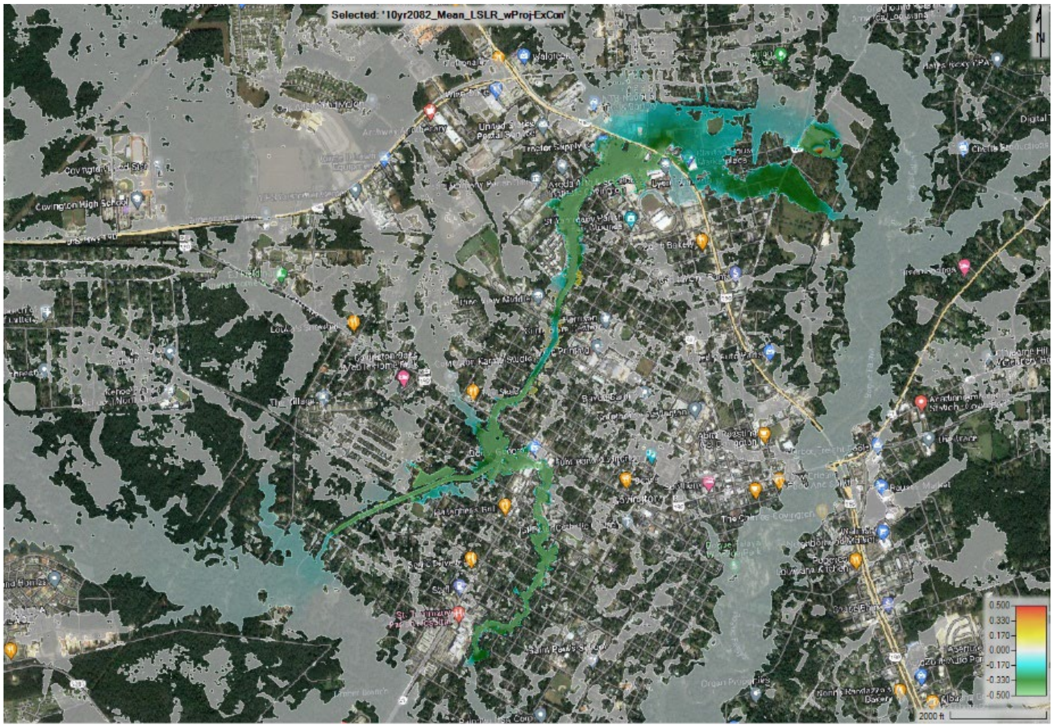


Figure E3:38. 10yr 2082 LSLR difference in WSE with project

Figure E3:39. 10-year 2032 ISLR difference in WSE with project

Figure E3:40. 10-yr 2082 ISLR difference in WSE with project

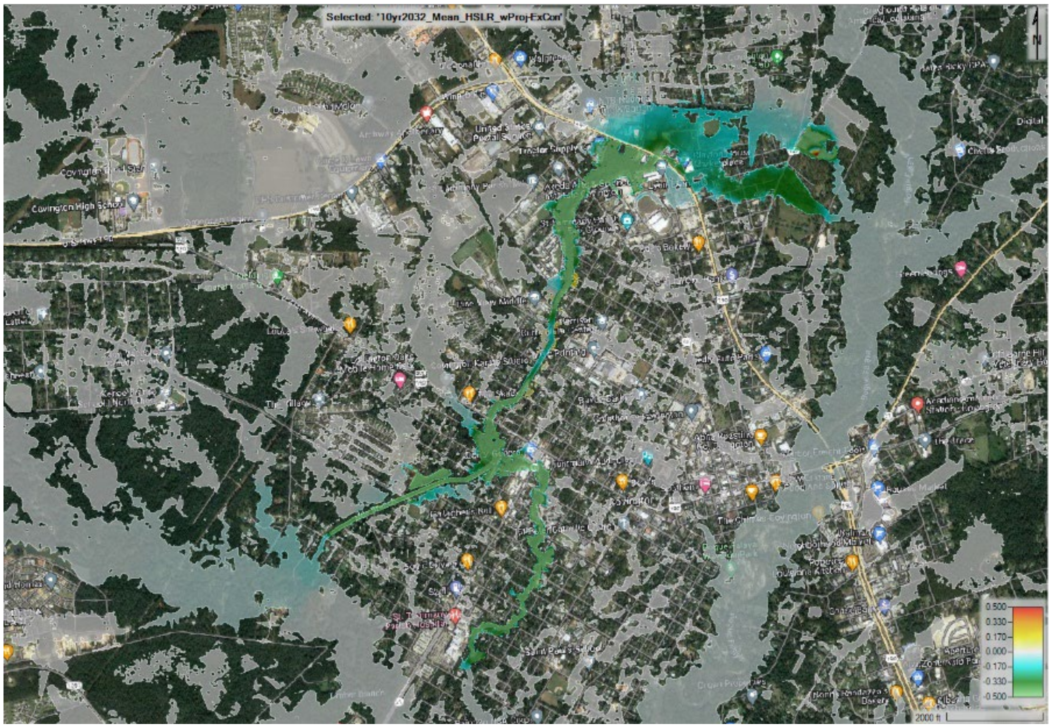


Figure E3:41. 10-year 2032 HSLR difference in WSE with project

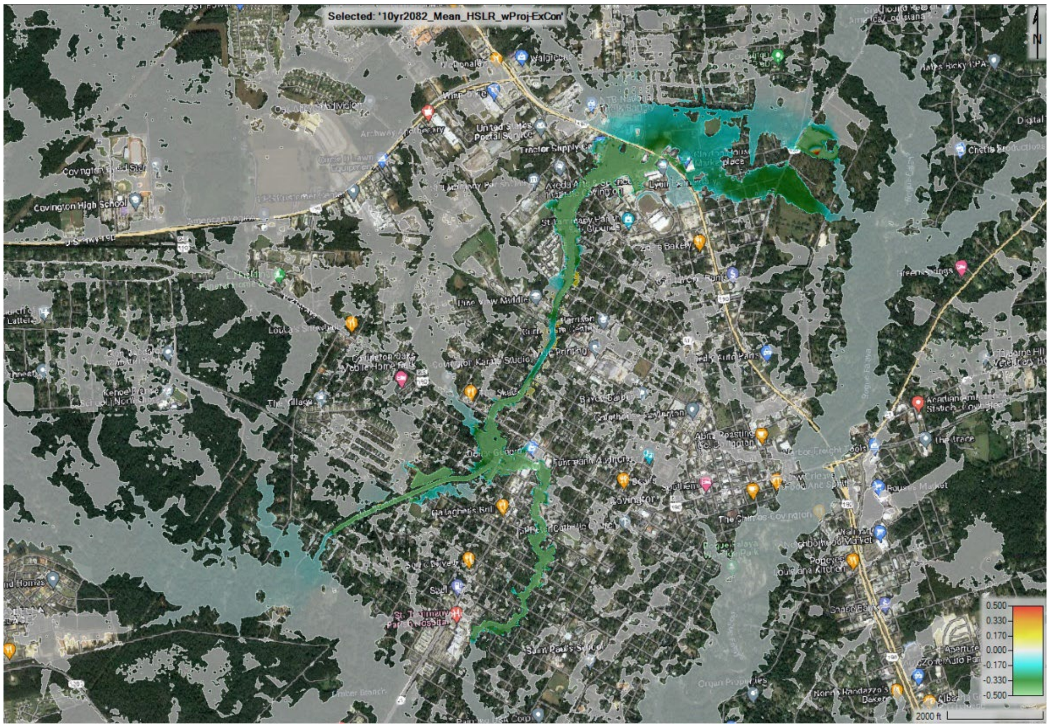


Figure E3:42. 10-year 2082 HSLR difference in WSE with project

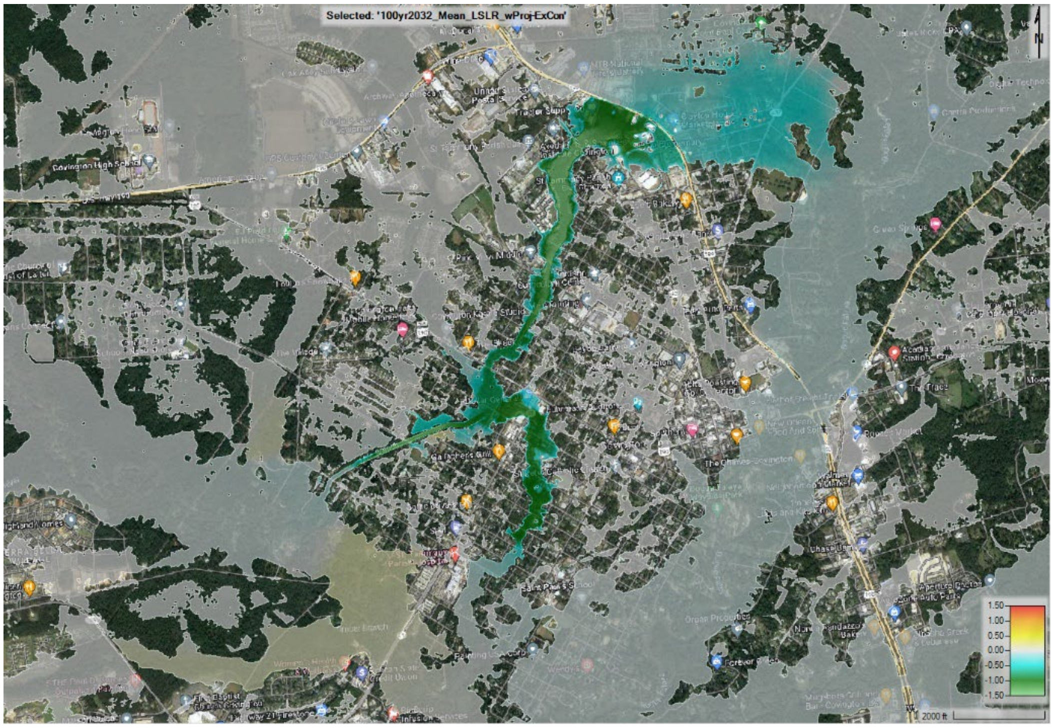


Figure E3:43. 100-year 2032 LSLR difference in WSE with project

Figure E3:44. 100-year 2082 LSLR difference in WSE with project

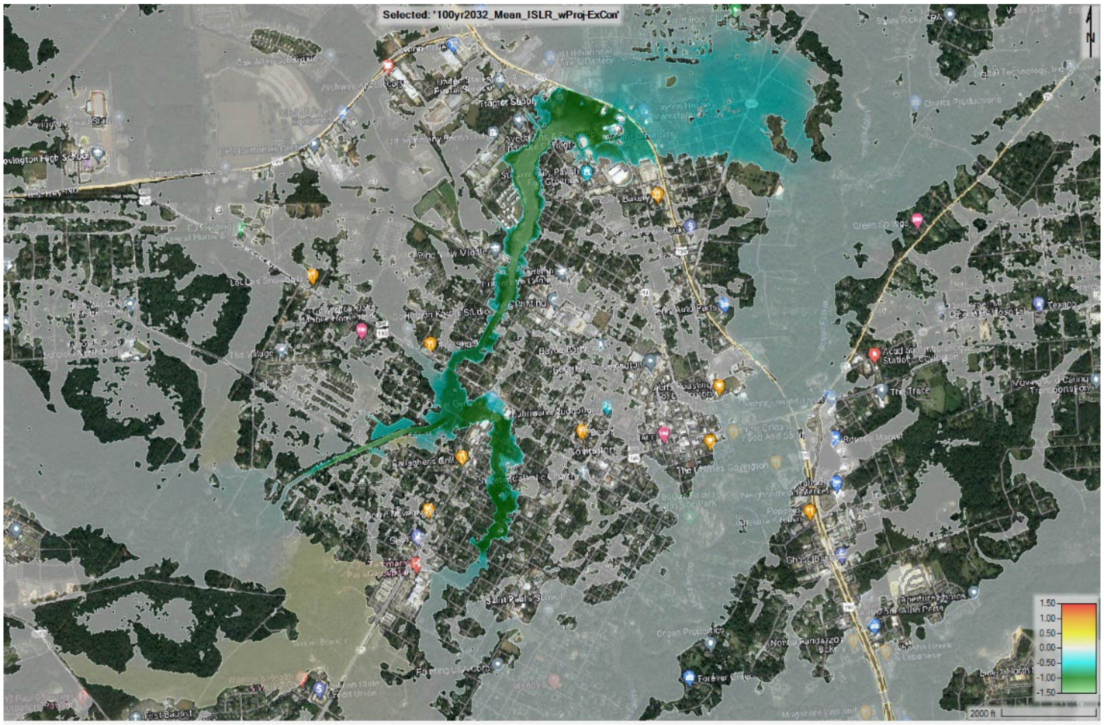


Figure E3:45. 100-year 2032 ISLR difference in WSE with project

Figure E3:46. 100-year 2082 ISLR difference in WSE with project

Figure E3:47. 100-year 2032 HSLR difference in WSE with project

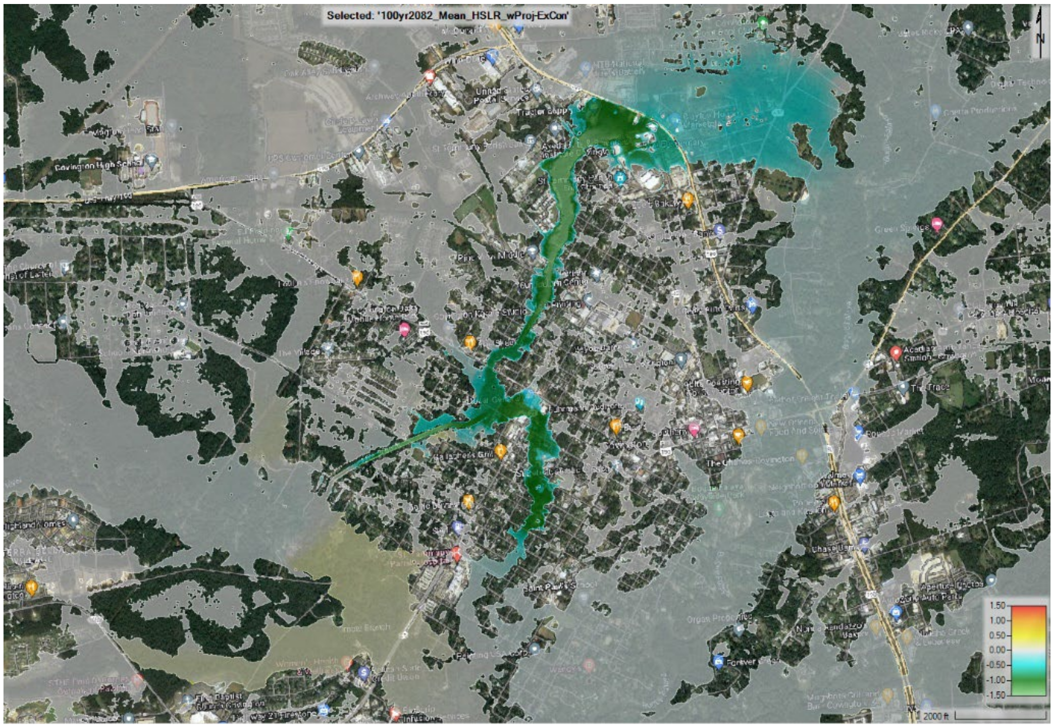


Figure E3:48. 100-year 2082 HSLR difference in WSE with project

SLR Comparison Difference Maps – Frequency Inflows East of Lacombe, Louisiana

Depicted in this section of the annex are difference maps for existing conditions and with-project runs showing the 10-year and 100-year, 2032 (baseline) and 2082 (future) results. The purpose of these difference maps is to depict the variance in WSE between the LSLR and HSLR rates and how that impacts the study area. Each run has coincident frequency precipitation and inflows from the Bogue Chitto and Pearl River. The difference grid takes the maximum WSE of the HSLR and subtracts the corresponding LSLR run for the frequencies listed above for the Existing Condition and With-Project scenarios.

Gray areas denote no change in WSE between the LSLR and HSLR runs. Red, orange, and warm toned colors denote a higher magnitude difference in WSE. Green, blue, and cool toned colors denote a smaller magnitude difference in WSE.

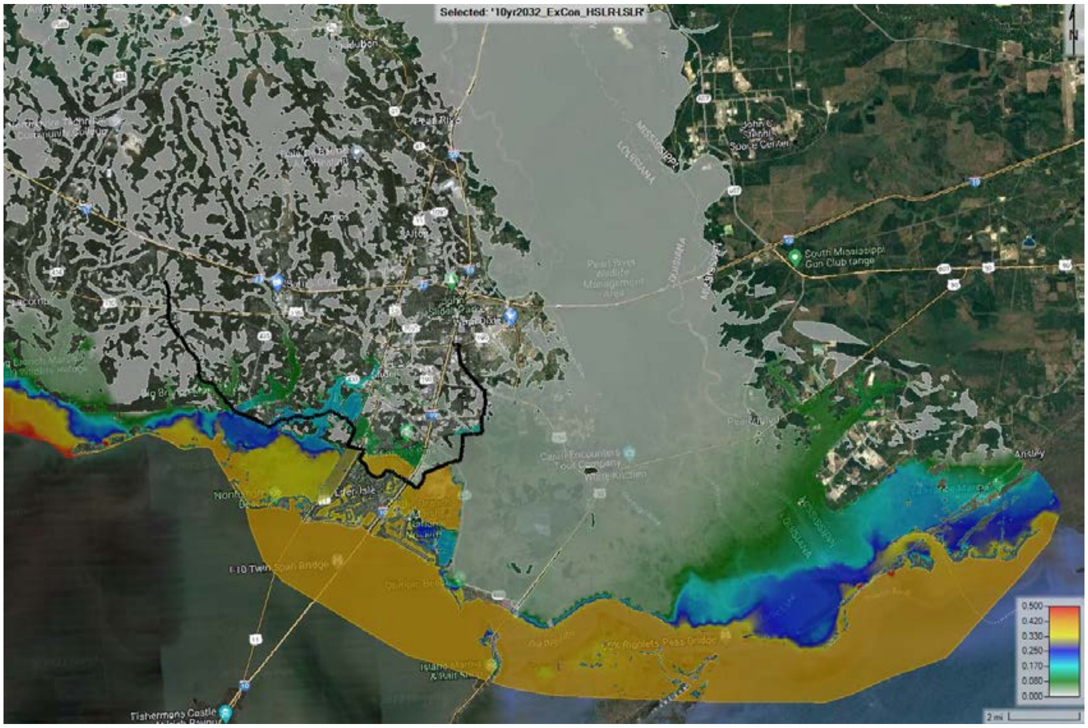


Figure E3:49. 10-year 2032 existing condition HSLR minus LSLR

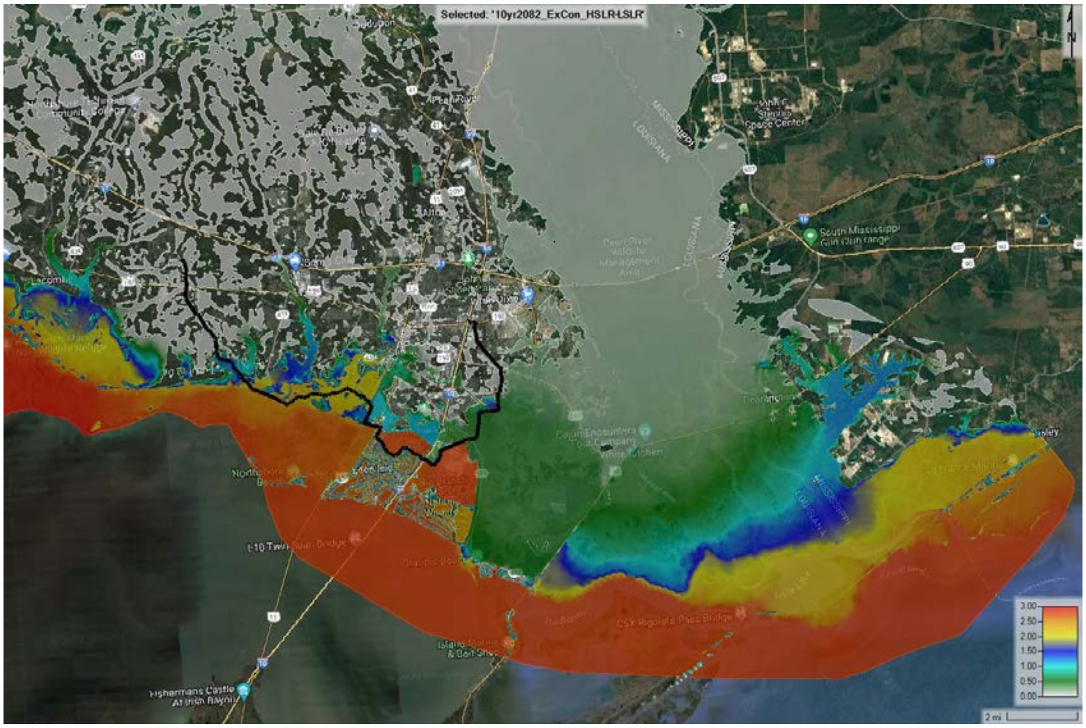


Figure E3:50. 10-year 2082 existing condition HSLR minus LSLR

Figure E3:51. 100-year 2032 existing condition HSLR minus LSLR

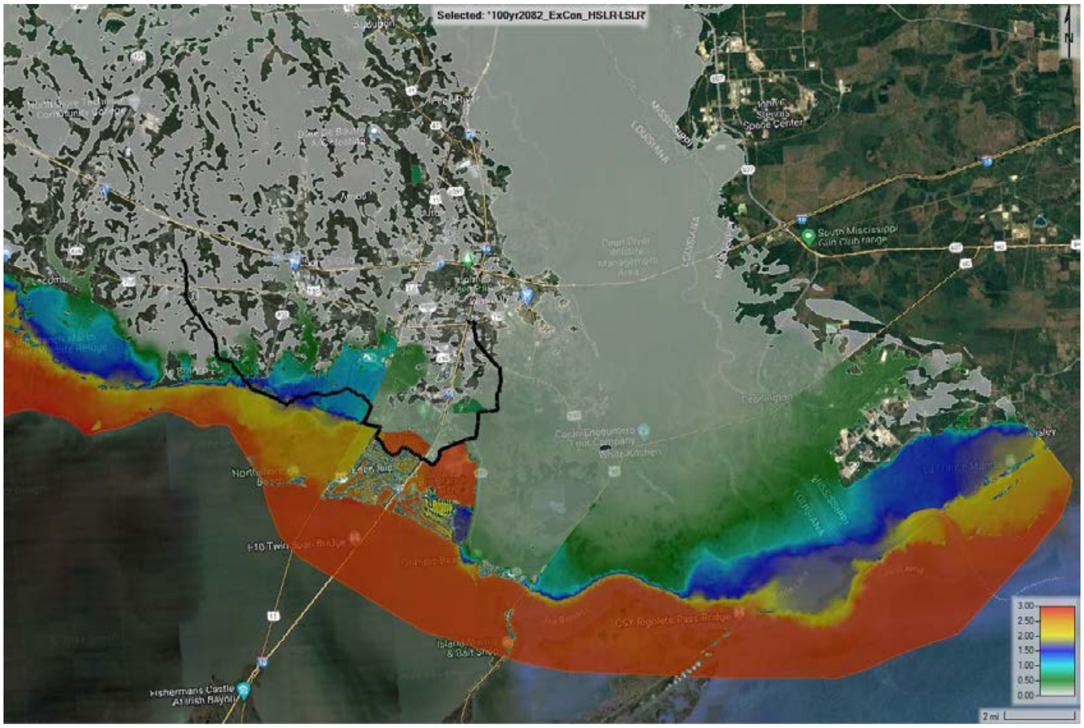


Figure E3:52. 100-year 2082 existing condition HSLR minus LSLR

Figure E3:53. 10-year 2032 with project HSLR minus LSLR

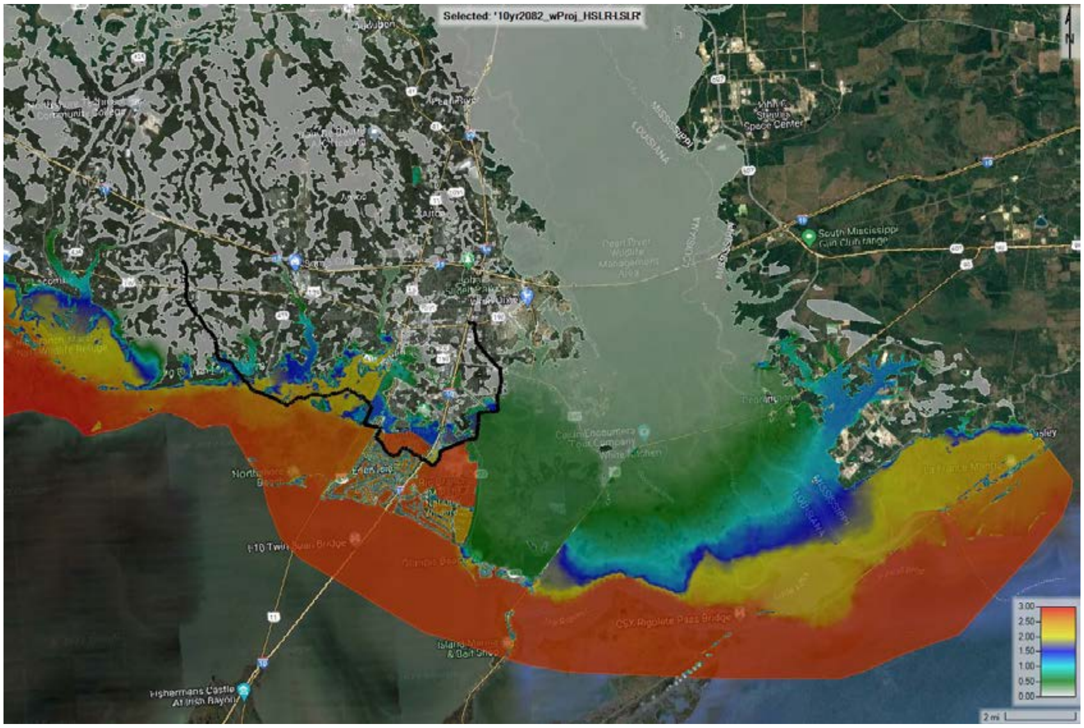


Figure E3:54. 10-year 2082 with-project HSLR minus LSLR

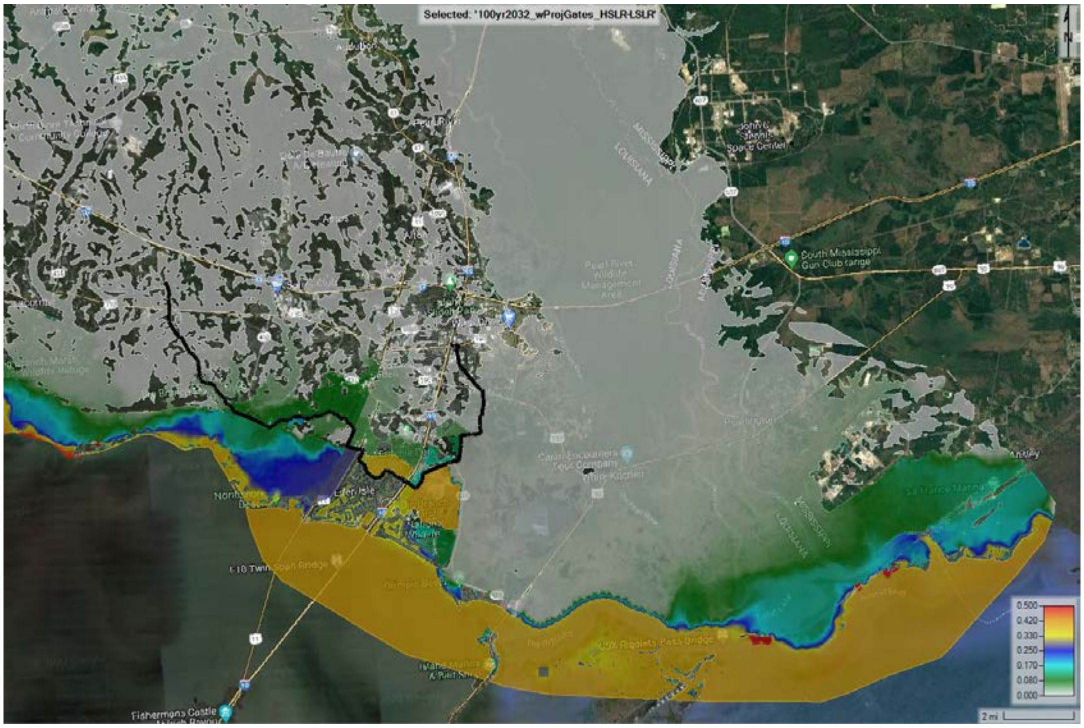


Figure E3:55. 100-year 2032 with-project HSLR minus LSLR

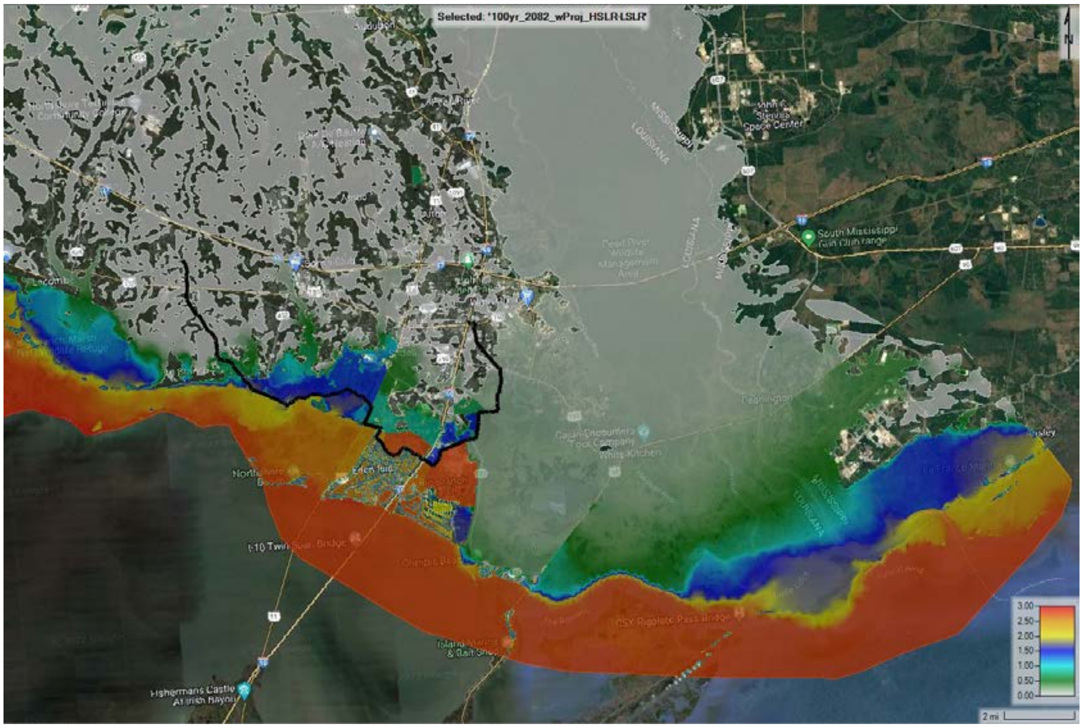


Figure E3:56. 100-year 2082 with-project HSLR minus LSLR

SLR Comparison Difference Maps – Frequency Inflows West of Lacombe, Louisiana

Depicted in this section of the annex are difference maps for existing conditions and with-project runs showing the 10-year and 100-year, 2032 (baseline) and 2082 (future) results. The purpose of these difference maps is to depict the variance in WSE between the LSLR and HSLR rates and how that impacts the study area. Each run has coincident frequency precipitation and inflows from the Bogue Chitto and Pearl River. The difference grid takes the maximum WSE of the HSLR and subtracts the corresponding LSLR run for the frequencies listed above for the existing condition and with-project scenarios.

Gray areas denote no change in WSE between the LSLR and HSLR runs. Red, orange, and warm toned colors denote a higher magnitude difference in WSE. Green, blue, and cool toned colors denote a smaller magnitude difference in WSE.

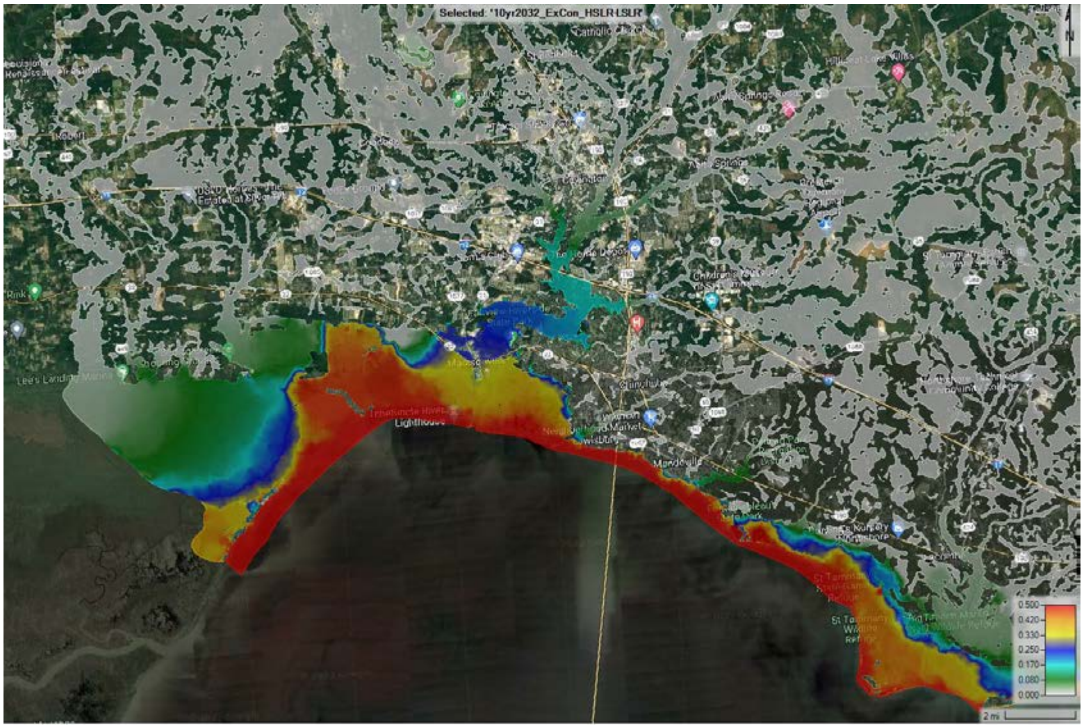


Figure E3:57. 10-year 2032 existing condition HSLR minus LSLR

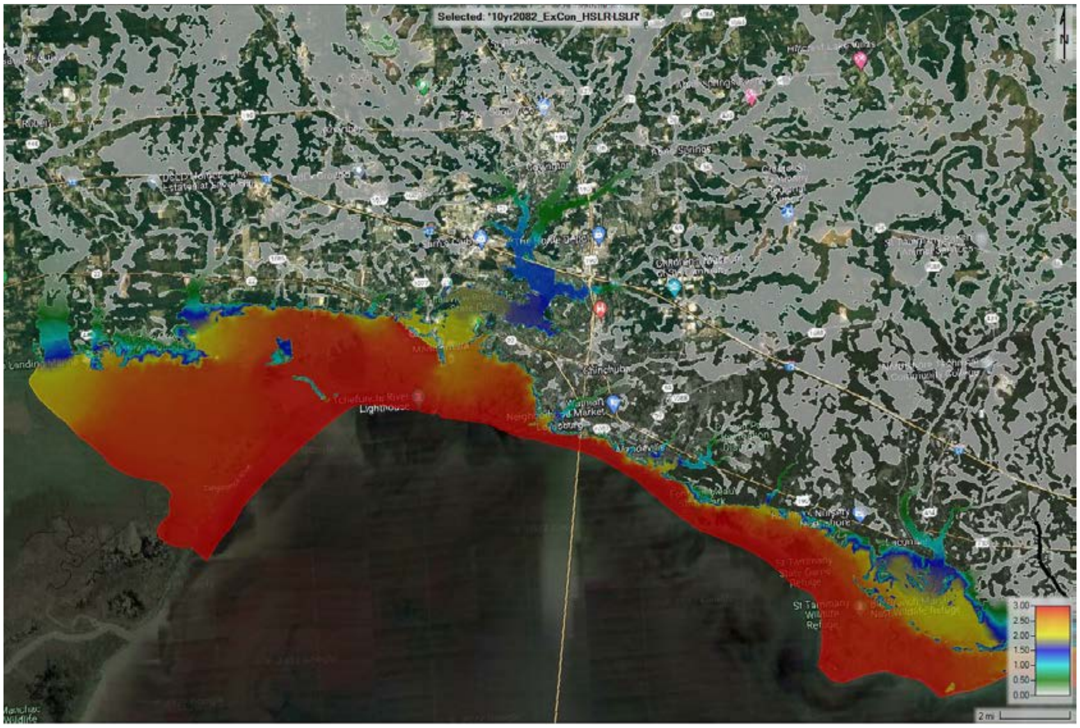


Figure E3:58. 10-year 2082 existing condition HSLR minus LSLR

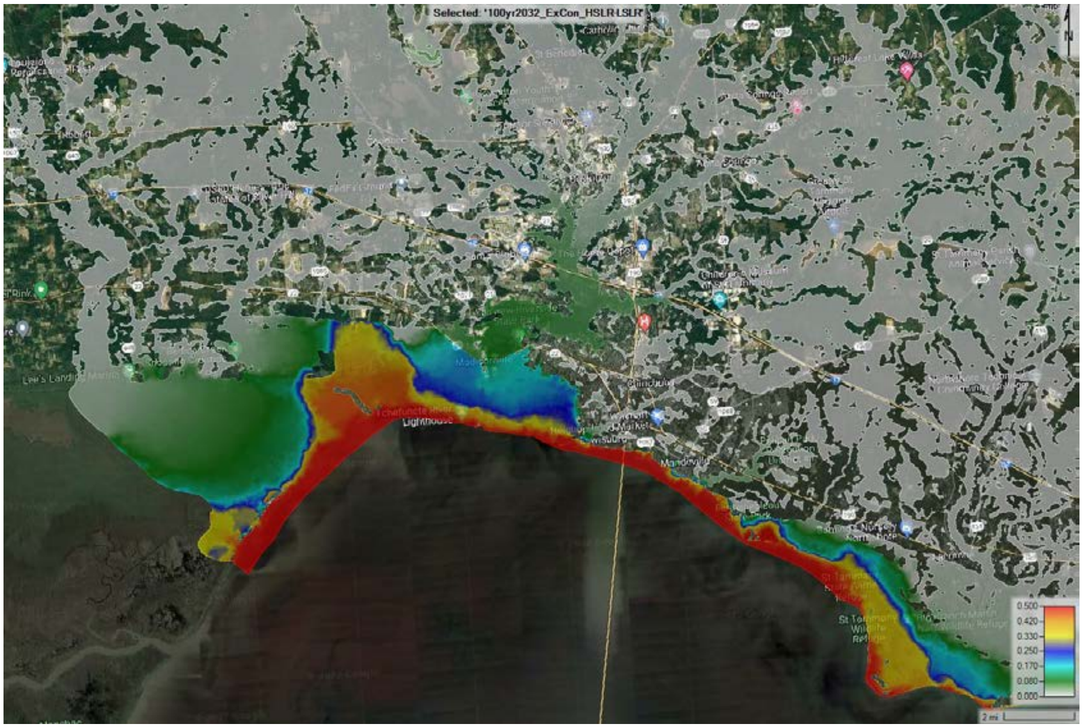


Figure E3:59. 100-year 2032 existing condition HSLR minus LSLR

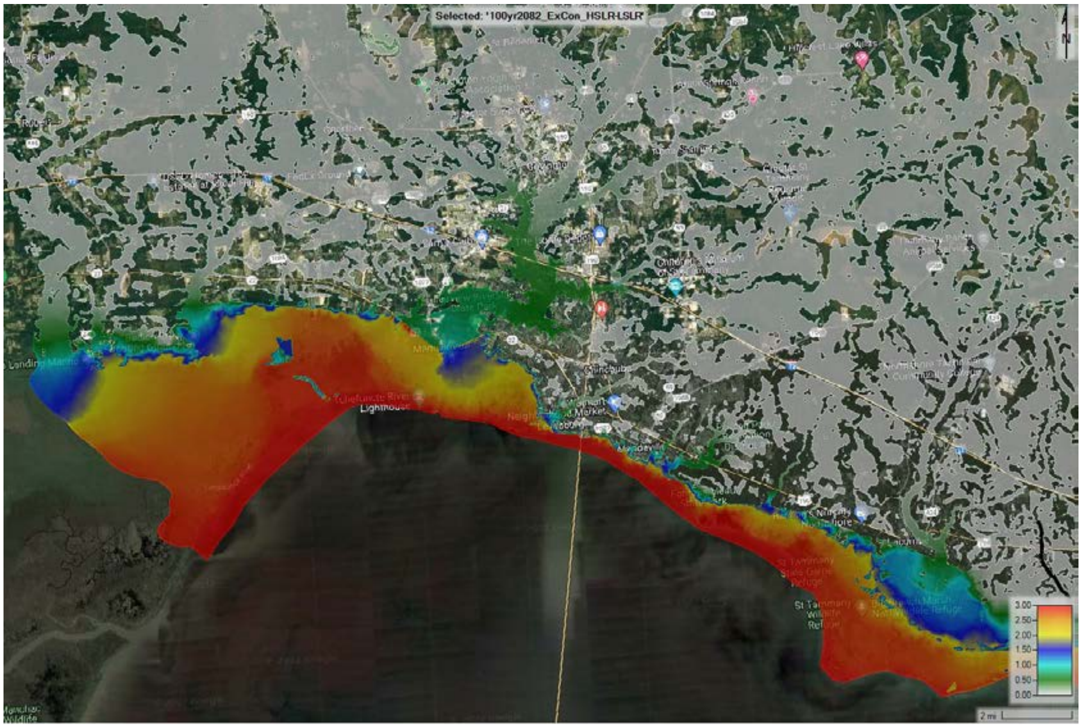


Figure E3:60. 100-year 2082 existing condition HSLR minus LSLR

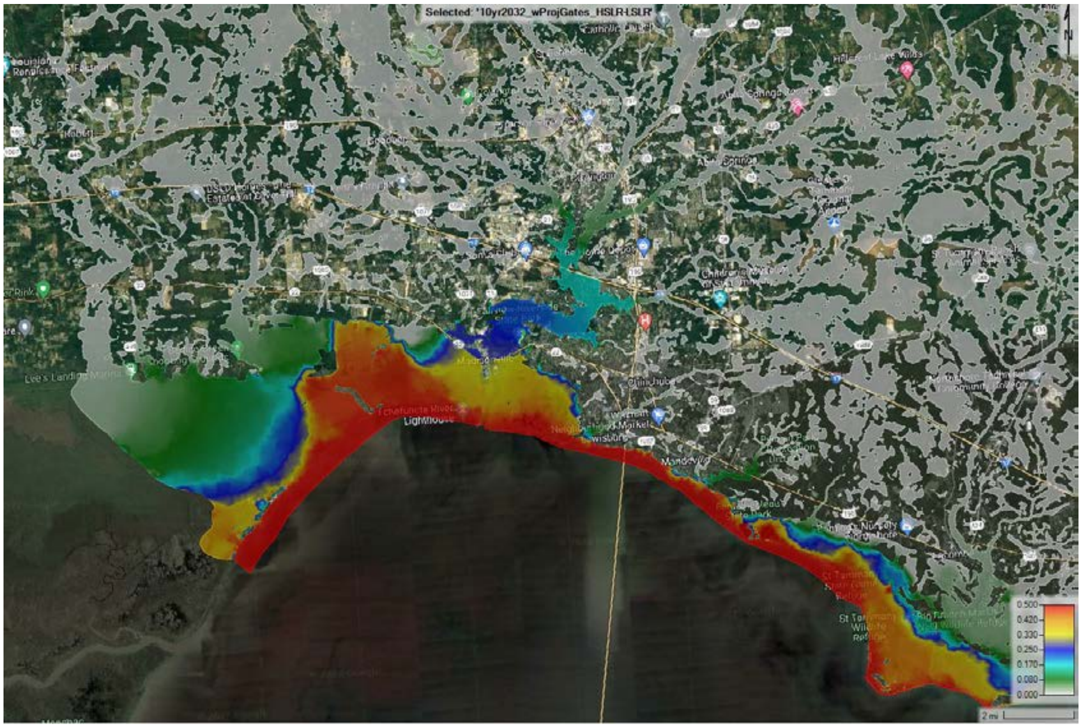


Figure E3:61. 10-year 2032 with-project HSLR minus LSLR

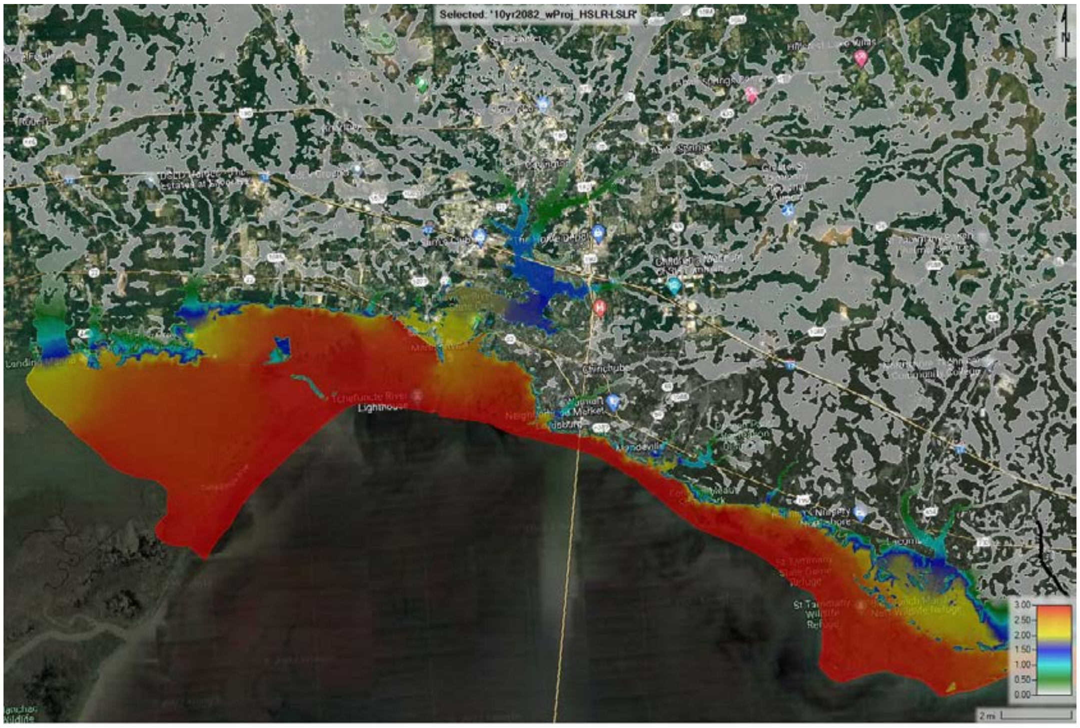


Figure E3:62. 10-year 2082 with-project HSLR minus LSLR

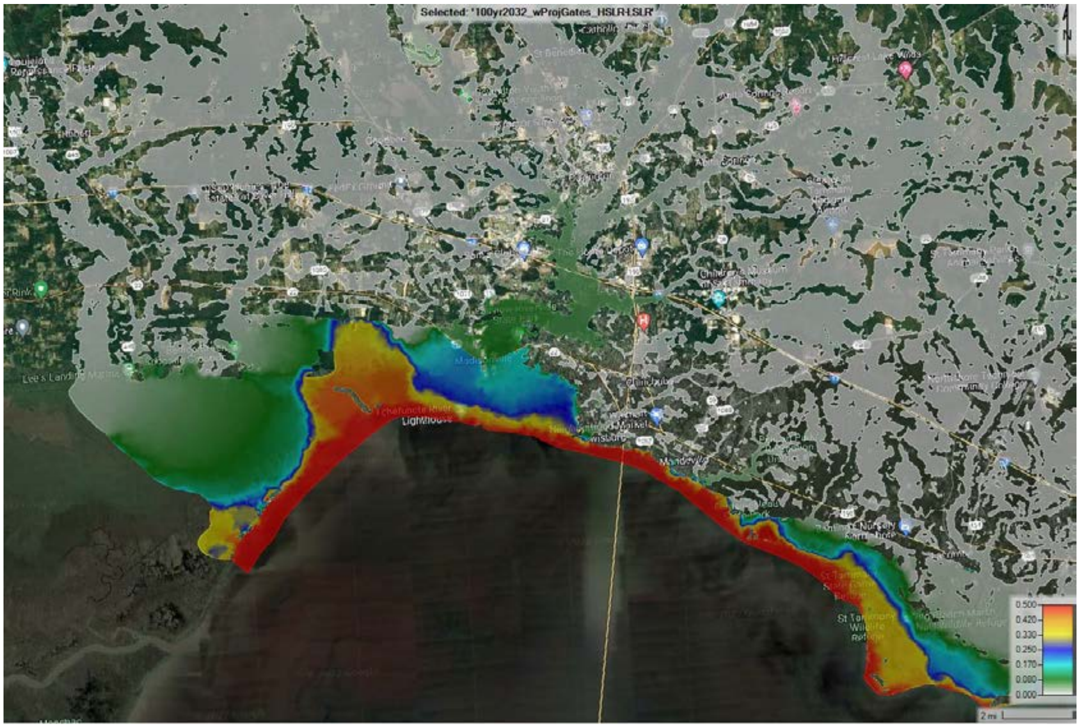


Figure E3:63. 100-year 2032 with-project HSLR minus LSLR

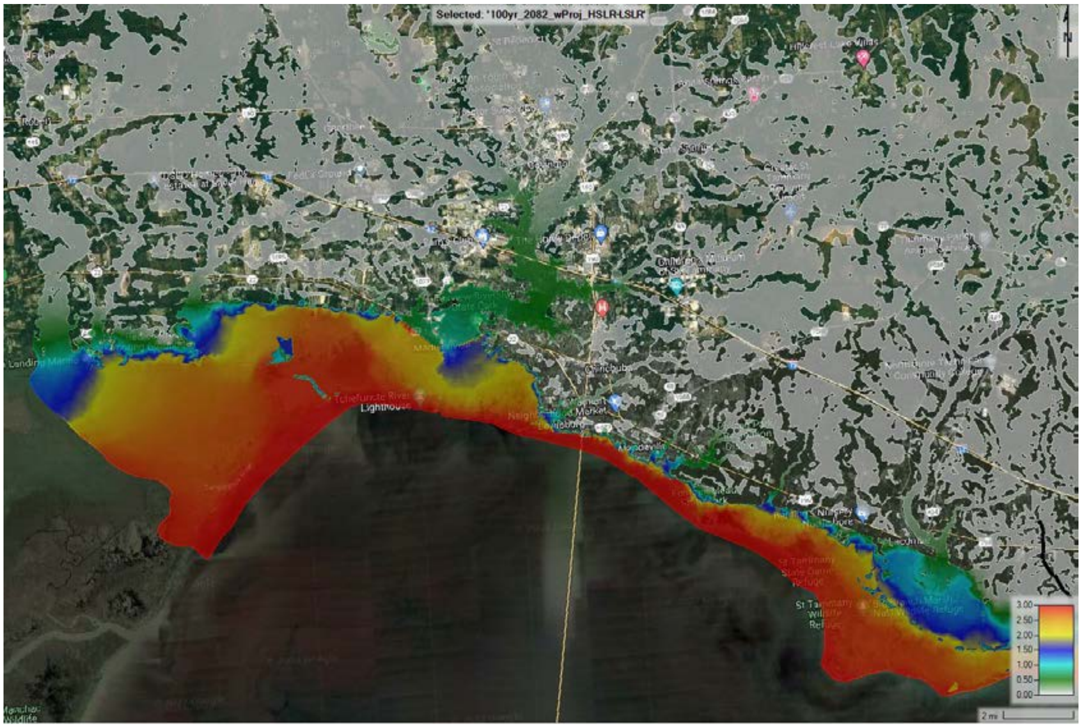


Figure E3:64. 100-year 2082 with-project HSLR minus LSLR

SLR Comparison Difference Maps – Mean Inflows East of Lacombe, Louisiana

Depicted in this section of the annex are difference maps for existing conditions and with-project runs showing the 10yr and 100-year, 2032 (baseline) and 2082 (future) results. The purpose of these difference maps is to depict the variance in WSE between the LSLR and HSLR rates and how that impacts the study area. Each run has historic mean inflows from the Bogue Chitto and Pearl River as inflow boundary conditions. The difference grid takes the maximum WSE of the HSLR and subtracts the corresponding LSLR run for the frequencies listed above for the Existing Condition and With-Project scenarios.

Gray areas denote no change in WSE between the LSLR and HSLR runs. Red, orange, and warm toned colors denote a higher magnitude difference in WSE. Green, blue, and cool toned colors denote a smaller magnitude difference in WSE.

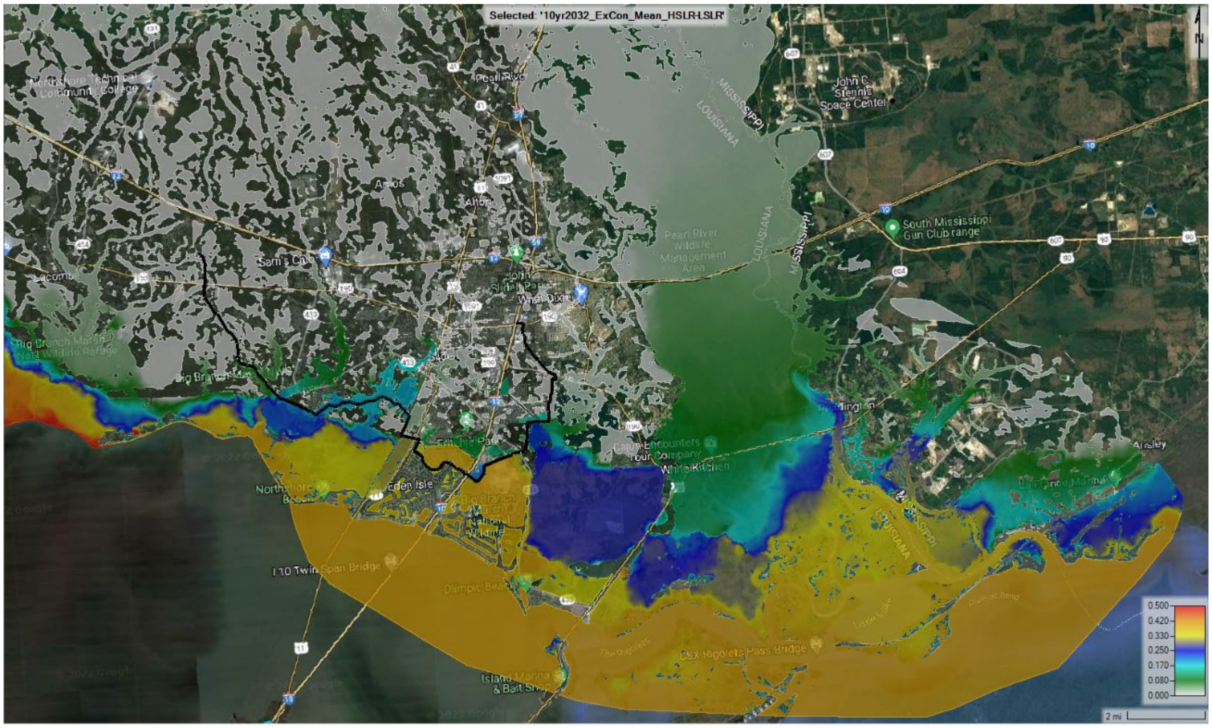


Figure E3:65. 10-year 2032 existing condition HSLR minus LSLR

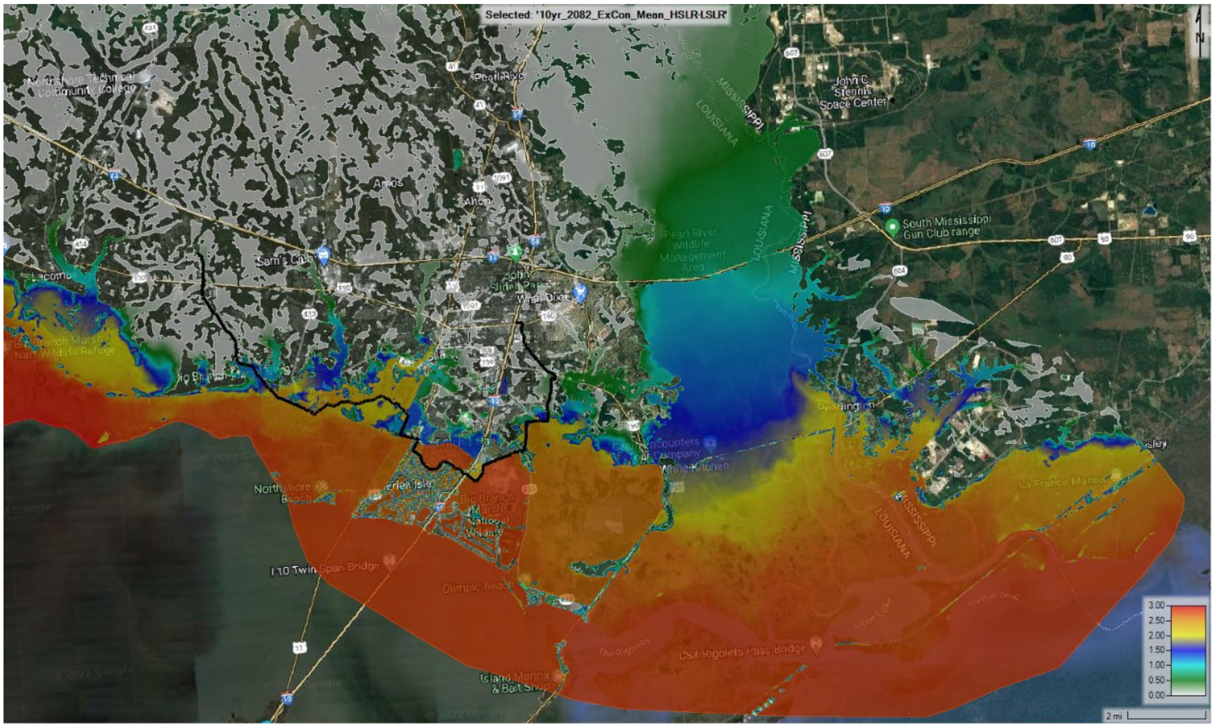


Figure E3:66. 10-year 2082 existing condition HSLR minus LSLR

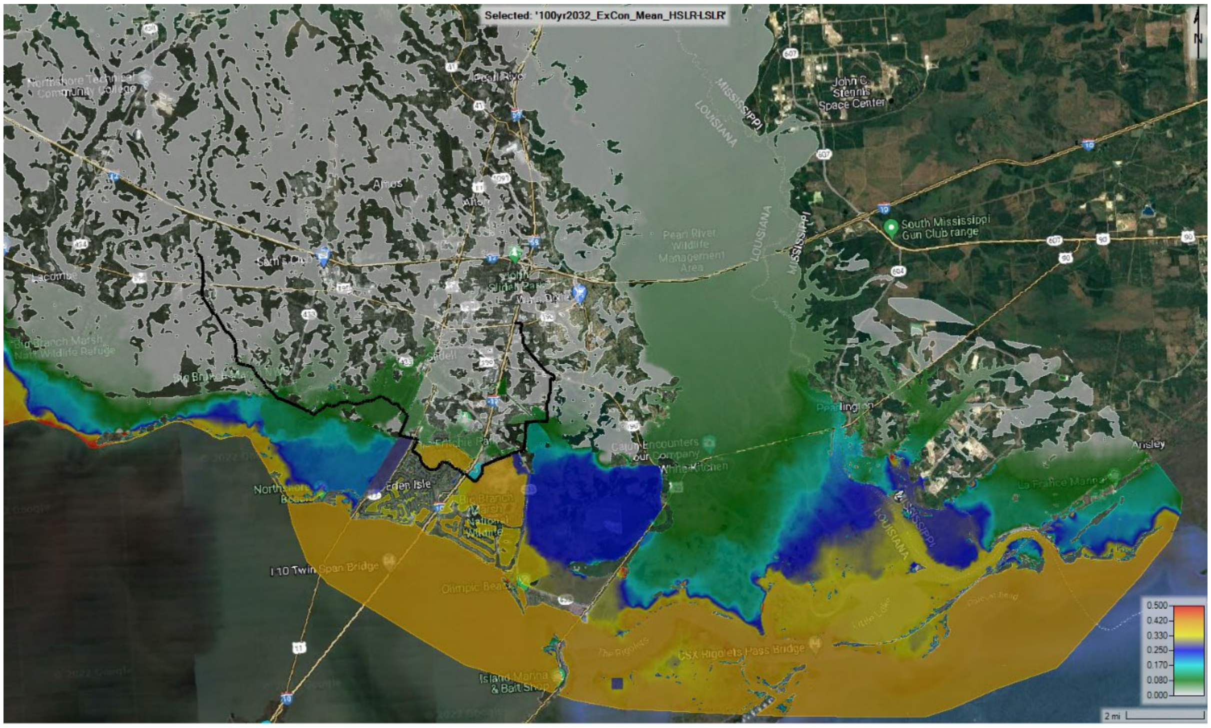


Figure E3:67. 100-year 2032 existing condition HSLR minus LSLR

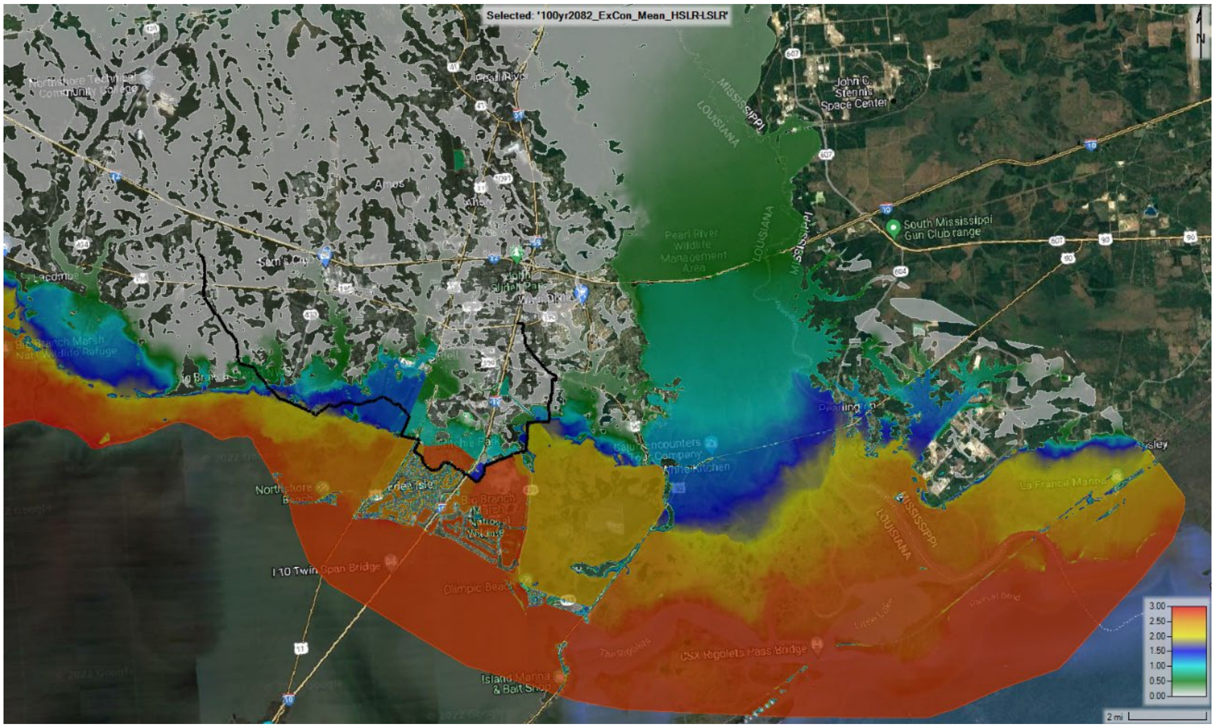


Figure E3:68. 100-year 2082 existing condition HSLR minus LSLR

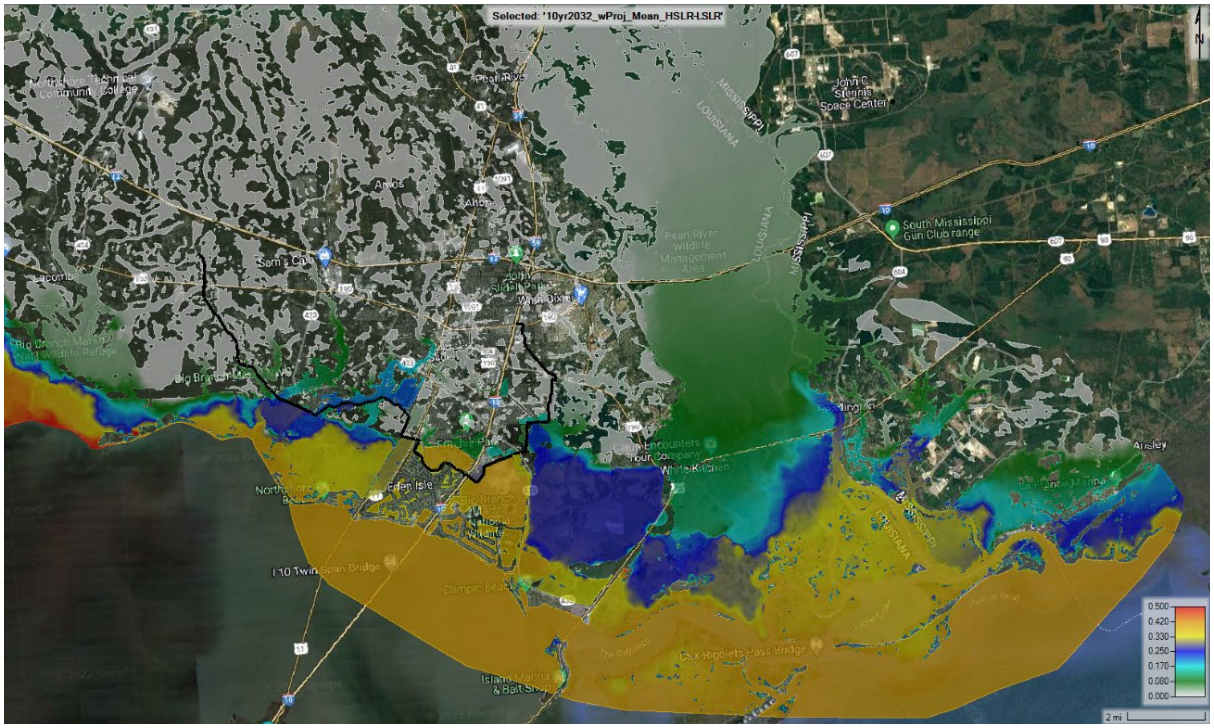


Figure E3:69. 10-year 2032 with-project HSLR minus LSLR

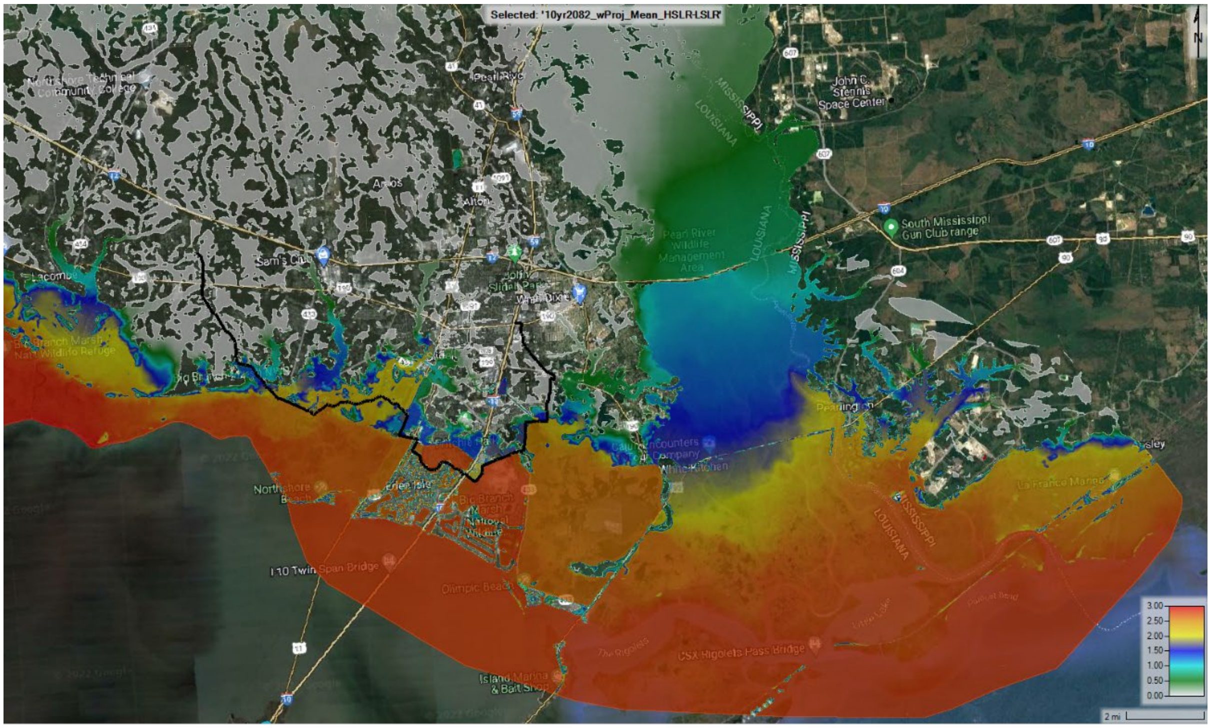


Figure E3:70. 10-year 2082 with-project HSLR minus LSLR

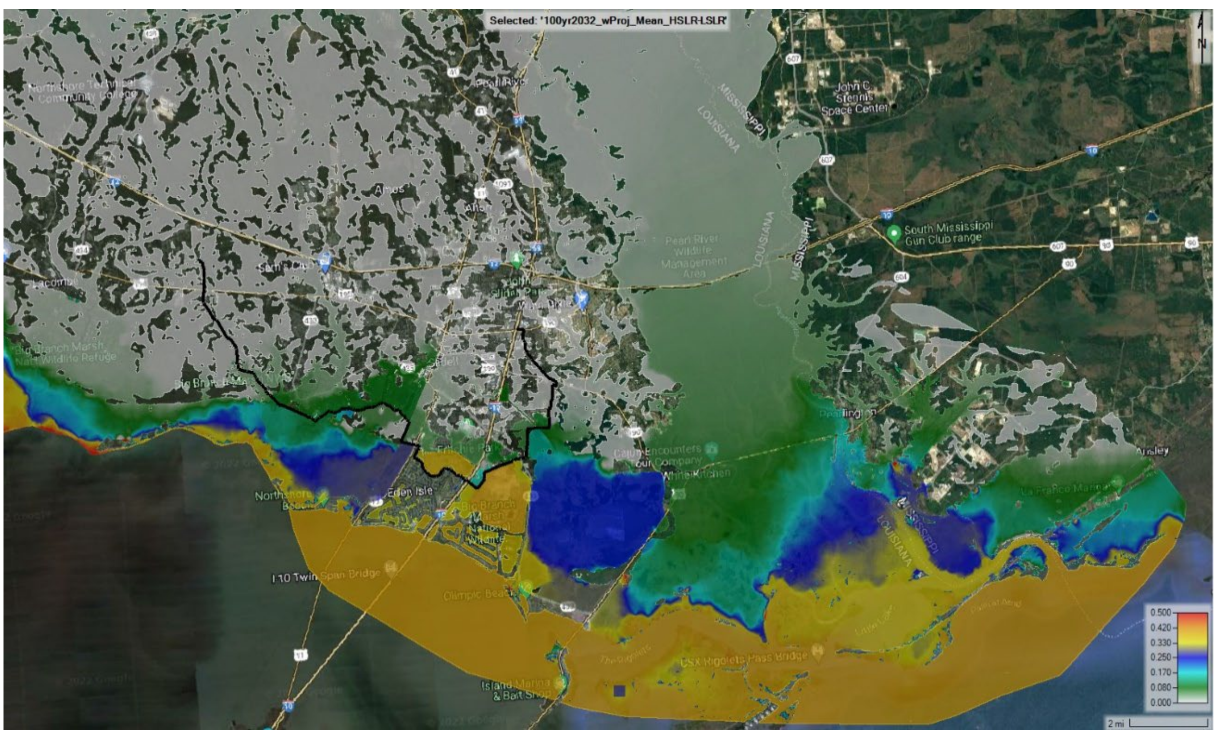


Figure E3:71. 100-year 2032 with-project HSLR minus LSLR

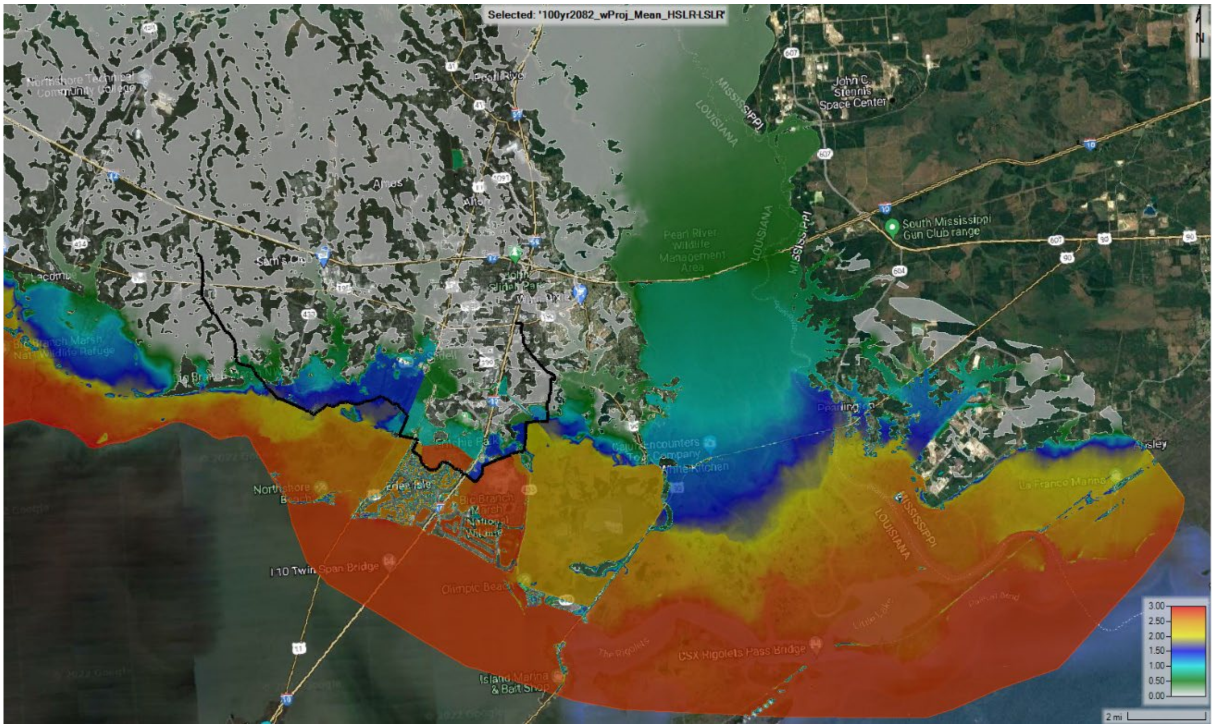


Figure E3:72. 100-year 2082 with-project HSLR minus LSLR

SLR Comparison Difference Maps – Mean Inflows West of Lacombe, Louisiana

Depicted in this section of the annex are difference maps for existing conditions and with-project runs showing the 10-year and 100-year, 2032 (baseline) and 2082 (future) results. The purpose of these difference maps is to depict the variance in WSE between the LSLR and HSLR rates and how that impacts the study area. Each run has historic mean inflows from the Bogue Chitto and Pearl River as inflow boundary conditions. The difference grid takes the maximum WSE of the HSLR and subtracts the corresponding LSLR run for the frequencies listed above for the existing condition and with-project scenarios.

Gray areas denote no change in WSE between the LSLR and HSLR runs. Red, orange, and warm toned colors denote a higher magnitude difference in WSE. Green, blue, and cool toned colors denote a smaller magnitude difference in WSE.

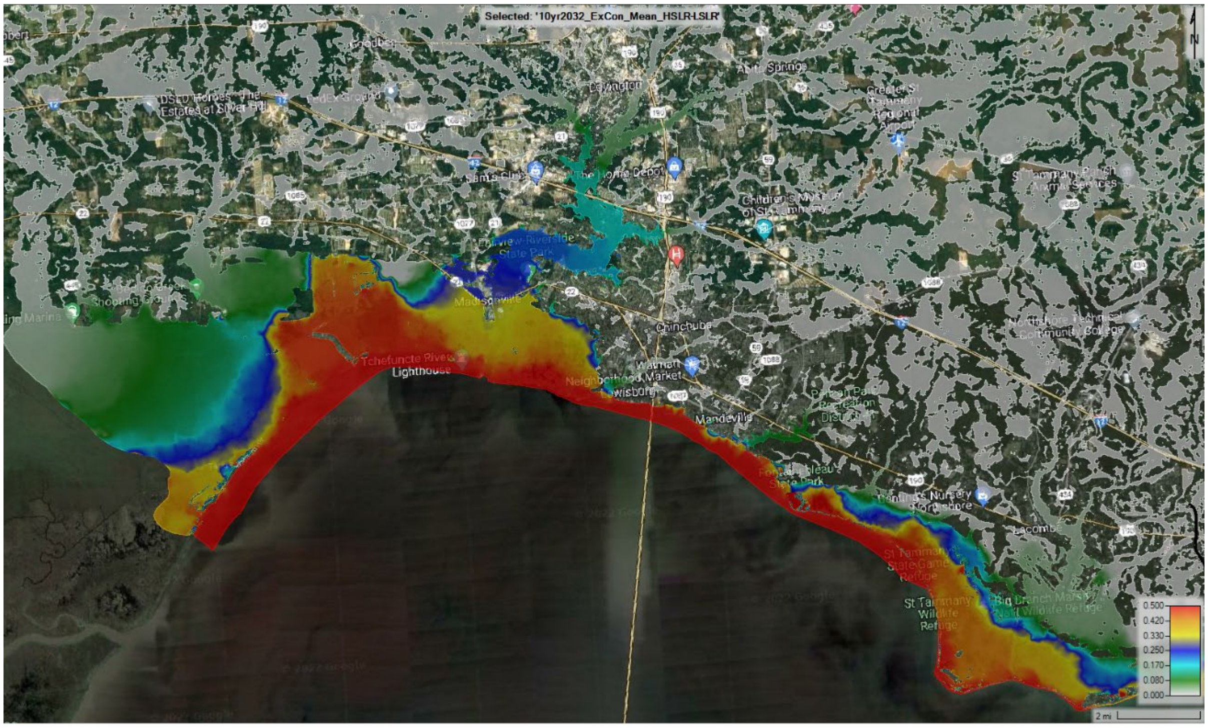


Figure E3:73. 10-year 2032 existing condition HSLR minus LSLR

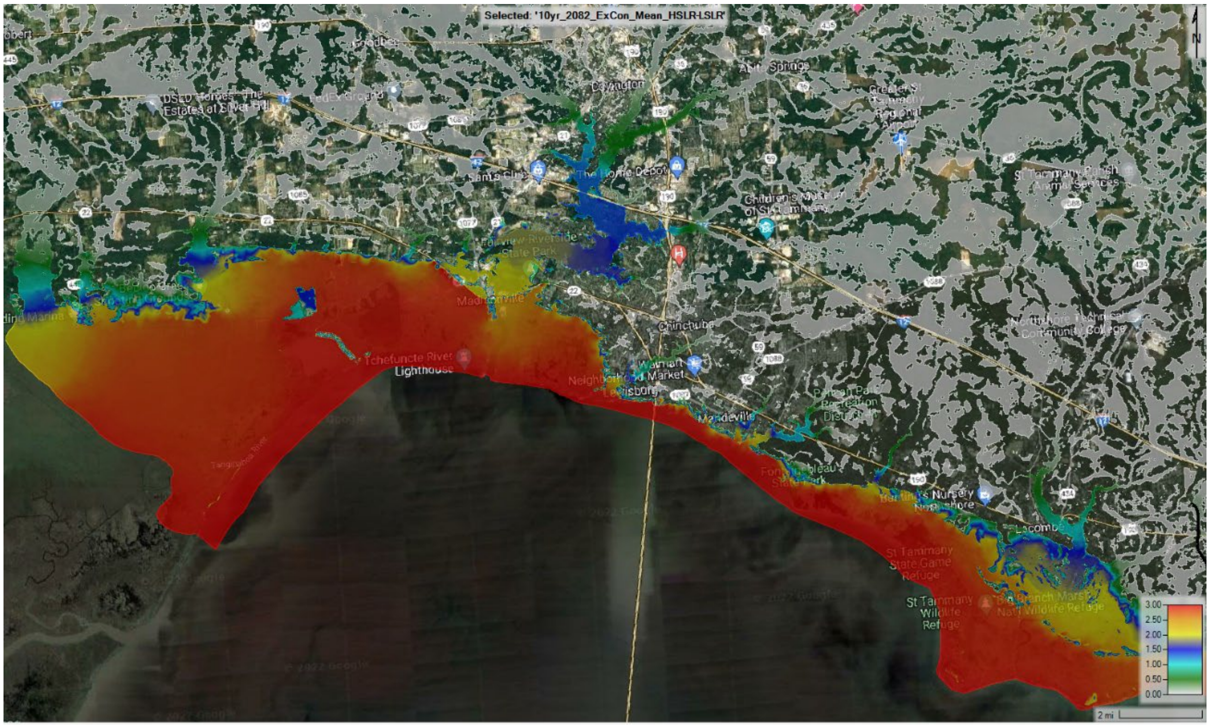


Figure E3:74. 10-year 2082 existing condition HSLR minus LSLR

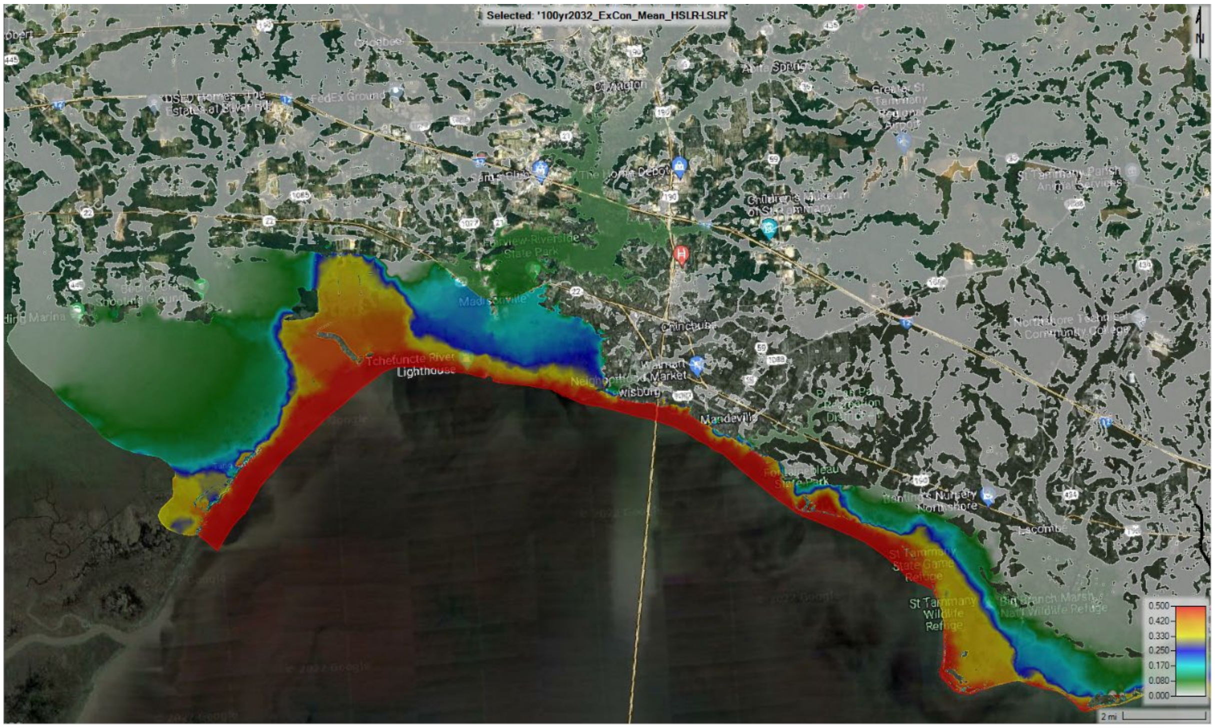


Figure E3:75. 100-year 2032 existing condition HSLR minus LSLR

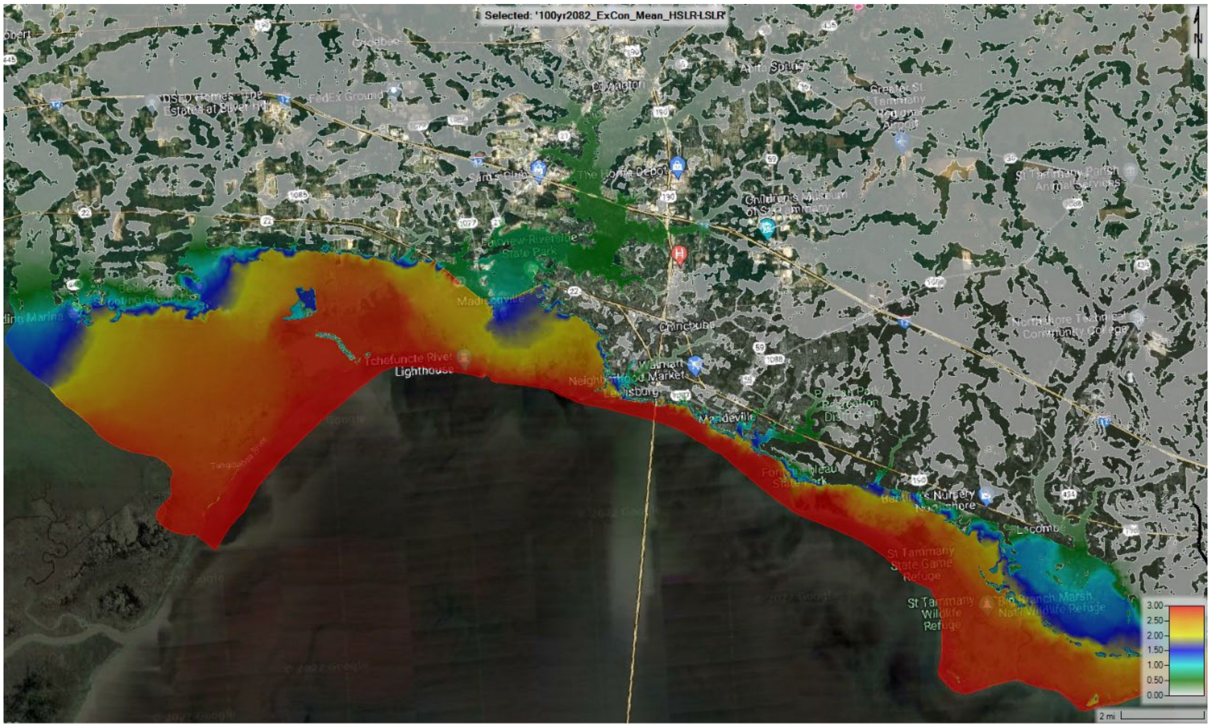


Figure E3:76. 100-year 2082 existing condition HSLR minus LSLR

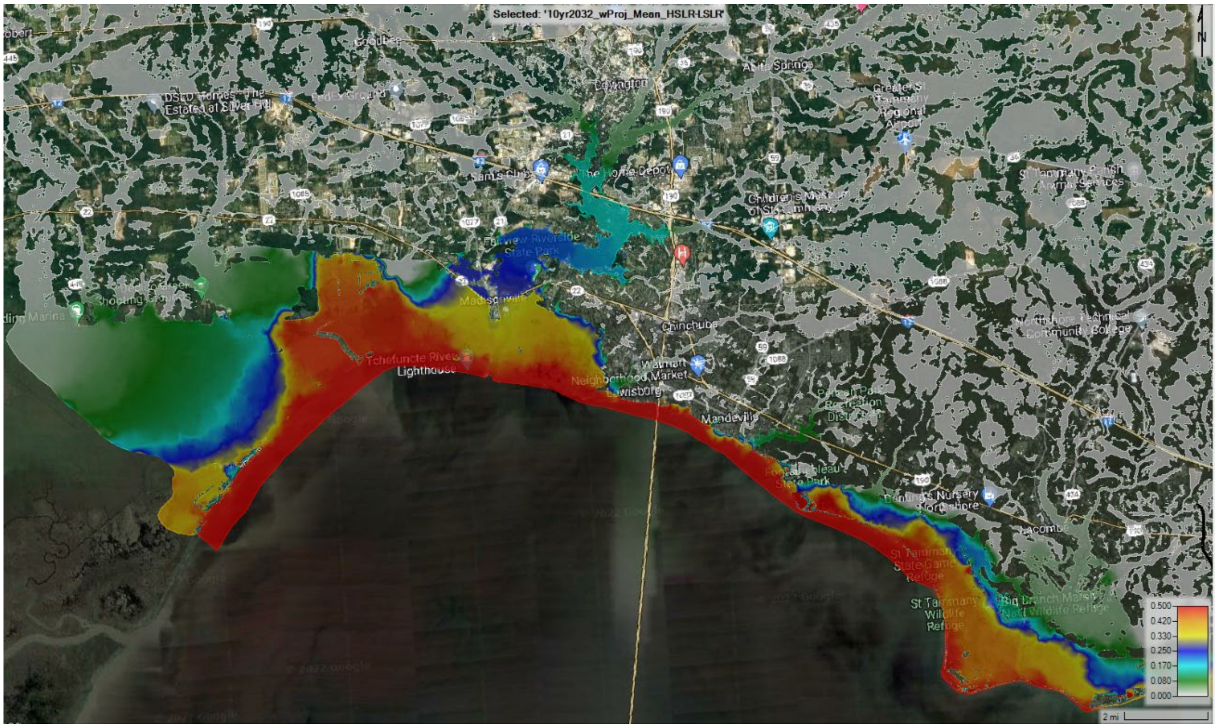


Figure E3:77. 10-year 2032 with-project HSLR minus LSLR

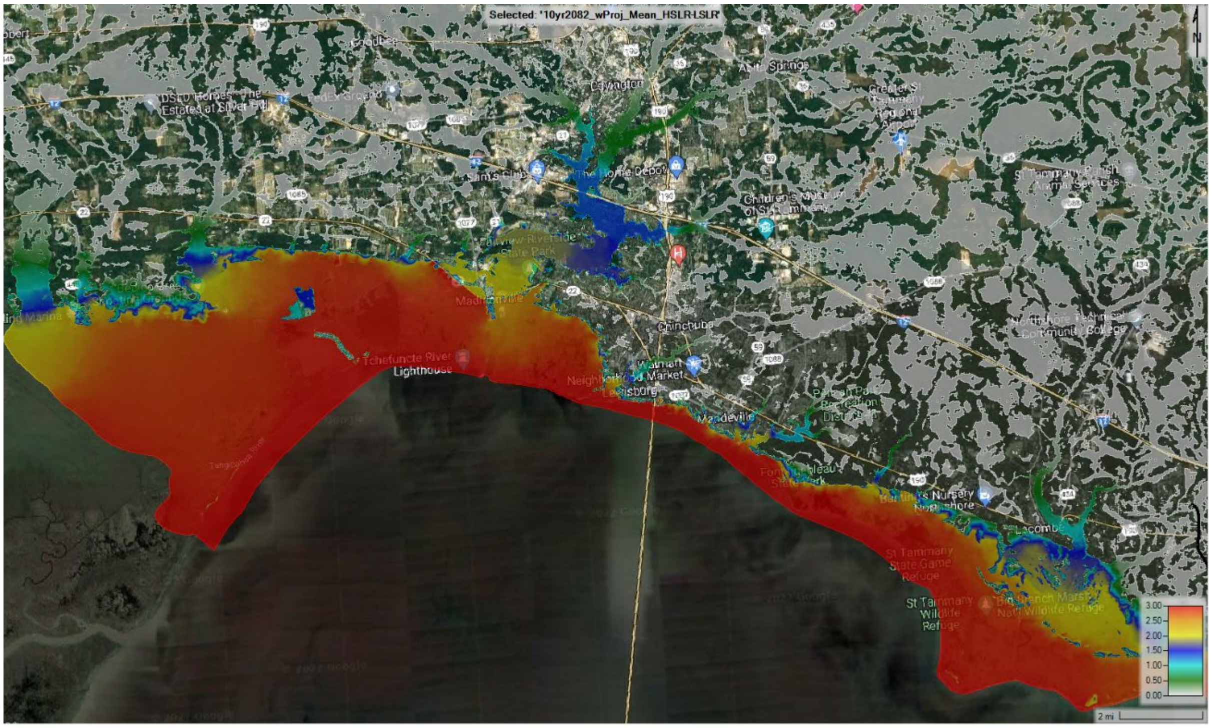


Figure E3:78. 10-year 2082 with-project HSLR minus LSLR

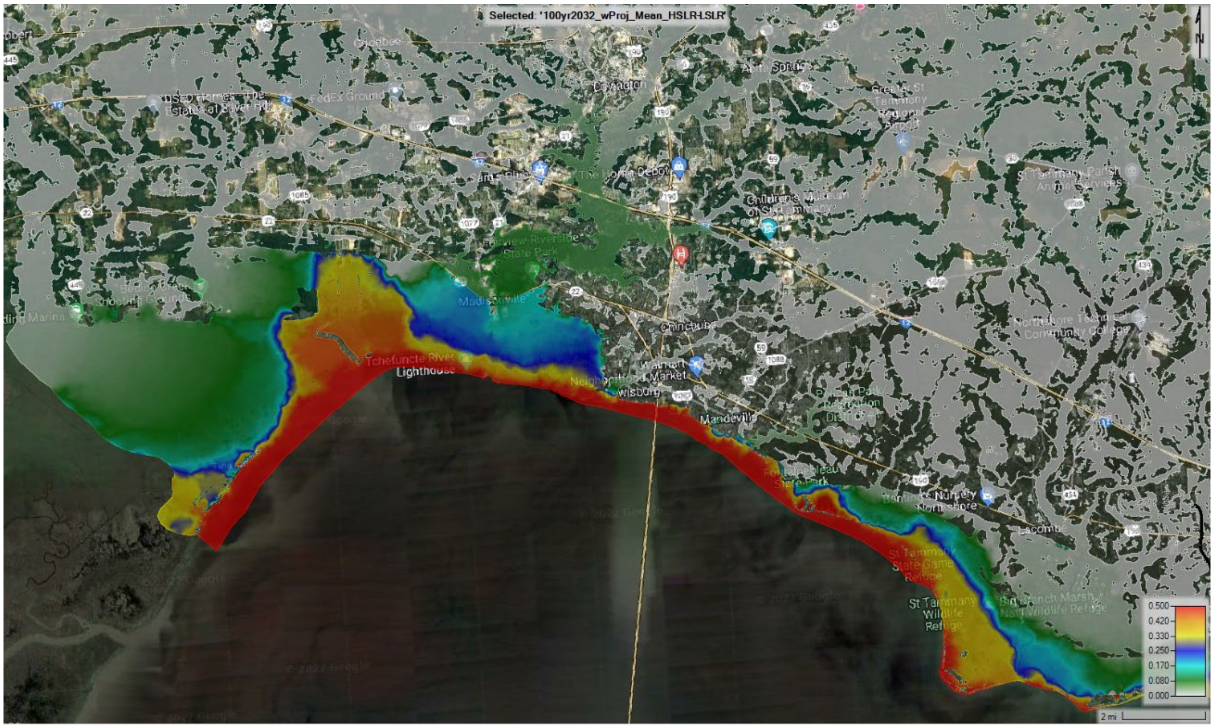


Figure E3:79. 100-year 2032 with-project HSLR minus LSLR

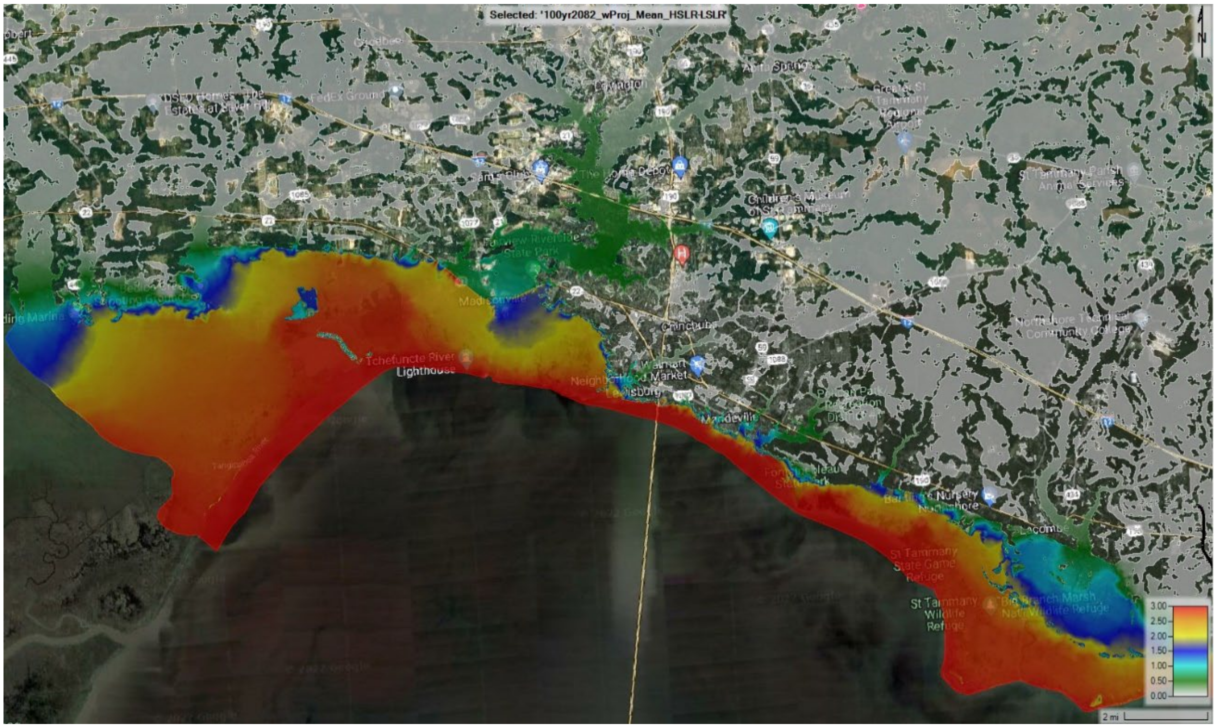


Figure E3:80. 100-year 2082 with-project HSLR minus LSLR

Annex E-4-RP Calibration Summary

Enclosed is a summary of calibration plots depicting hydrographs comparing modeled and observed water levels. Additionally, the below table summarizes the recorded gage peak for the two calibration events used in this modeling effort – September 2011 and March 2016 rain events – and denotes the difference between maximum WSE in the simulated gage peak at each gage location. A full description of the calibration effort can be reviewed in Section 12.6 of this Appendix.

Table E4:1. Tabulated Peak WSE Comparisons

	Tabulated Peak WSE Comparison (ft)									
	Bogue Falaya River		**Tchefuncte River**			**Abita River**	**Bayou Liberty**	**Pearl River**		**Bogue Chitto River**
	Boston Street, LA	**Camp Covington, LA**	**Folsom, LA**	**Covington, LA**	**Madisonville, LA**	**Abita Springs, LA**	**Slidell, LA**	**Pearl River, LA**	**Bogalusa, LA**	**Bush, LA**
Gage Peak 2011	**7.63**	**46.61**	**78.42**	**24.62**	**No Data**	**No Data**	**5.46**	**13.9**	**74.31**	**56.76**
Simulation Peak	9.32	48.46	79.47	24.96	NA	NA	5.48	15.41	62.13	56.87
Δ	*1.69*	*1.85*	*1.05*	*0.34*	NA	NA	*0.02*	*1.51*	*12.18*	*0.11*
Gage Peak 2016	**18.93**	**61.14**	**86.38**	**31.19**	**3.1**	**20.27**	**4.2**	**19.72**	**77.35**	**64.66**
Simulation Peak	17.64	58.08	84.63	30.07	4.44	20.42	3.37	19.08	65.63	61.44
Δ	*1.29*	*3.06*	*1.75*	*1.12*	*1.34*	*0.15*	*0.83*	*0.64*	*11.72*	*3.22*

September 2011

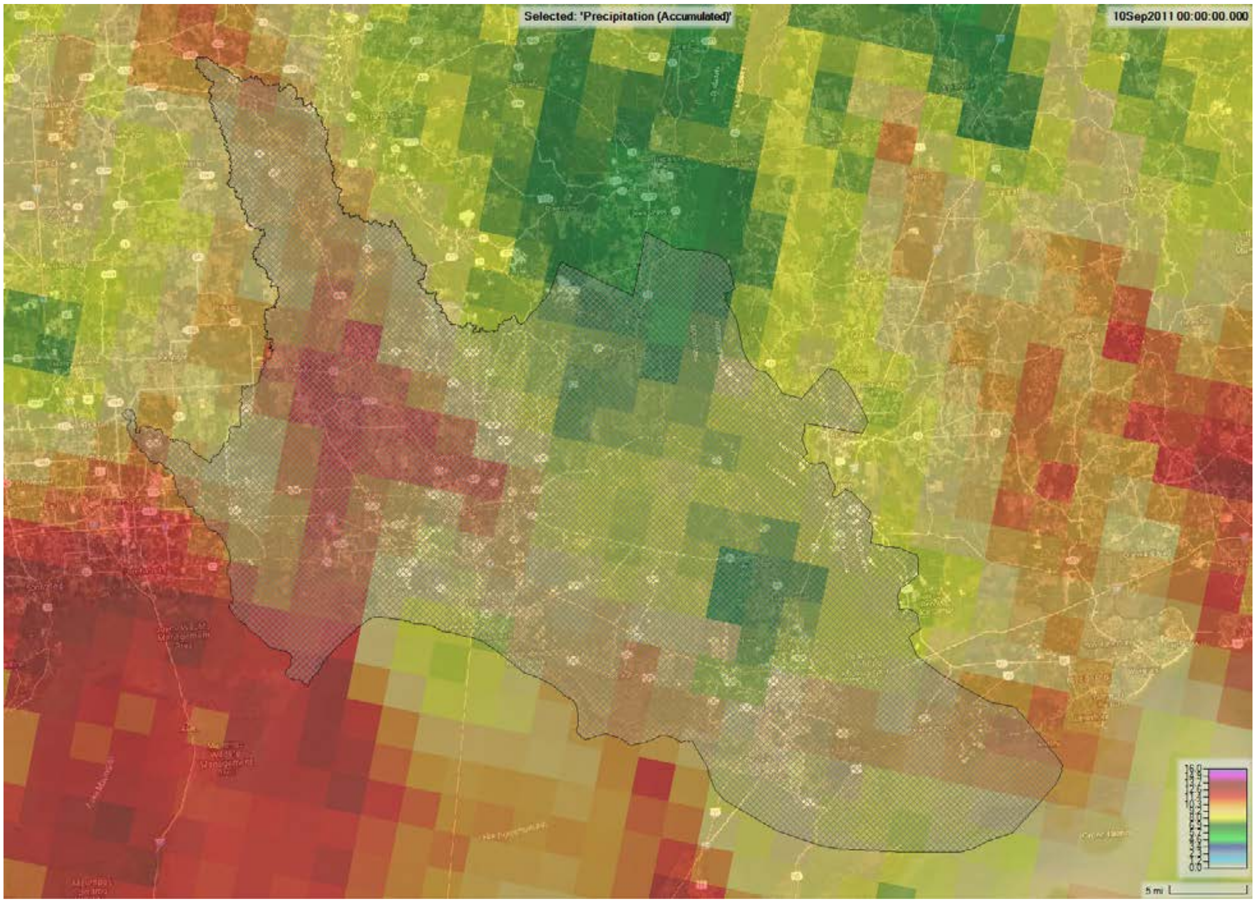


Figure E4:1. September 2011 Accumulated Precipitation Grid

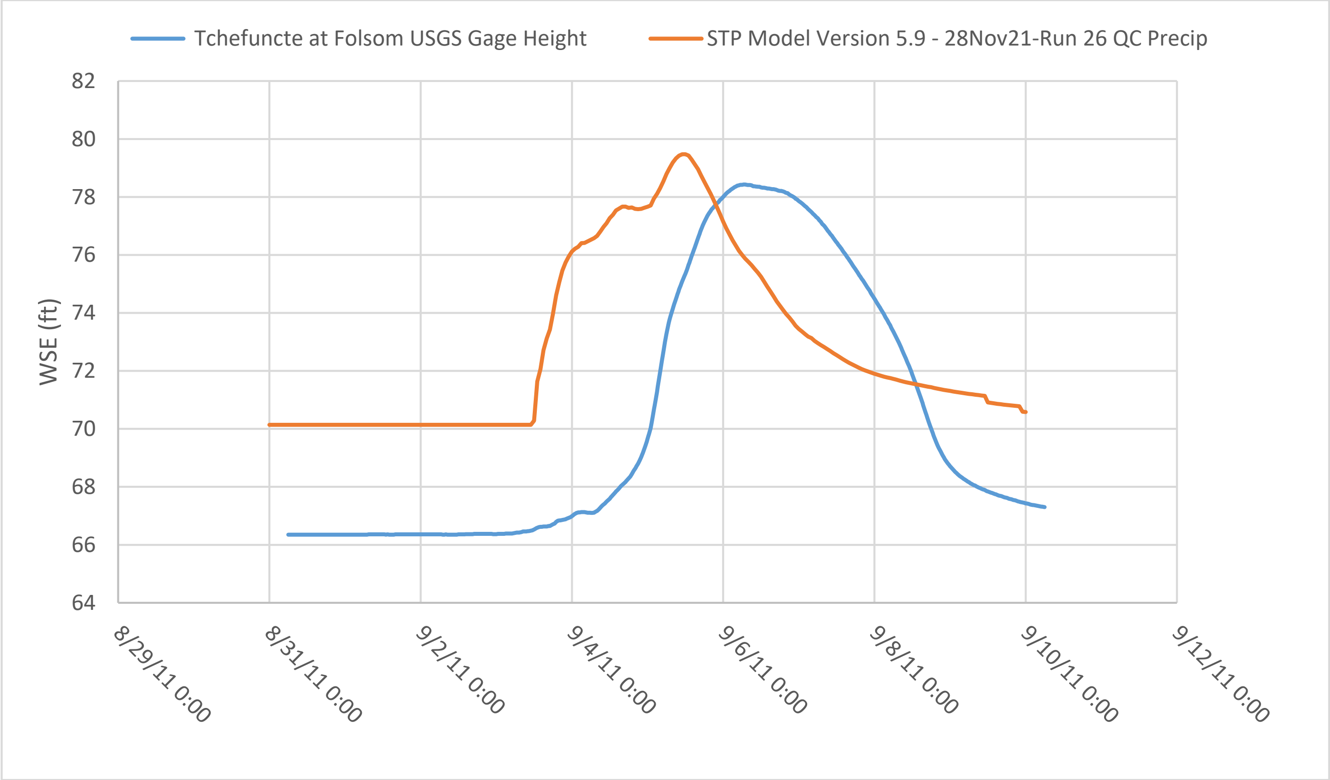


Figure E4:2. September 2011 calibration event plot for USGS Gage -Tchefuncte River at Folsom, LA

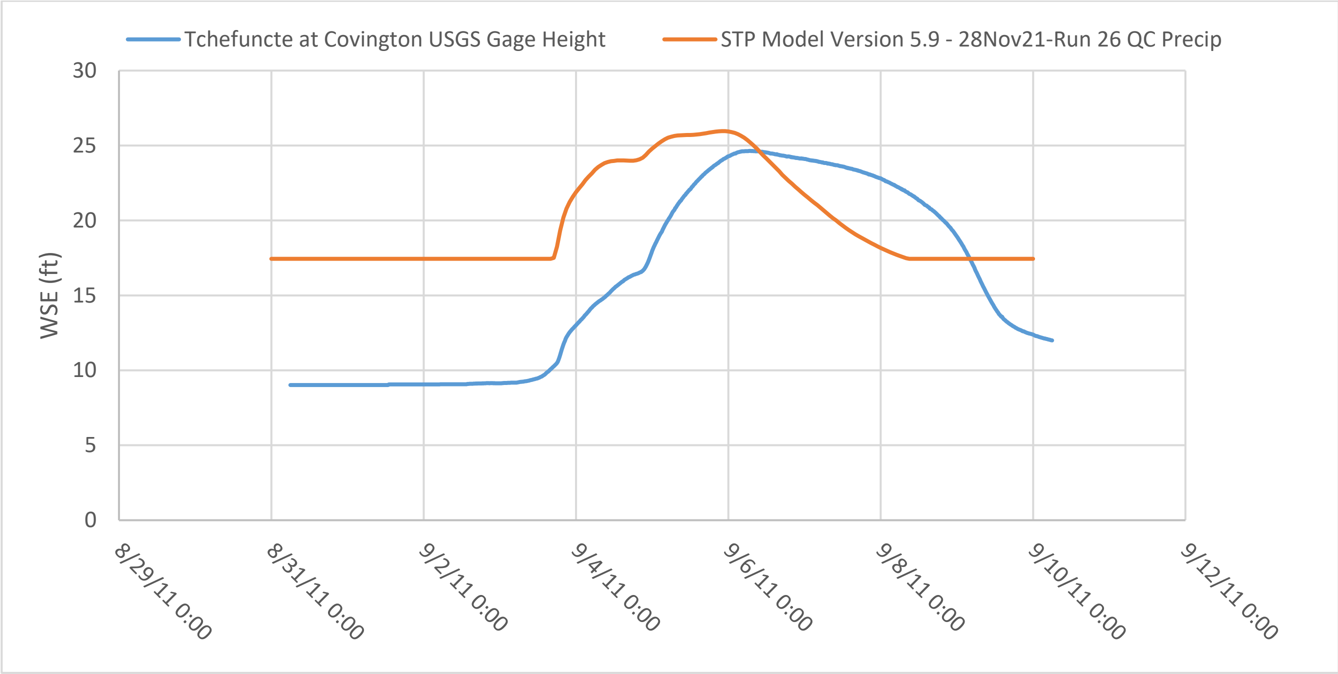


Figure E4:3. September 2011 calibration event plot for USGS Gage -Tchefuncte River at

Covington, LA

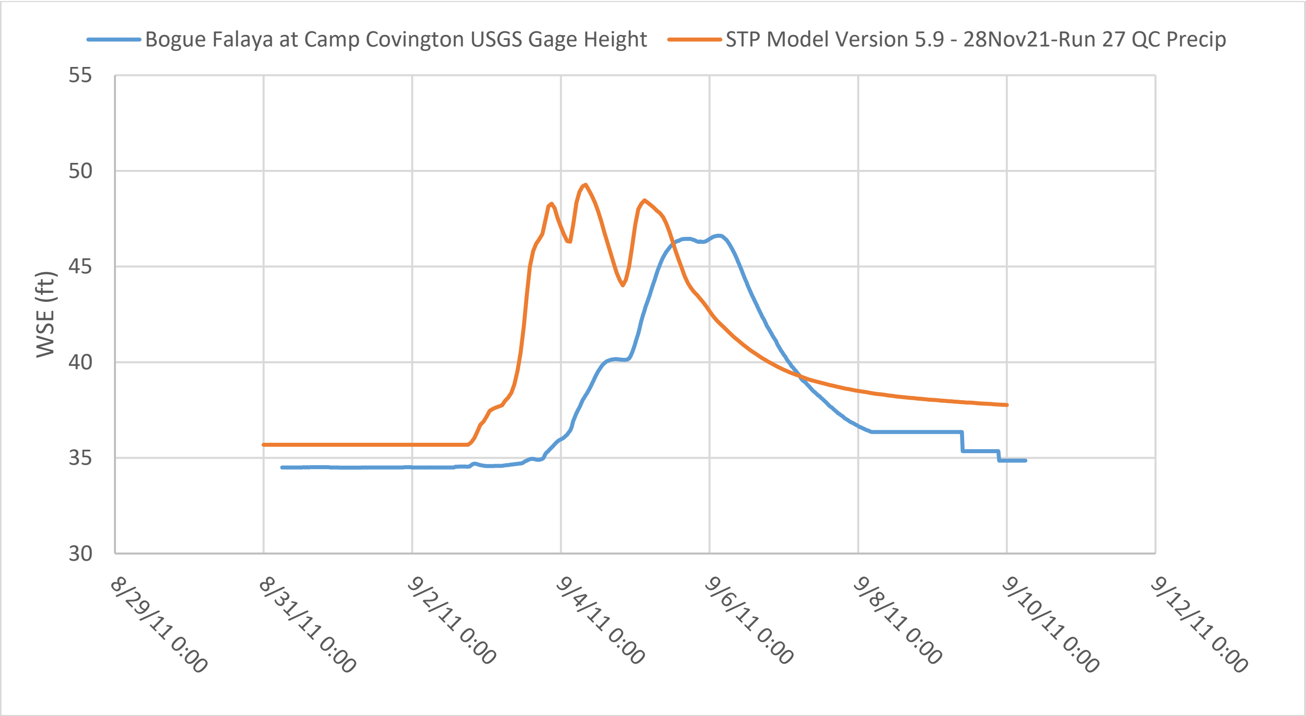


Figure E4:4. September 2011 calibration event plot for USGS Gage -Bogue Falaya at Campe Covington, LA

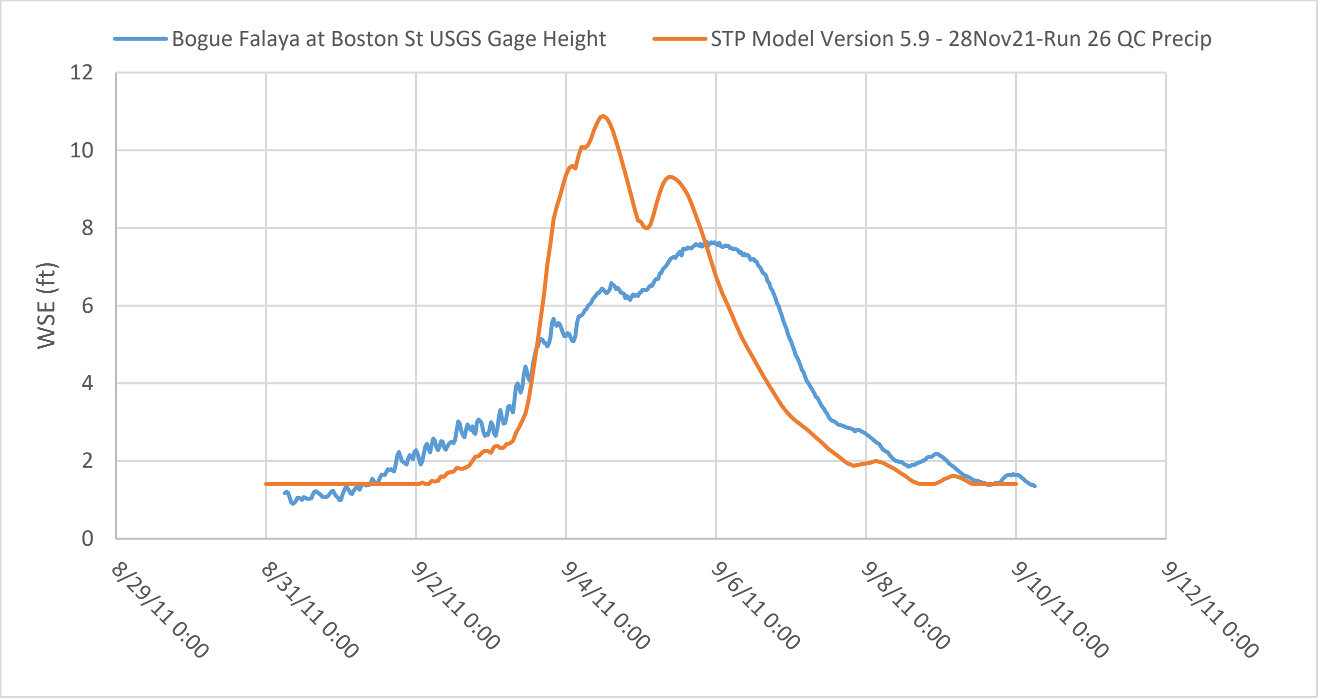


Figure E4:5. September 2011 calibration event plot for USGS Gage -Bogue Falaya at Boston Street

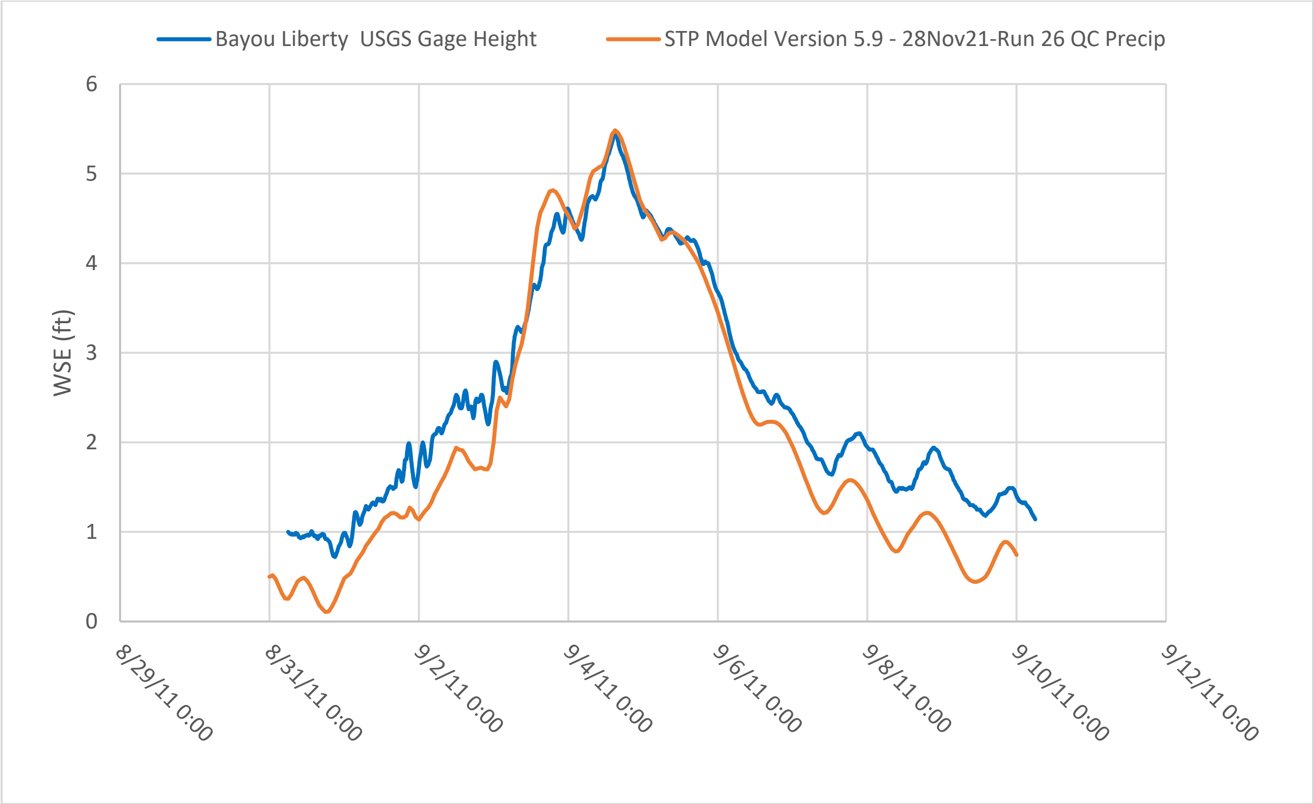


Figure E4:6. September 2011 calibration event plot for USGS Gage -Bayou Liberty

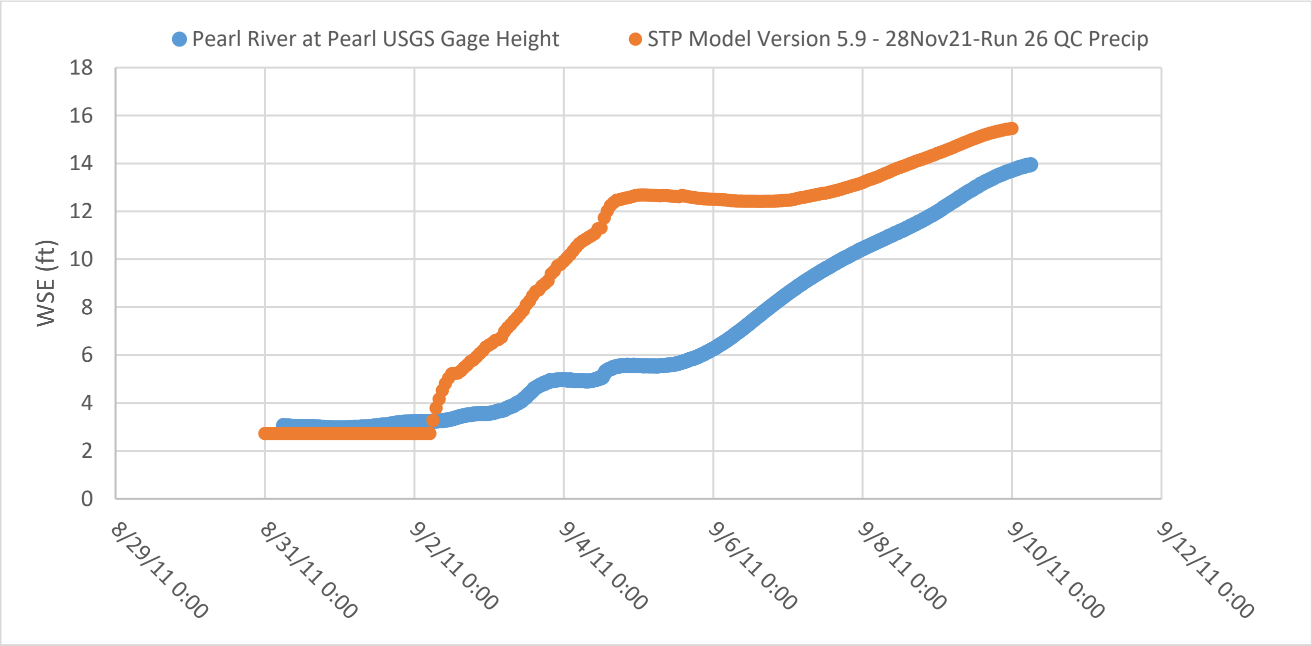


Figure E4:7. September 2011 calibration event plot for USGS Gage -Pearl River at Pearl, LA

March 2016

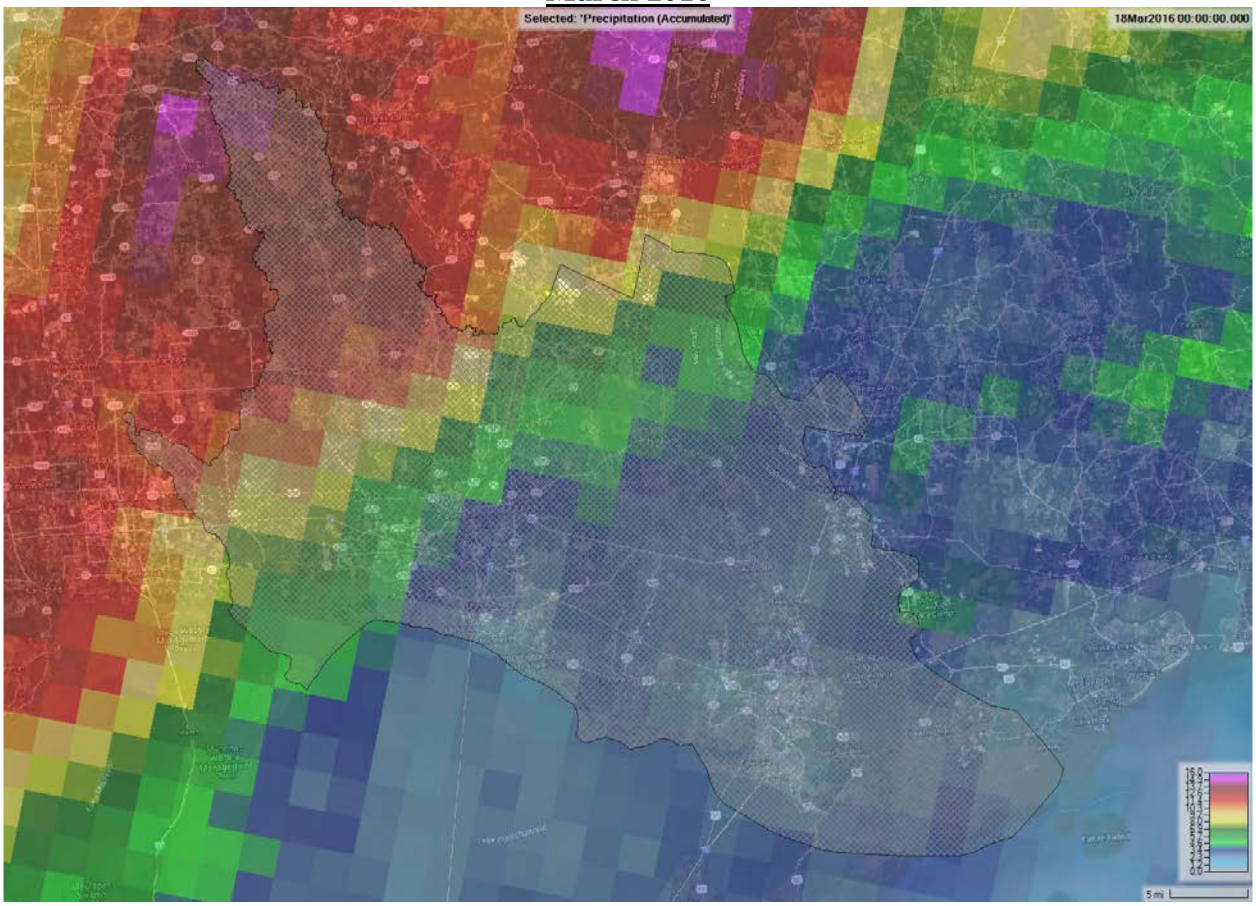


Figure E4:8. March 2016 Accumulated Precipitation Grid

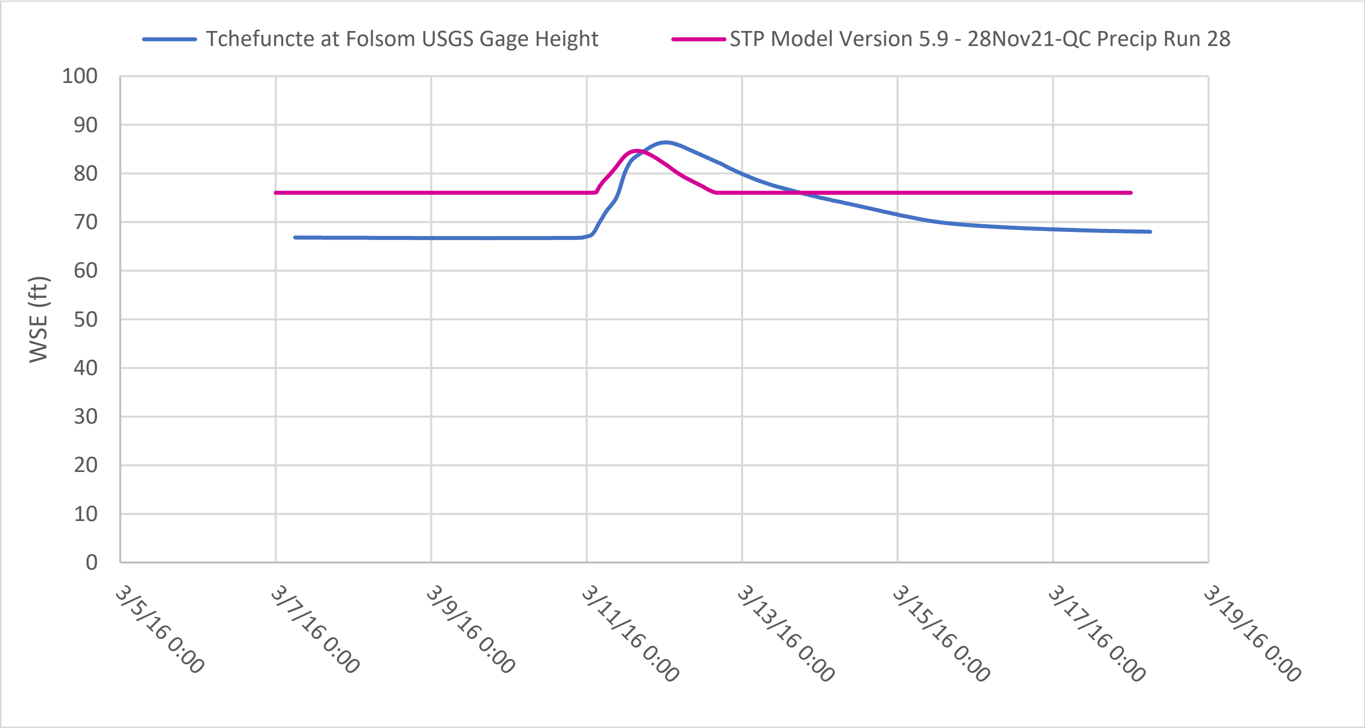


Figure E4:9. March 2016 calibration event plot for USGS Gage -Tchefuncte River at Folsom, LA

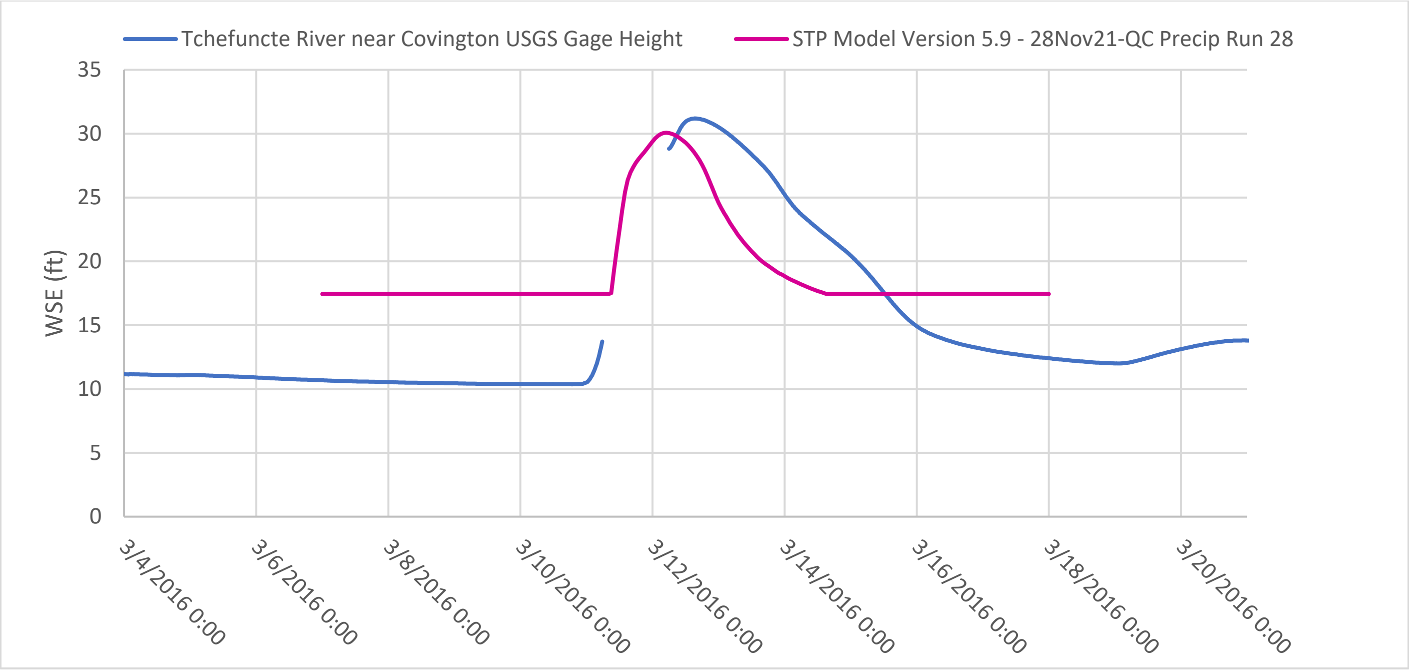


Figure E4:10. March 2016 calibration event plot for USGS Gage – Tchefuncte River near Covington, LA

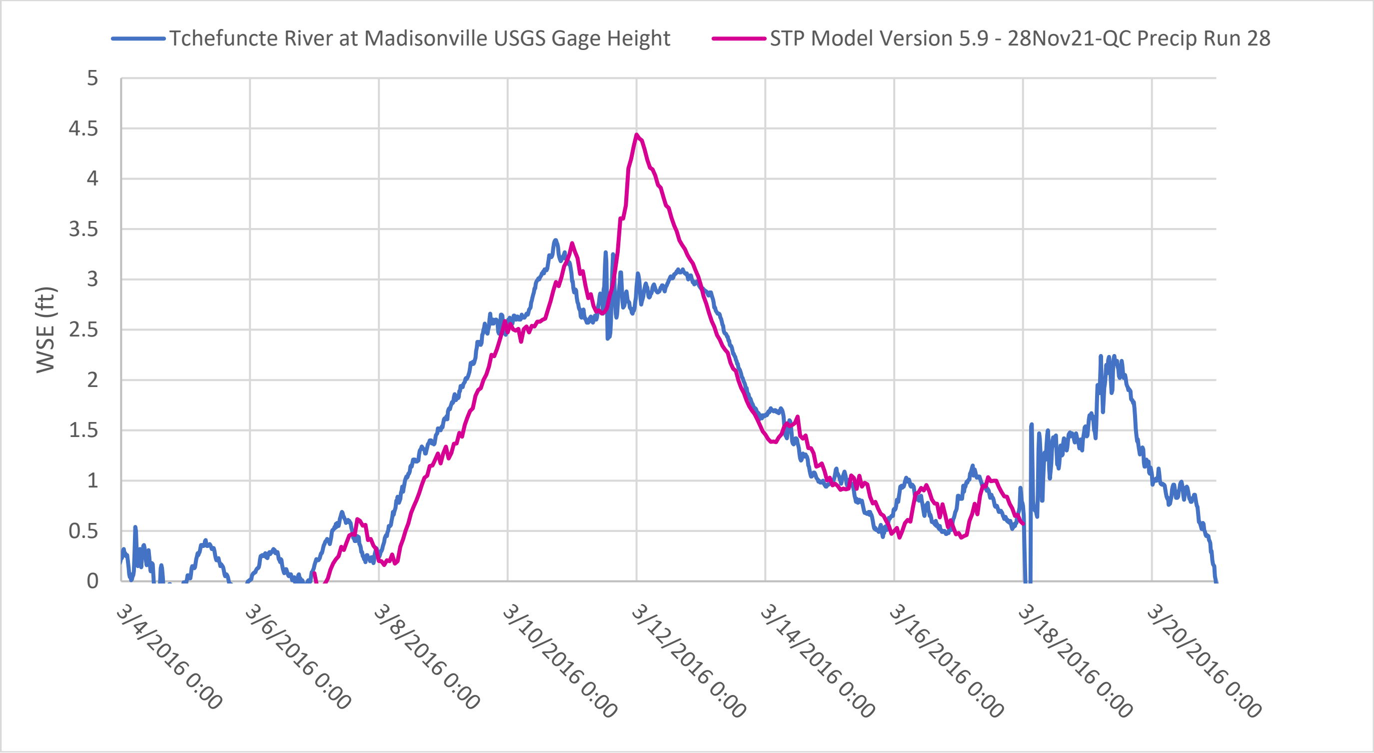


Figure E4:11. March 2016 calibration event plot for USGS Gage – Tchefuncte River at Madiosnville, LA

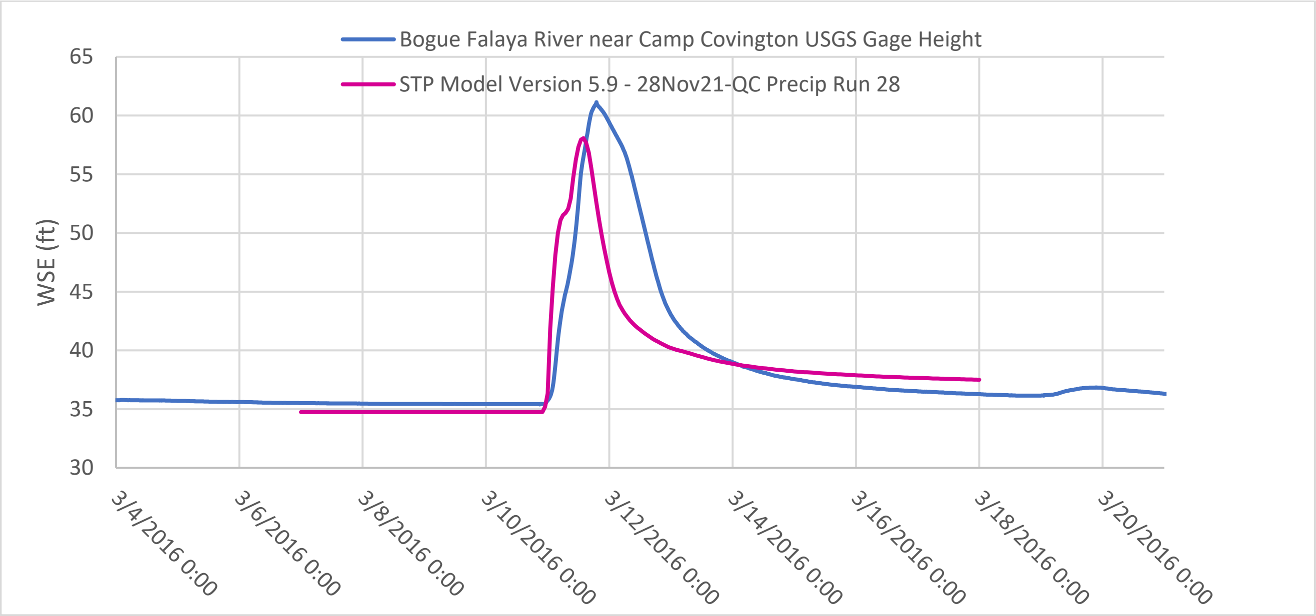


Figure E4:12. March 2016 calibration event plot for USGS Gage – Bogue Falaya River near Camp Covington, LA

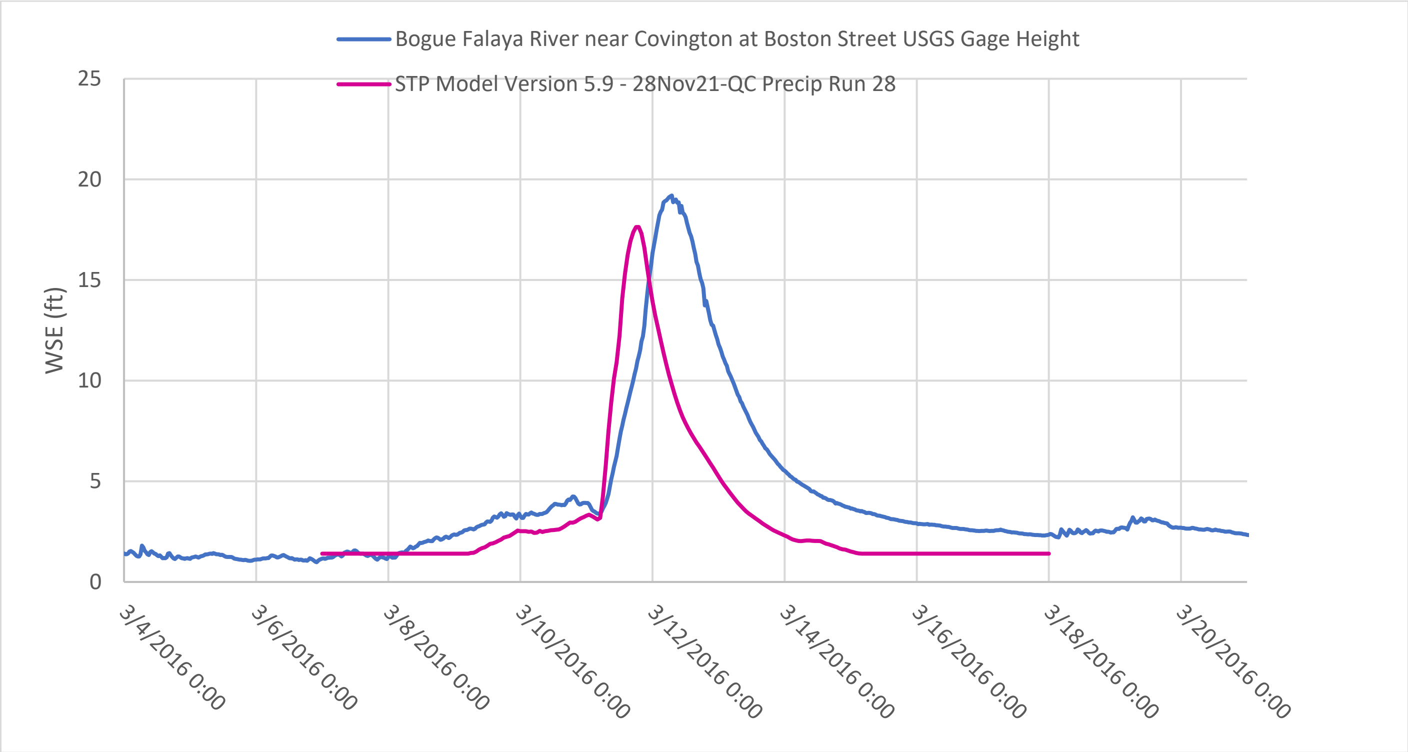


Figure E4:13. March 2016 calibration event plot for USGS Gage – Bogue Falaya River near Covington, LA at Boston Street

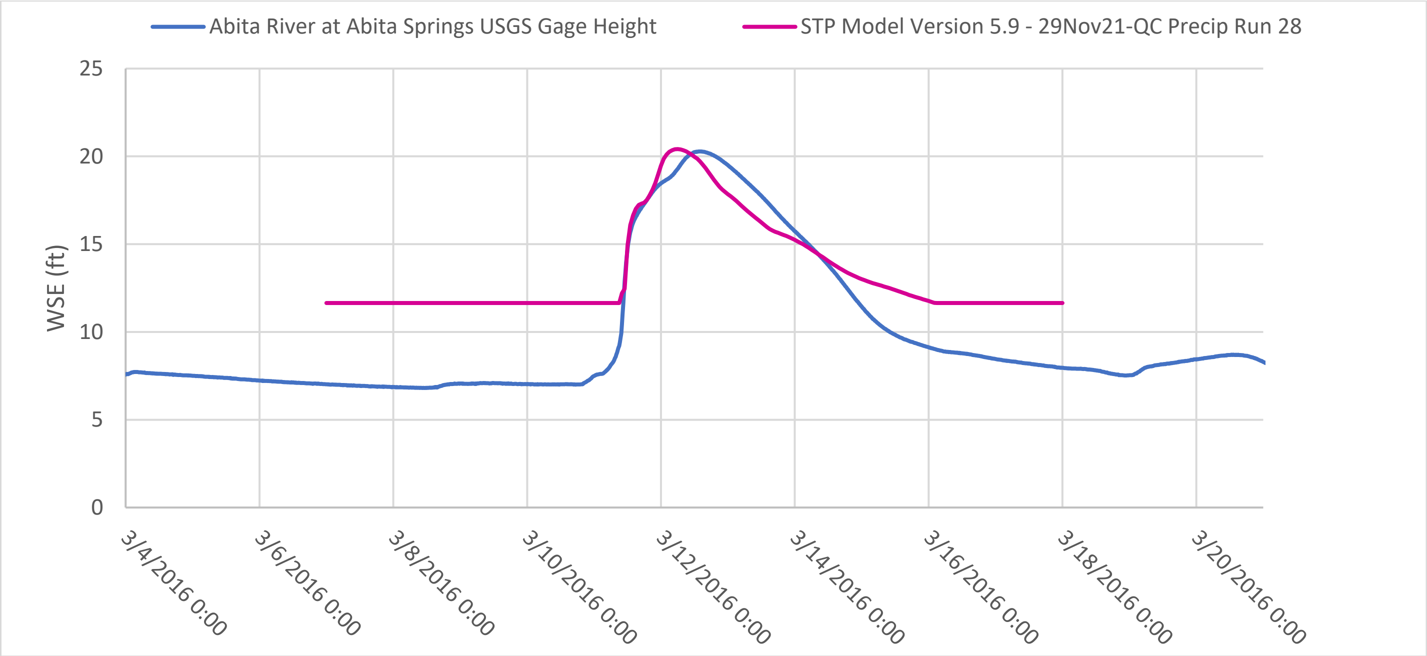


Figure E4:14. March 2016 calibration event plot for USGS Gage – Abita River at Abita Springs, LA

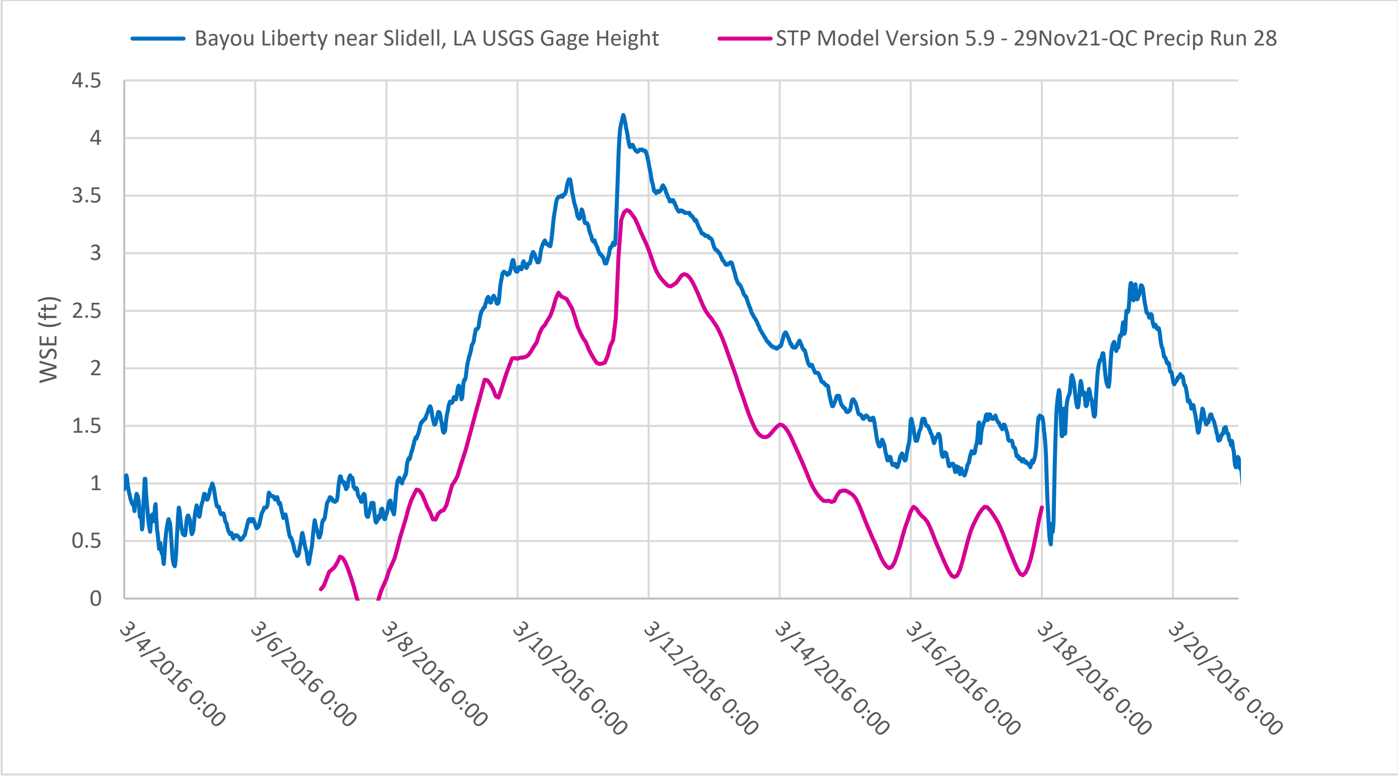


Figure E4:15. March 2016 calibration event plot for USGS Gage – Bayou Liberty near Slidell, LA

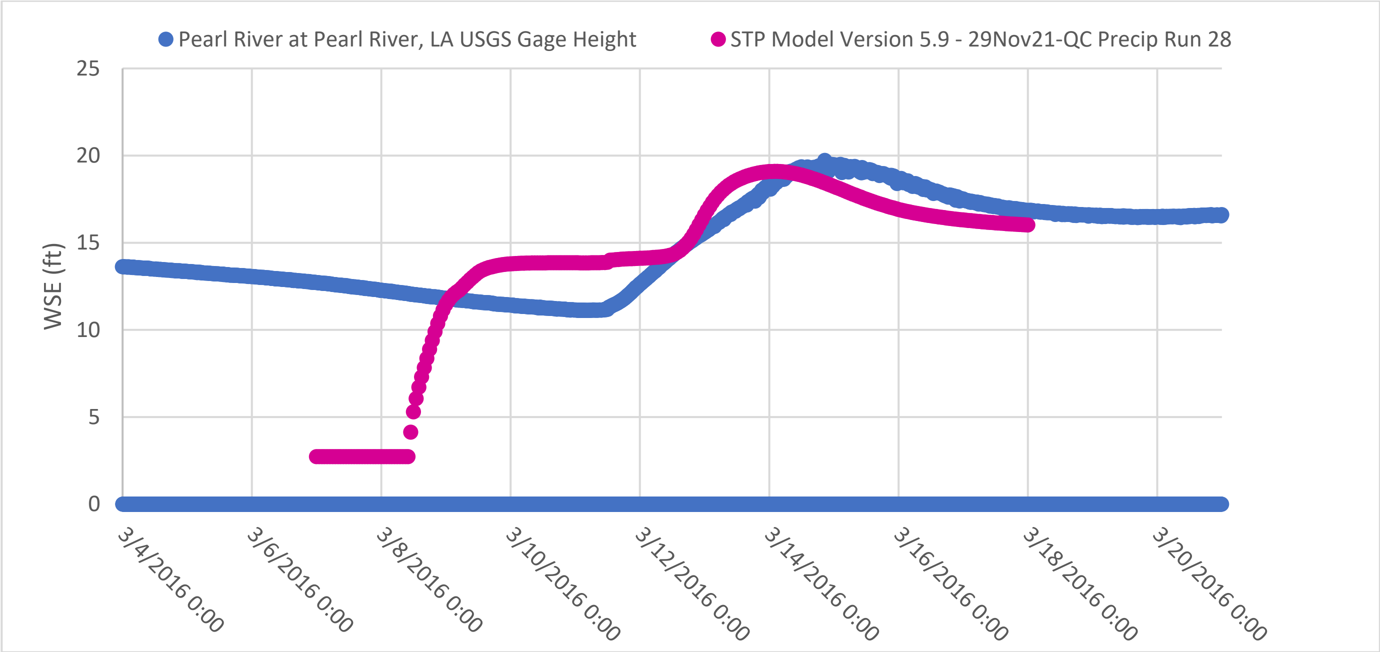


Figure E4:16. March 2016 calibration event plot for USGS Gage – Pearl River at Pearl, LA

Annex E-5-Particle Tracing

The enclosed screen shots depict particle tracing for the existing conditions and with project scenario for each extent of the RP Alternate 6c3 alignment, outlined in green. The blue color represents water depth in the 10-year rainfall event. Darker blues represent deeper water, lighter water represents shallower water. North is straight up in every figure. Purple dots represent gates of all types including road gates, access gates, and drainage gates.

<u>Segment 1</u>

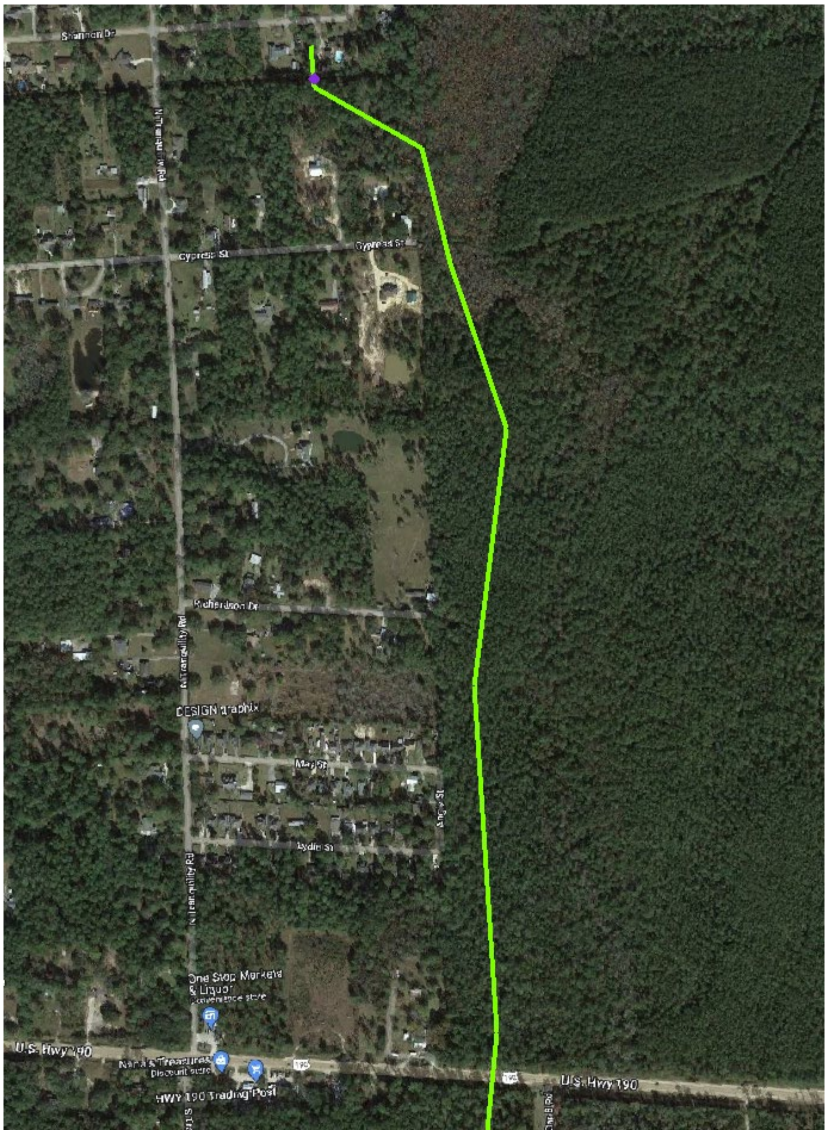


Figure E5:1. Segment 1

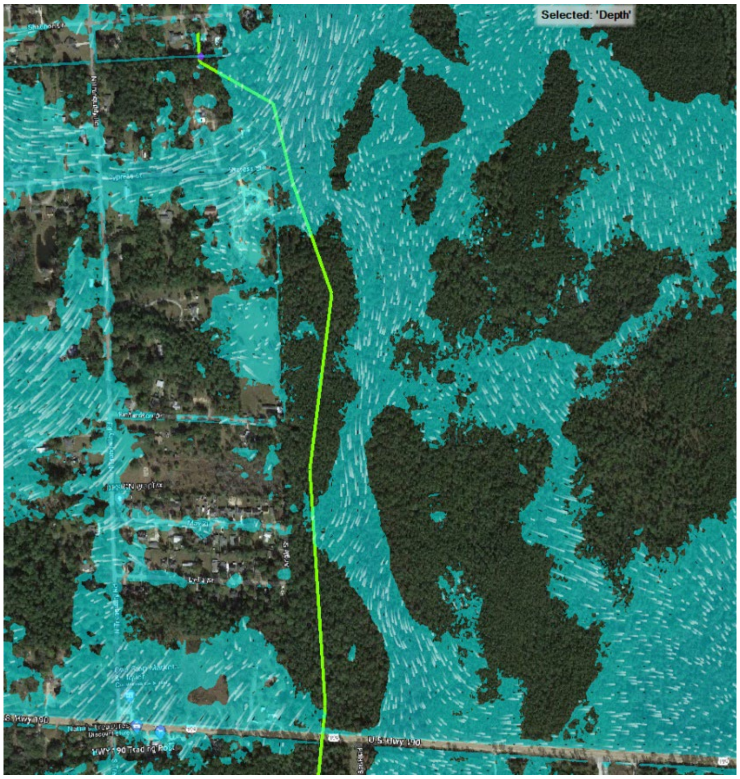


Figure E5:2. Segment 1 Existing Conditions

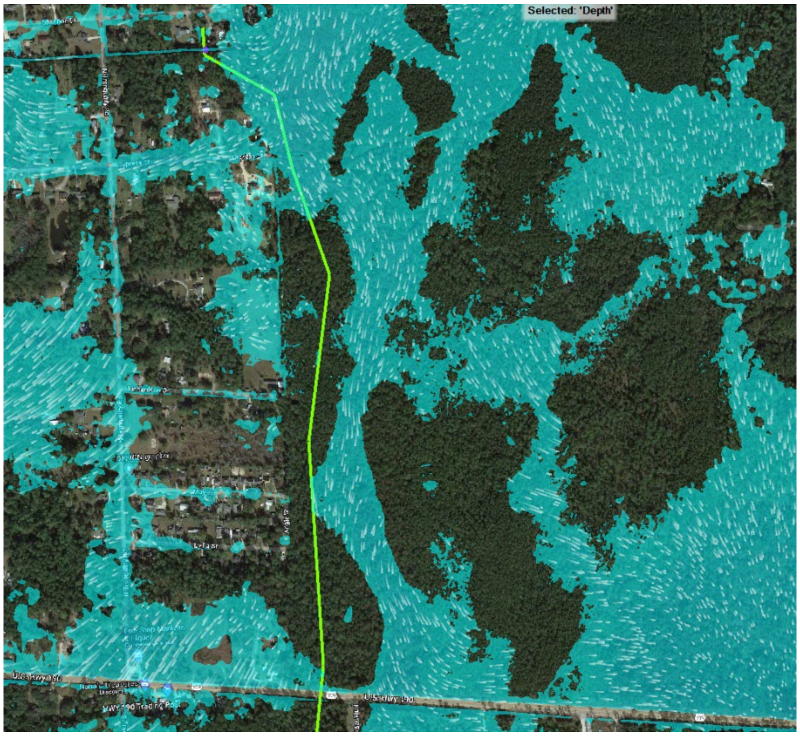


Figure E5:3. Segment 1 With Project

Segment 2

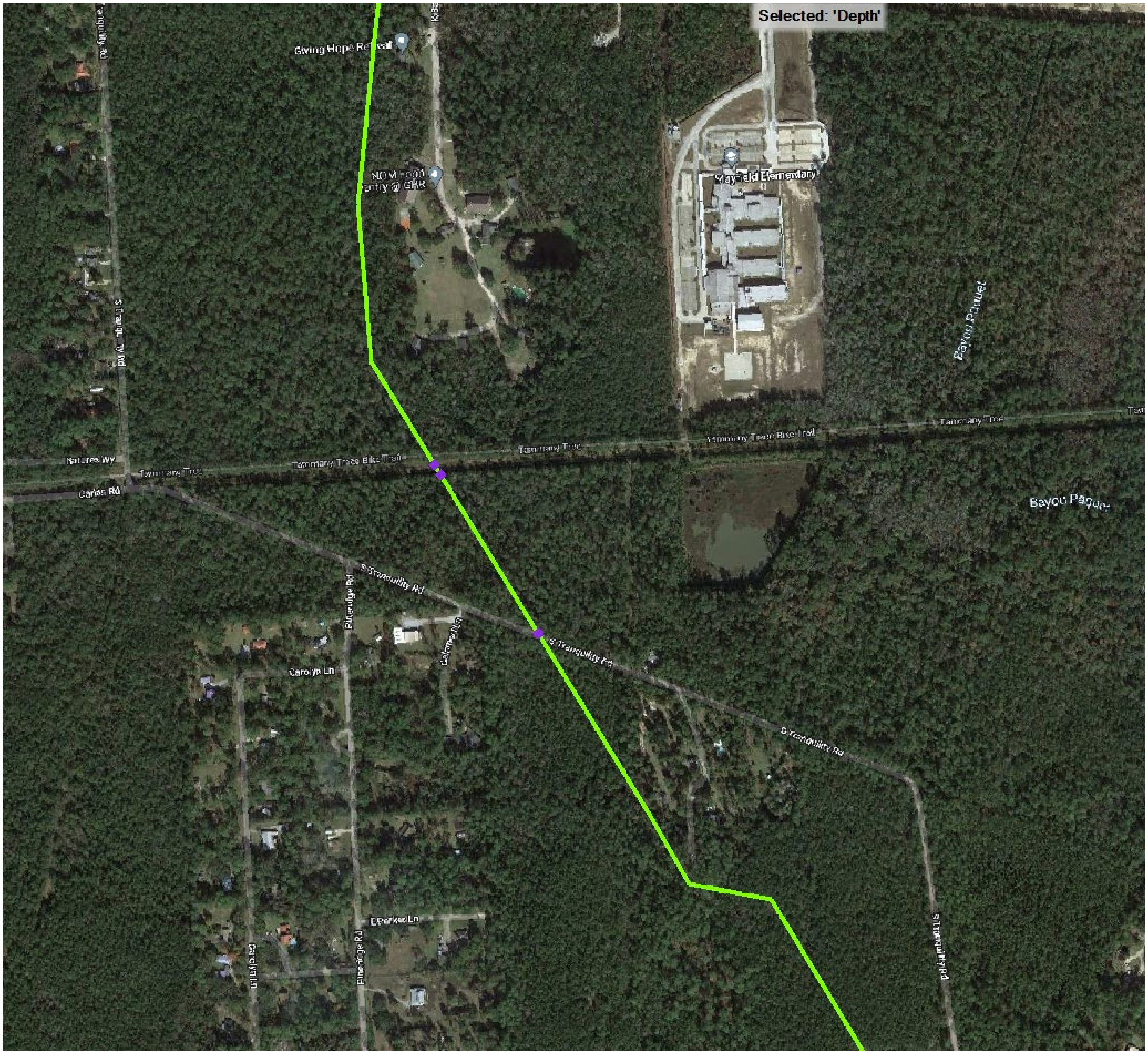


Figure E5:4. Segment 2

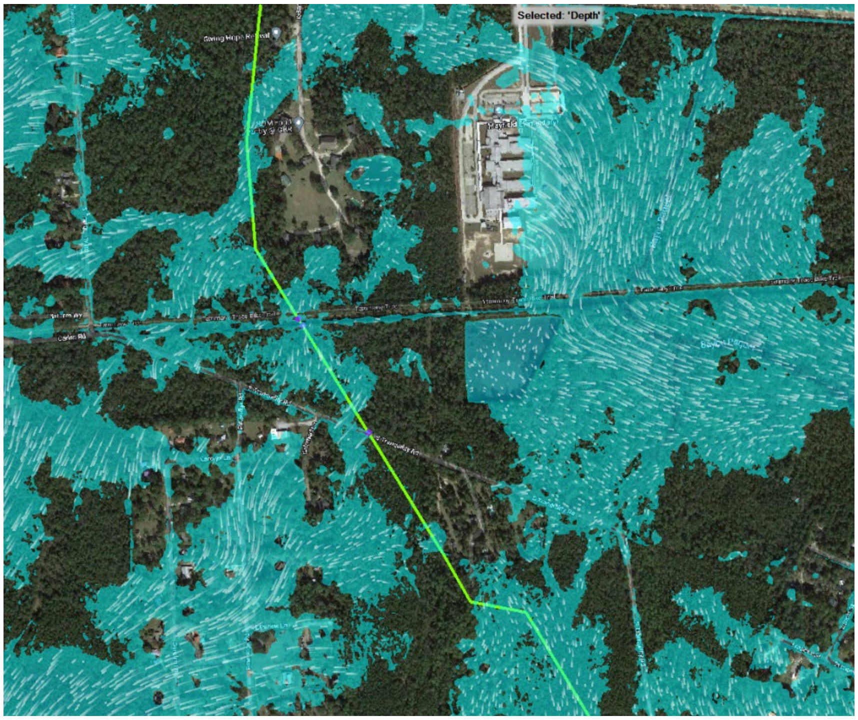


Figure 45.Segment 2 Existing Conditions

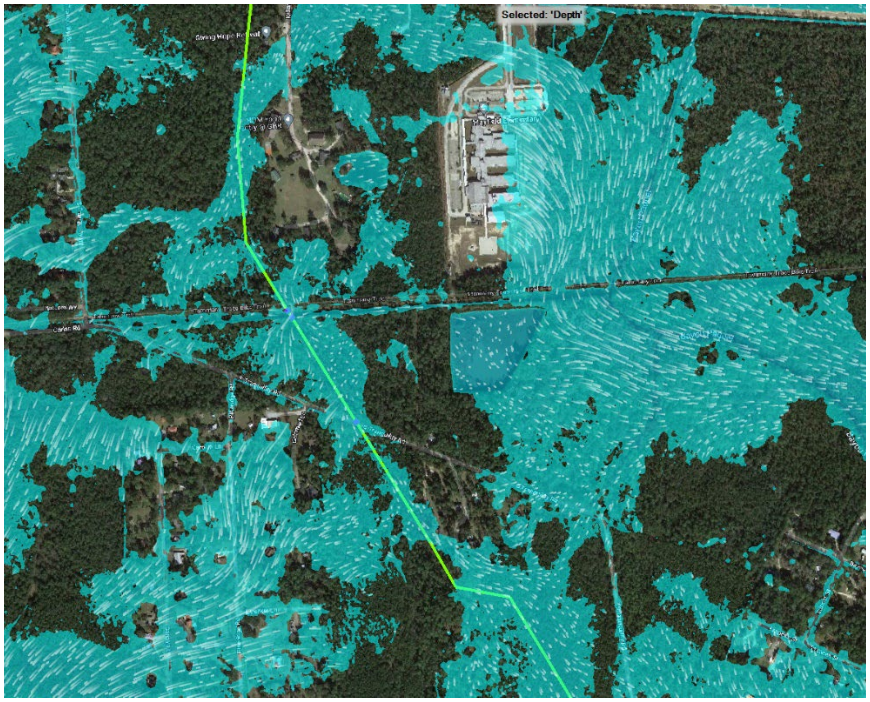


Figure 5. Segment 2 With Project

Segment 3

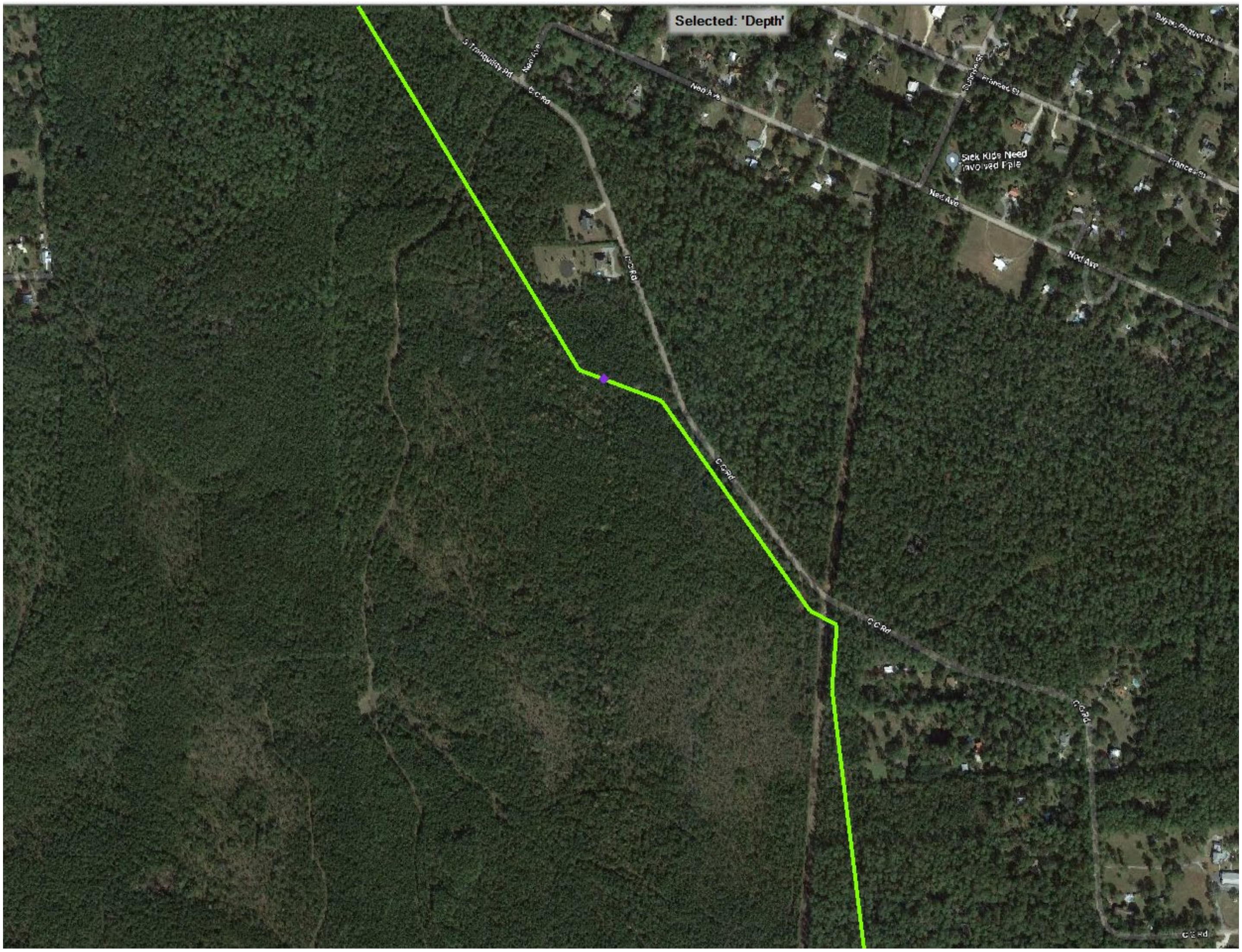


Figure E5:7. Segment 3

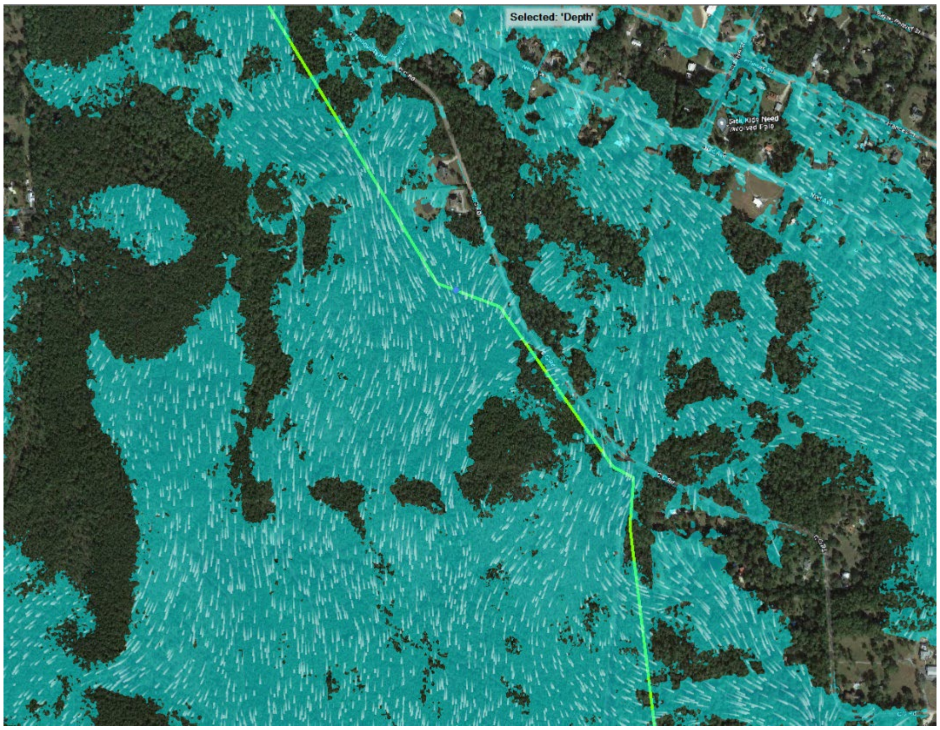


Figure 6. Segment 3 Existing Conditions

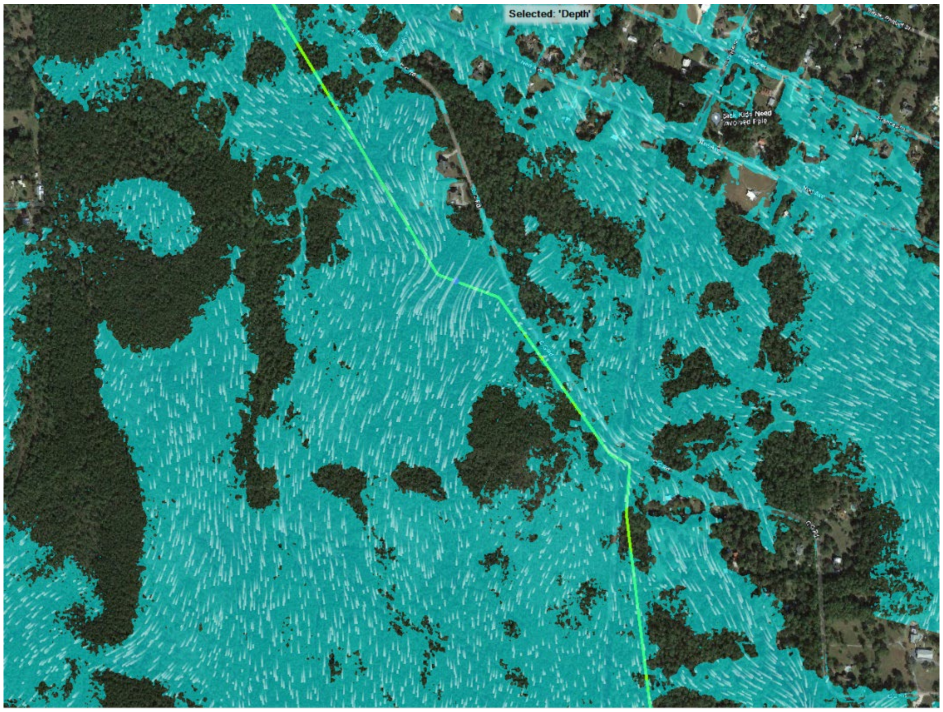


Figure E5:9. Segment 3 With Project

Segment 4

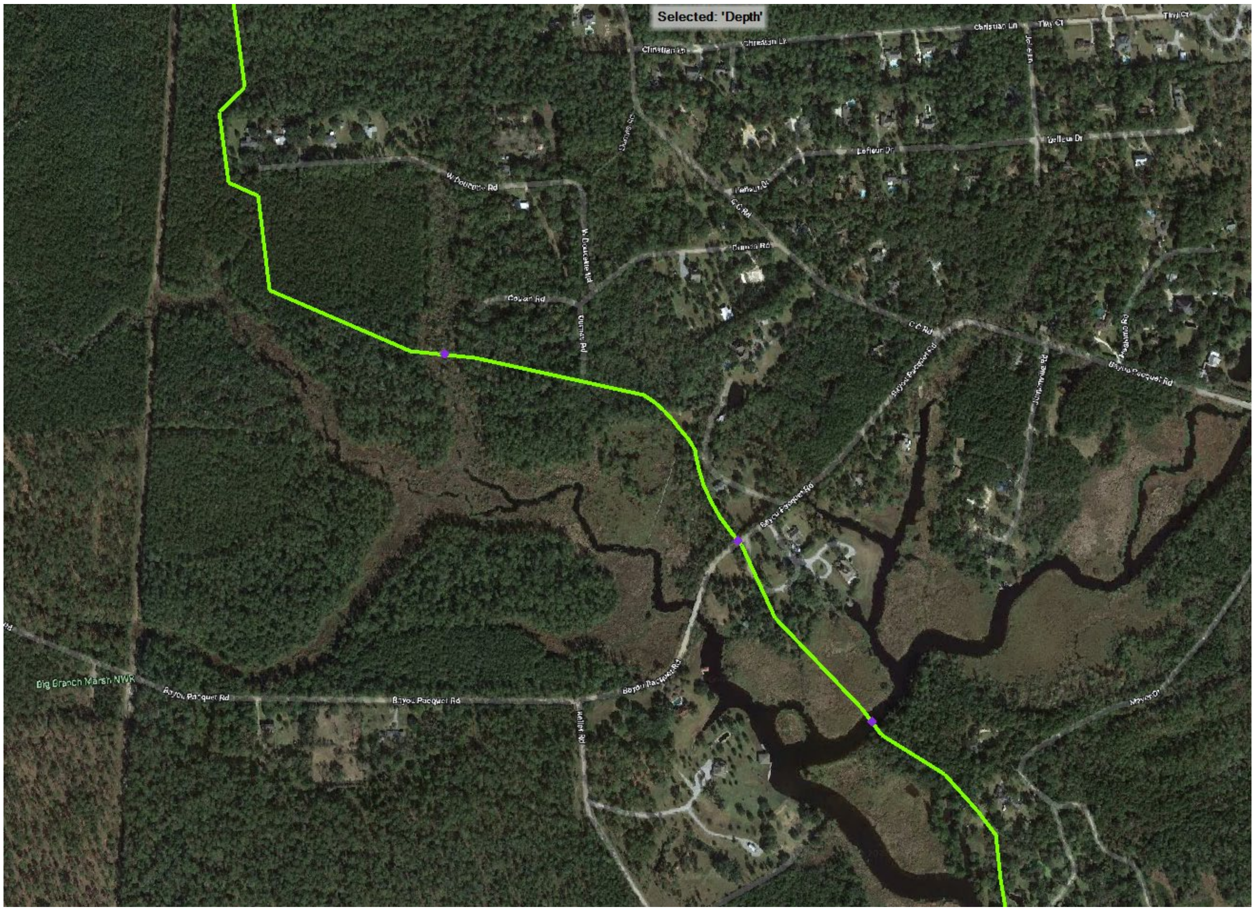


Figure E5:10. Segment 4

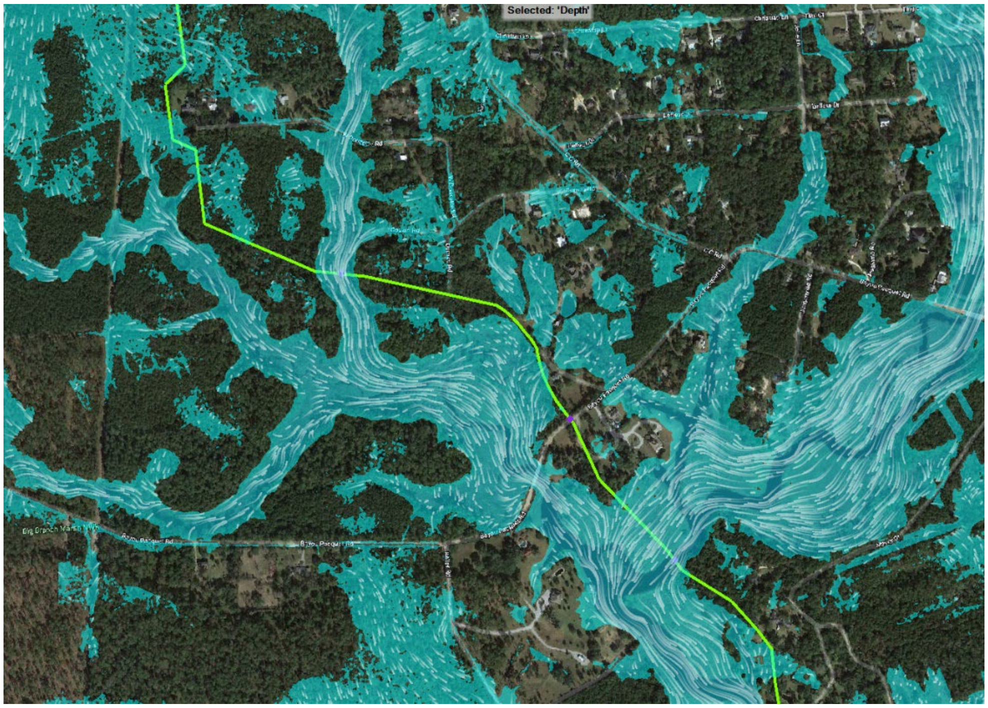


Figure E5:11. Segment 4 Existing Conditions

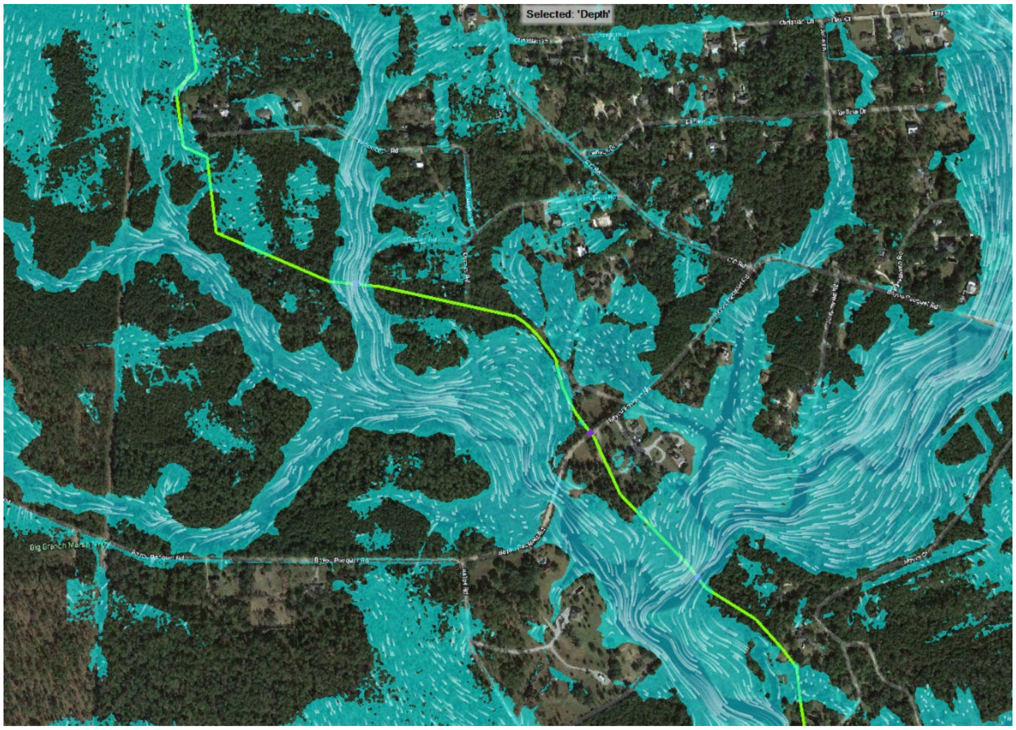


Figure 7. Segment 4 With Project

Segment 5

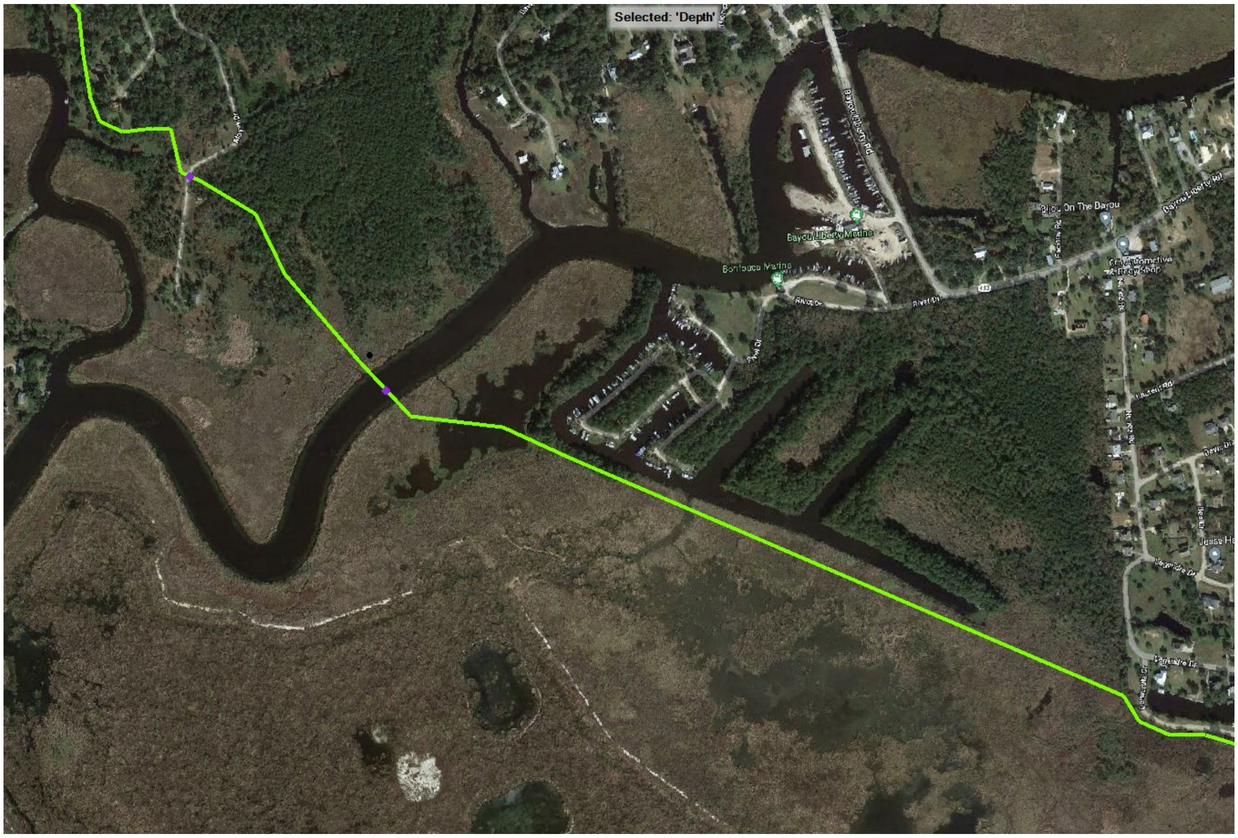


Figure E5:13. Segment 5

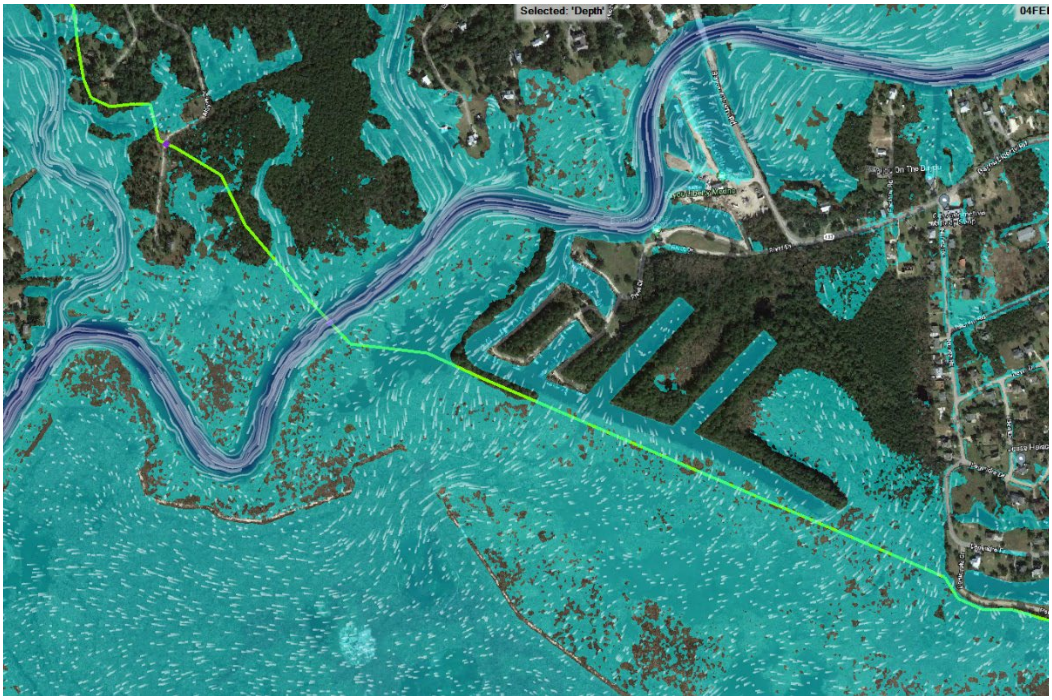


Figure E5:14. Segment 5 Existing Conditions

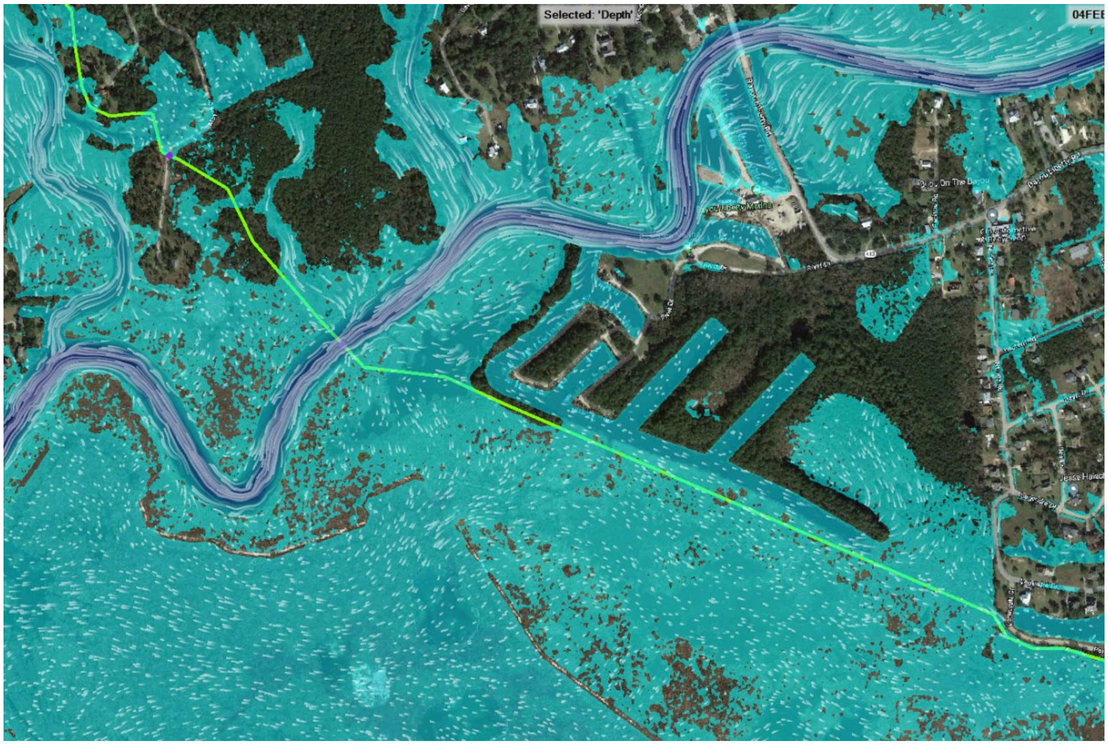


Figure E5:15. Segment 5 With Project

Segment 6

Figure E5:16. Segment 6

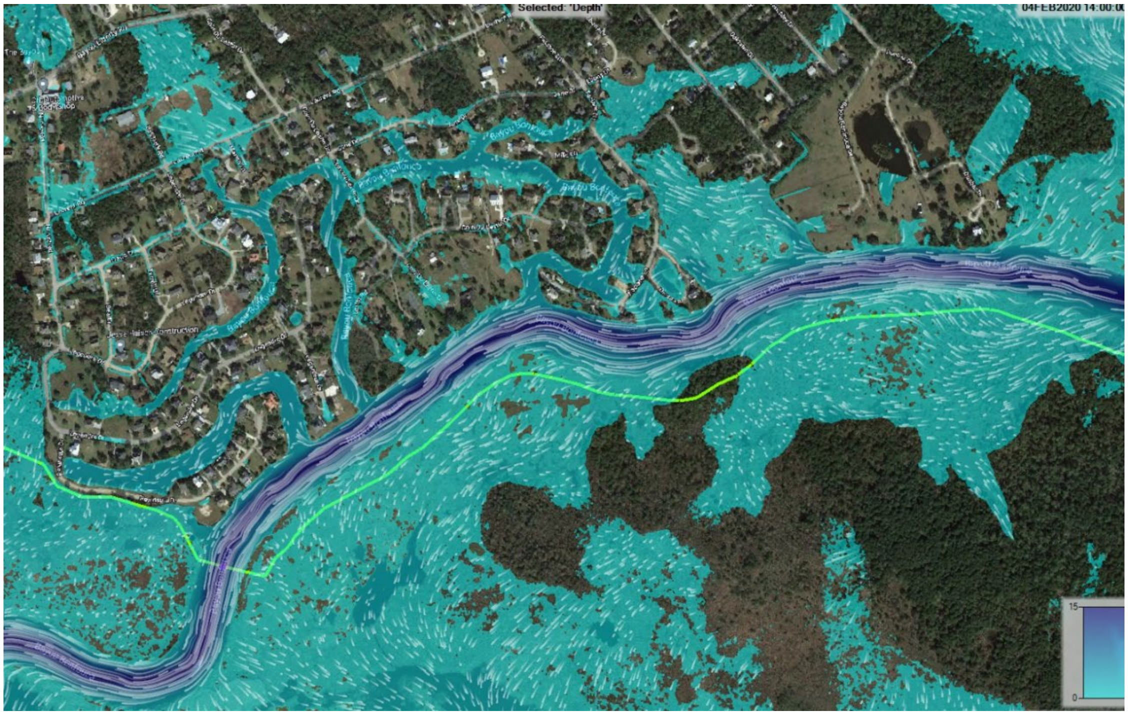


Figure E5:17. Segment 6 Existing Conditions

Figure E5:18. Segment 6 With Project

Segment 7

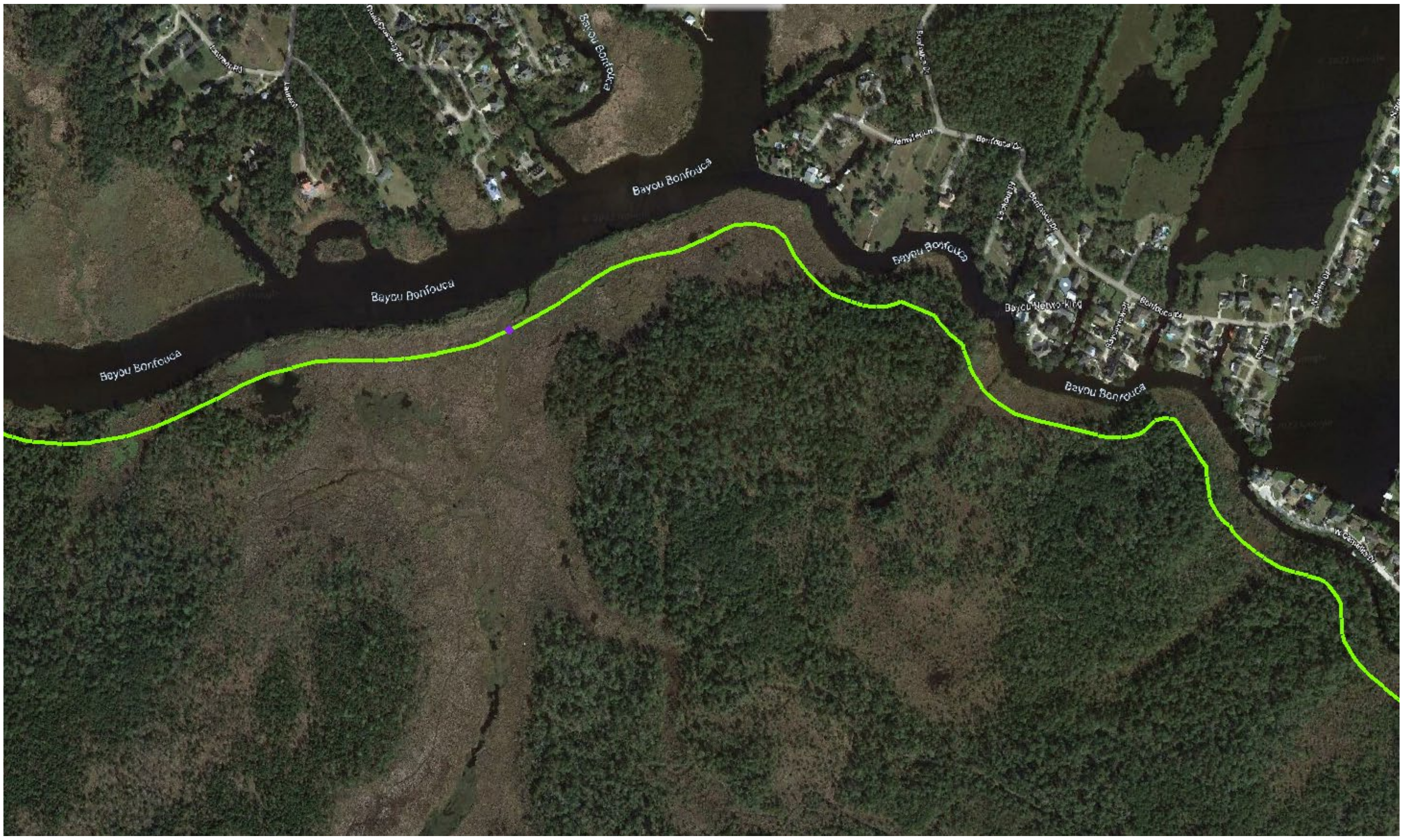


Figure E5:19. Segment 7

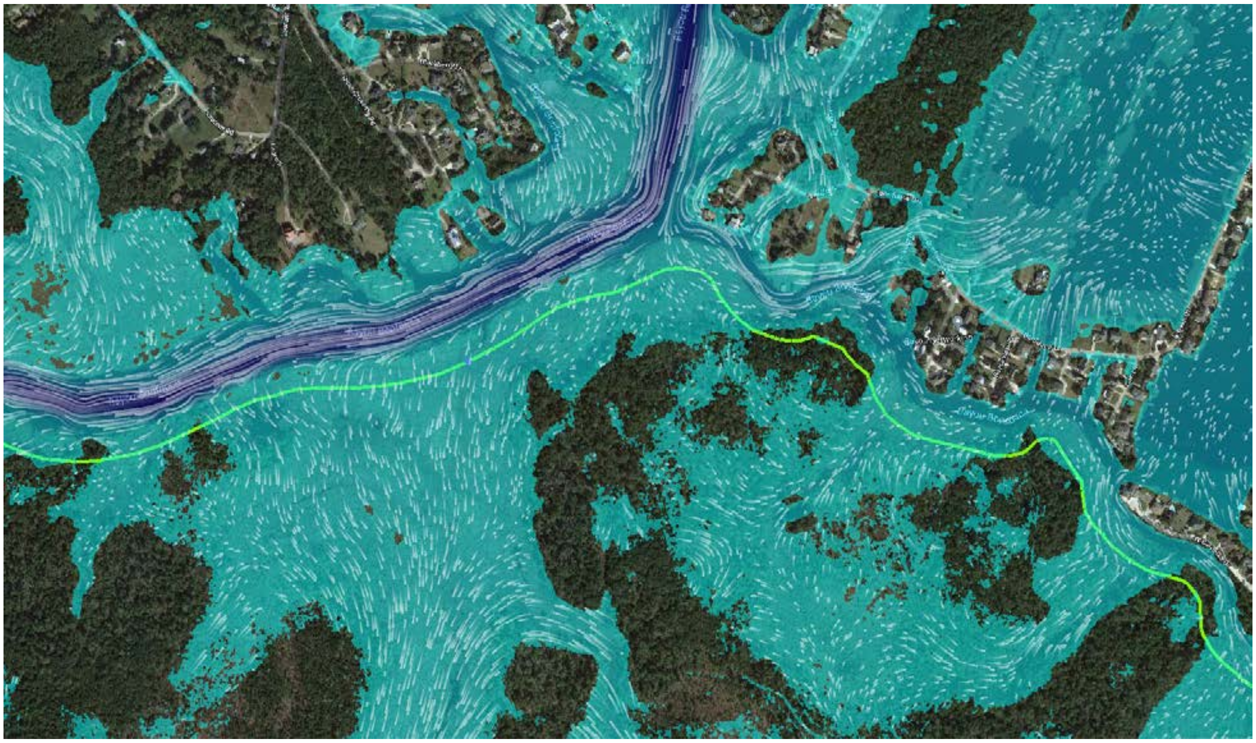


Figure E5:20. Segment 7 Existing Conditions

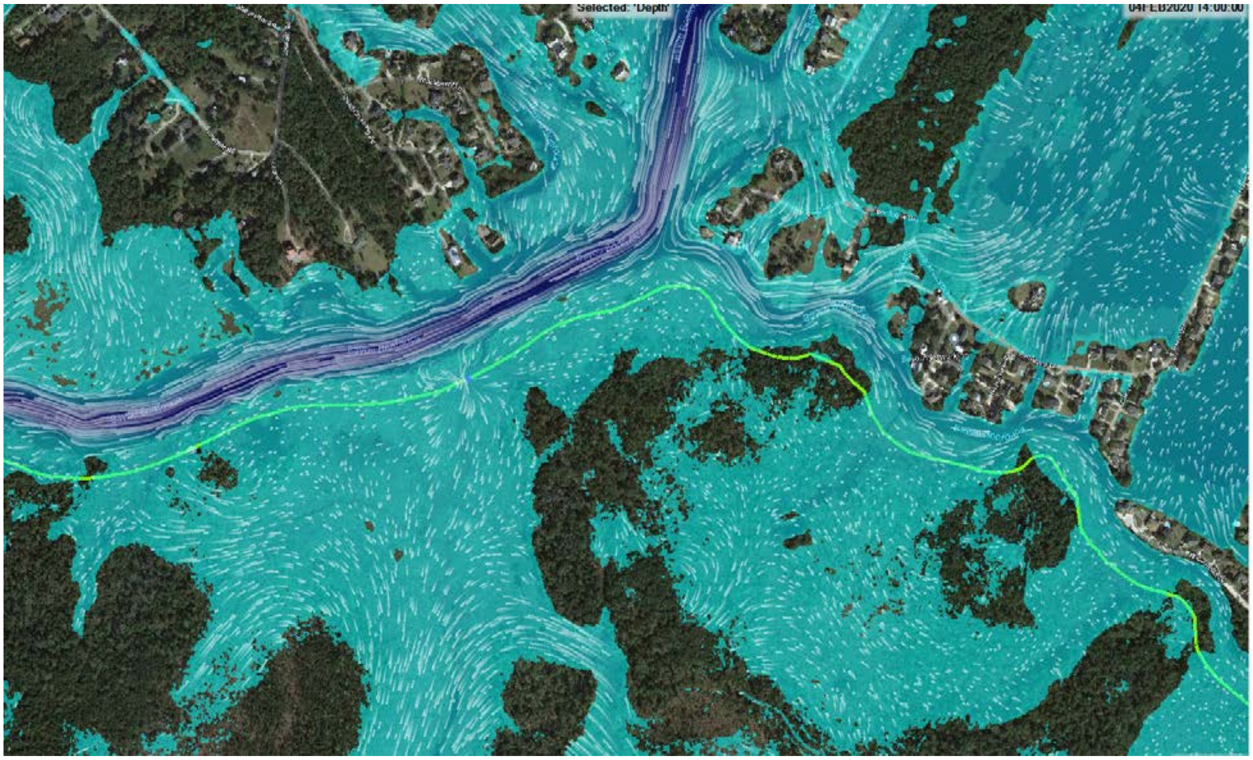


Figure E5:21. Segment 7 With Project

Segment 8

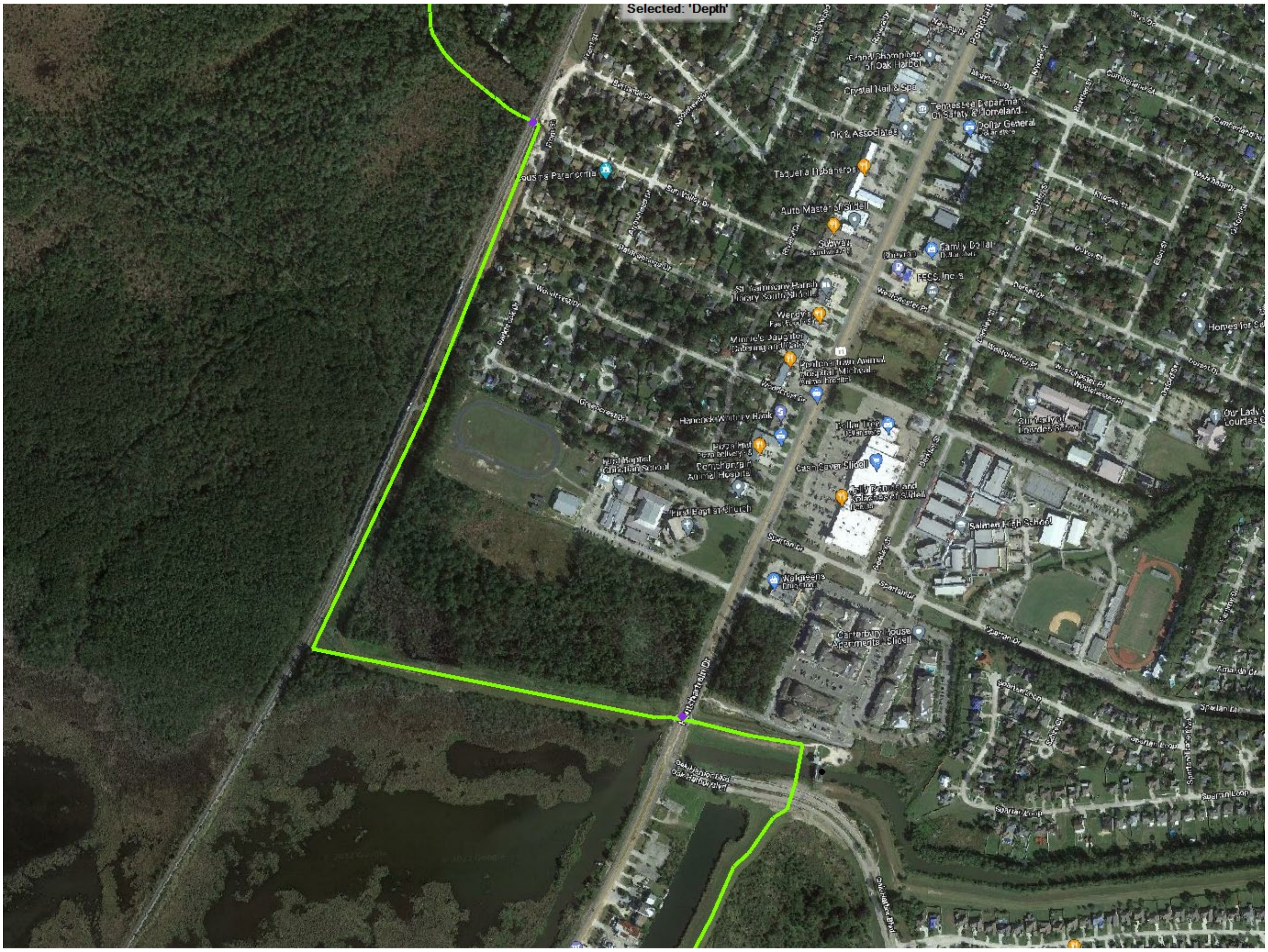


Figure E5:22. Segment 8

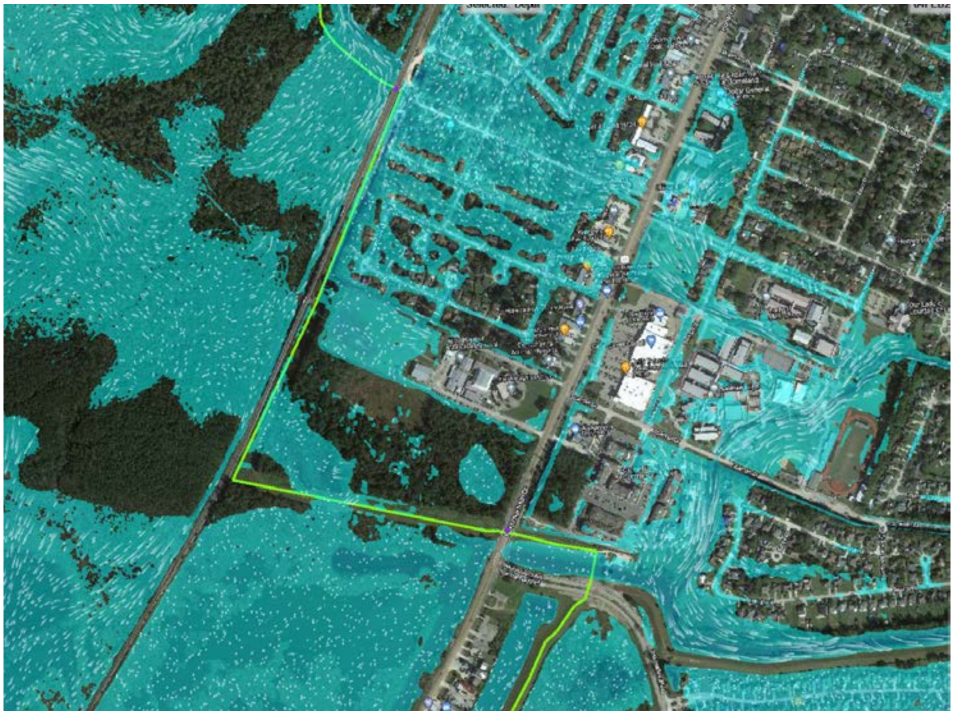


Figure E5:23. Segment 8 Existing Conditions

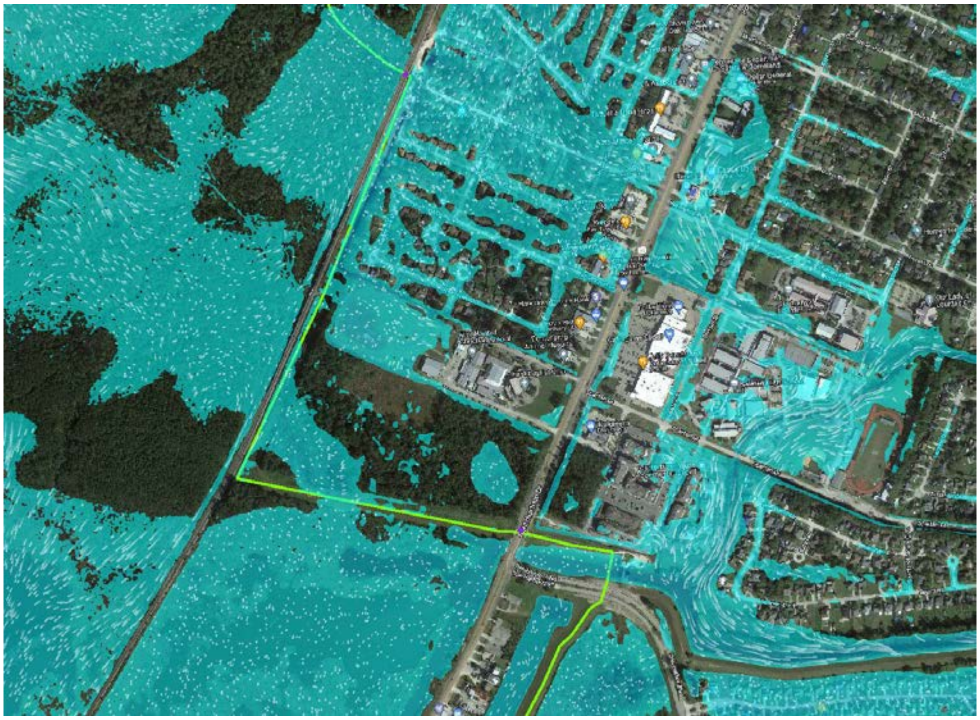


Figure E5:24. Segment 8 With Project

Segment 9

Figure E5:25. Segment 9

Figure E5:26. Segment 9 Existing Conditions

Figure E5:27. Segment 9 With Project

Segment 10

Figure E5:288. Segment 10

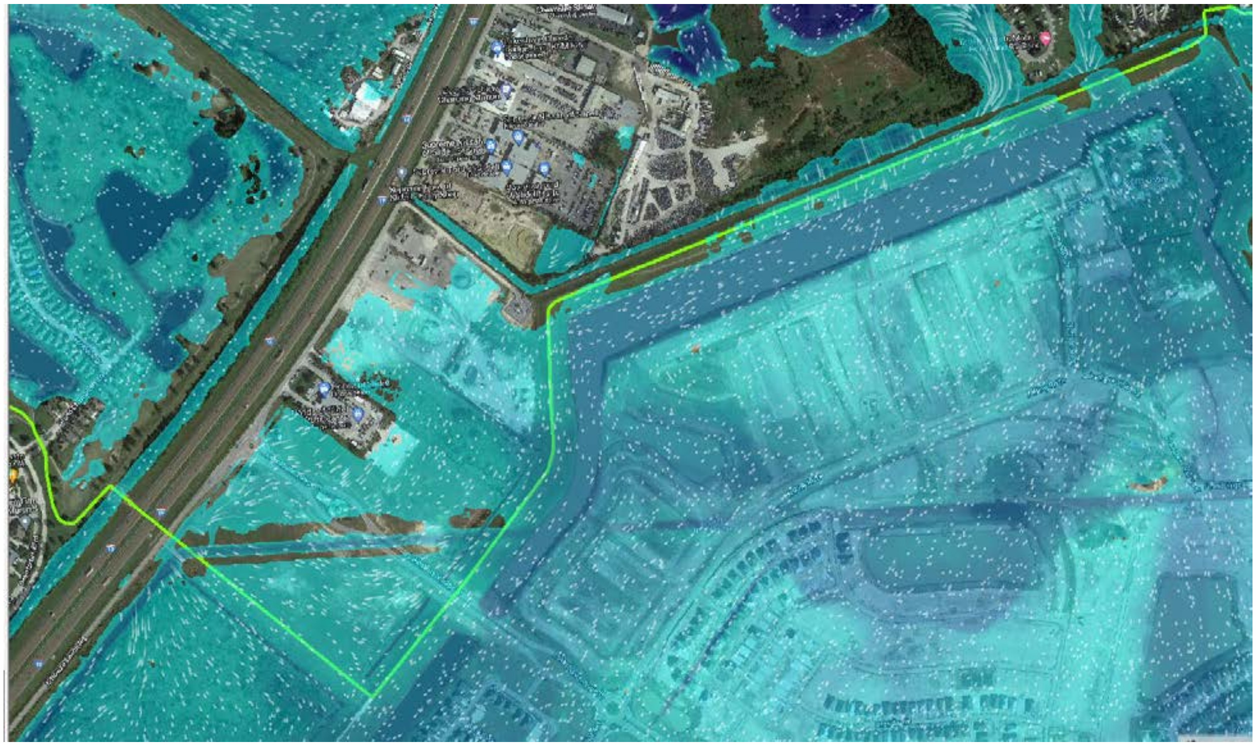


Figure E5:29. Segment 10 Existing Conditions

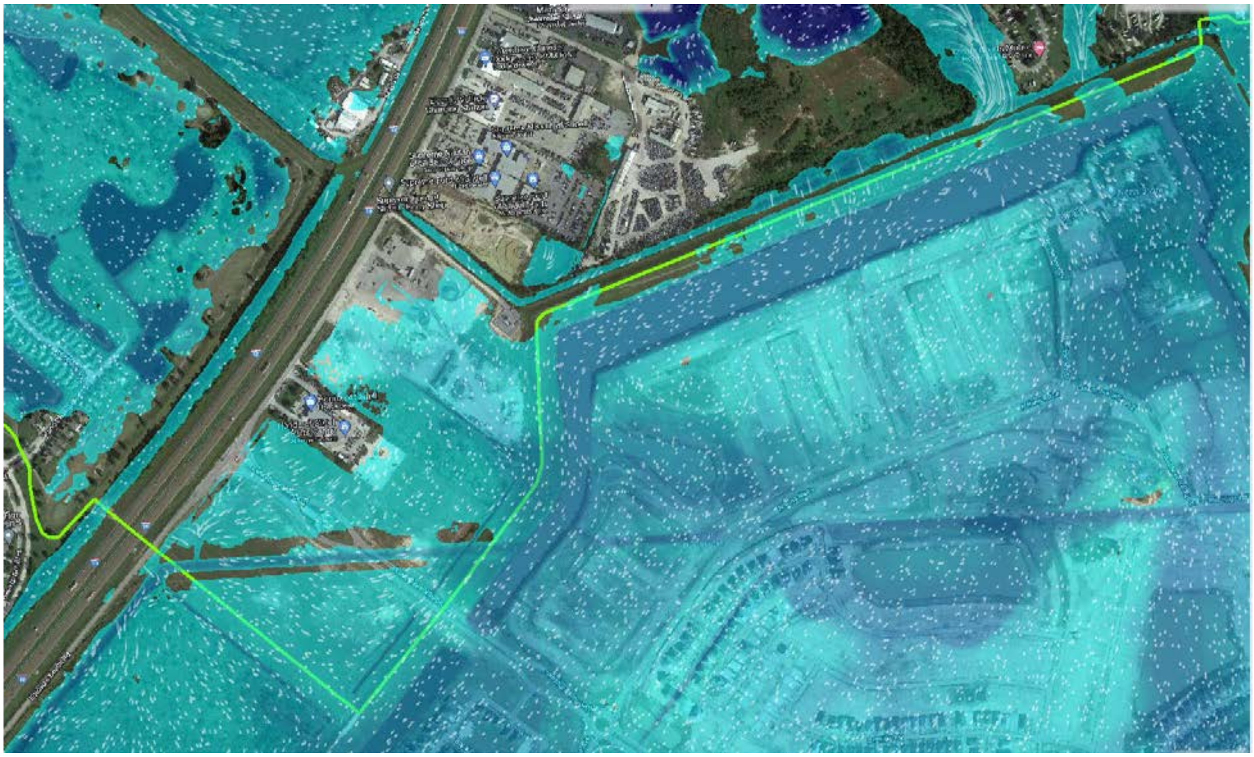


Figure E5:30. Segment 10 With Project

Segment 11

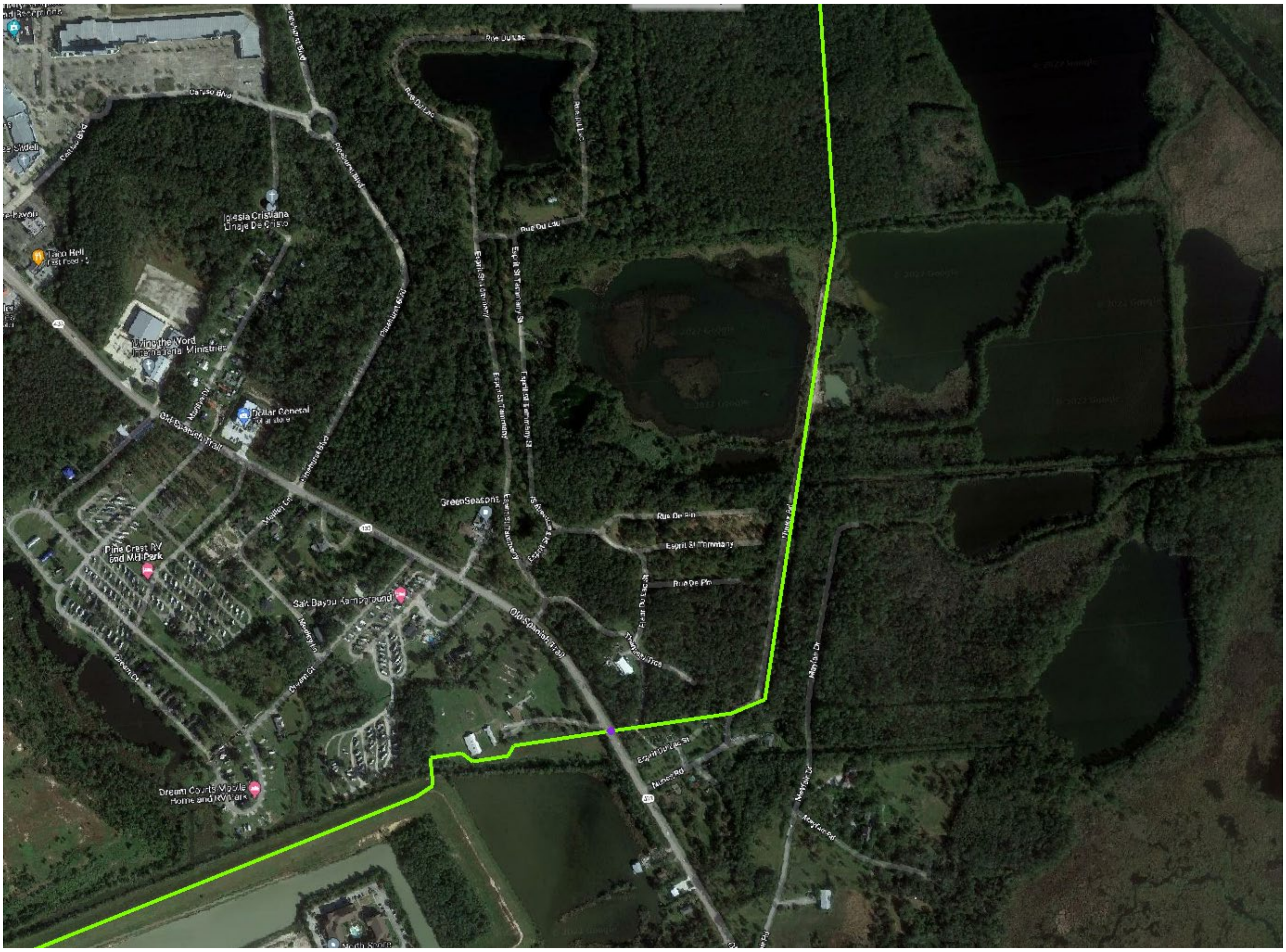


Figure 5:31. Segment 11

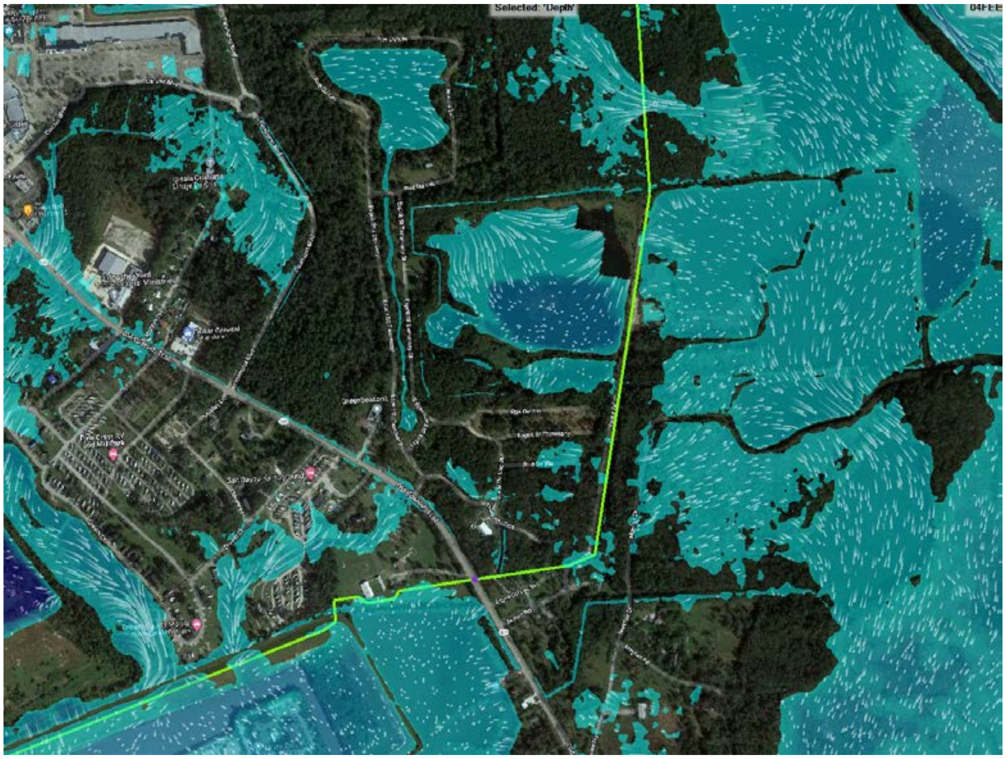


Figure E5:32. Segment 11 Existing Conditions

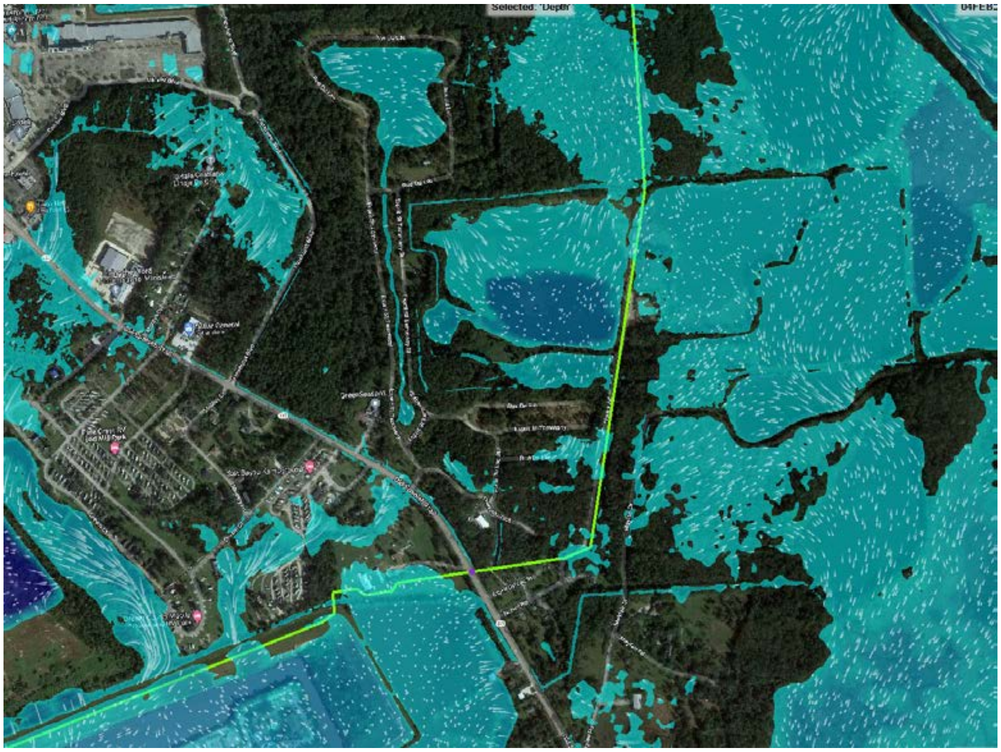


Figure E5:33. Segment 11 With Project

Segment 12

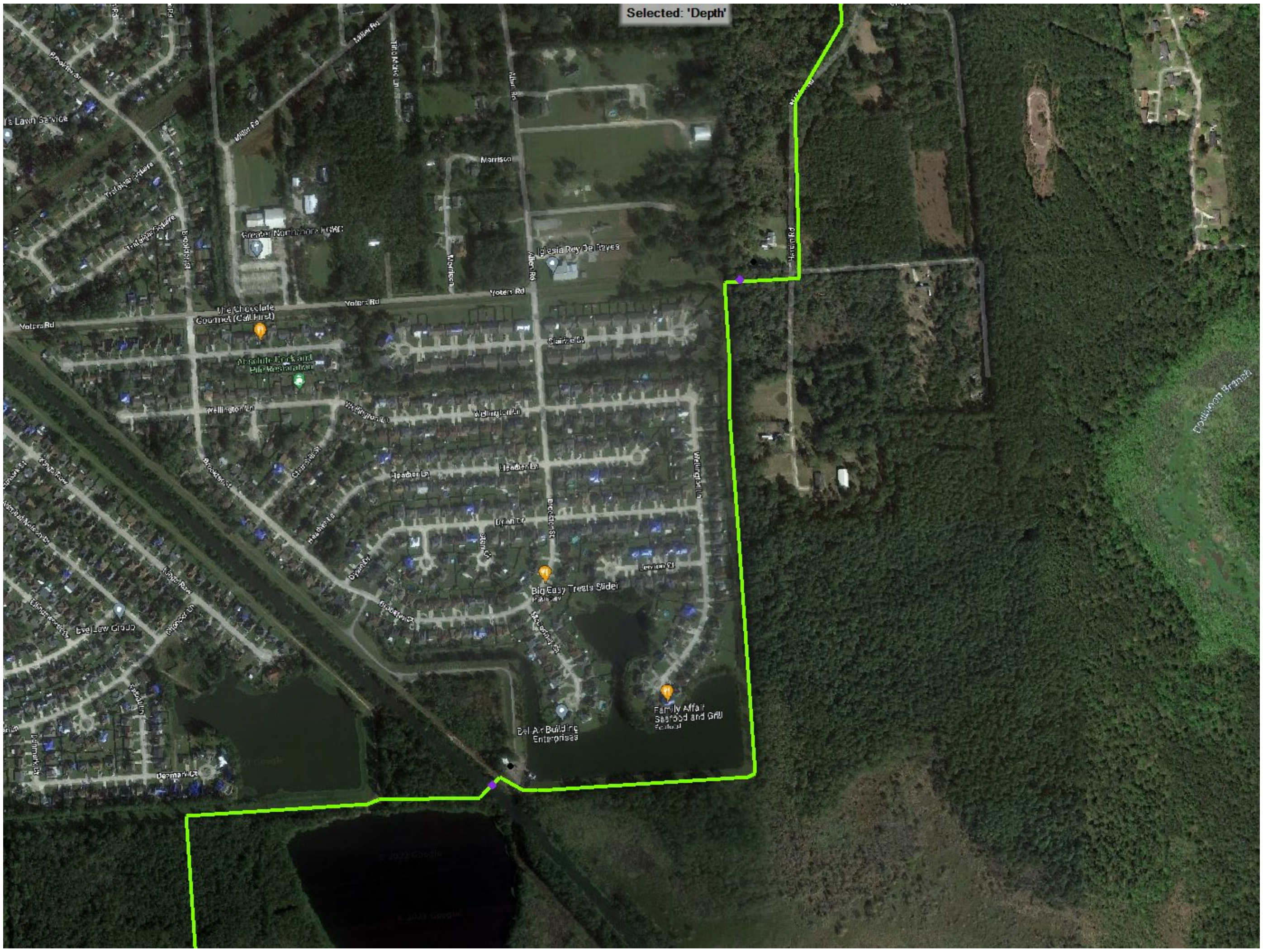


Figure E5:34. Segment 12

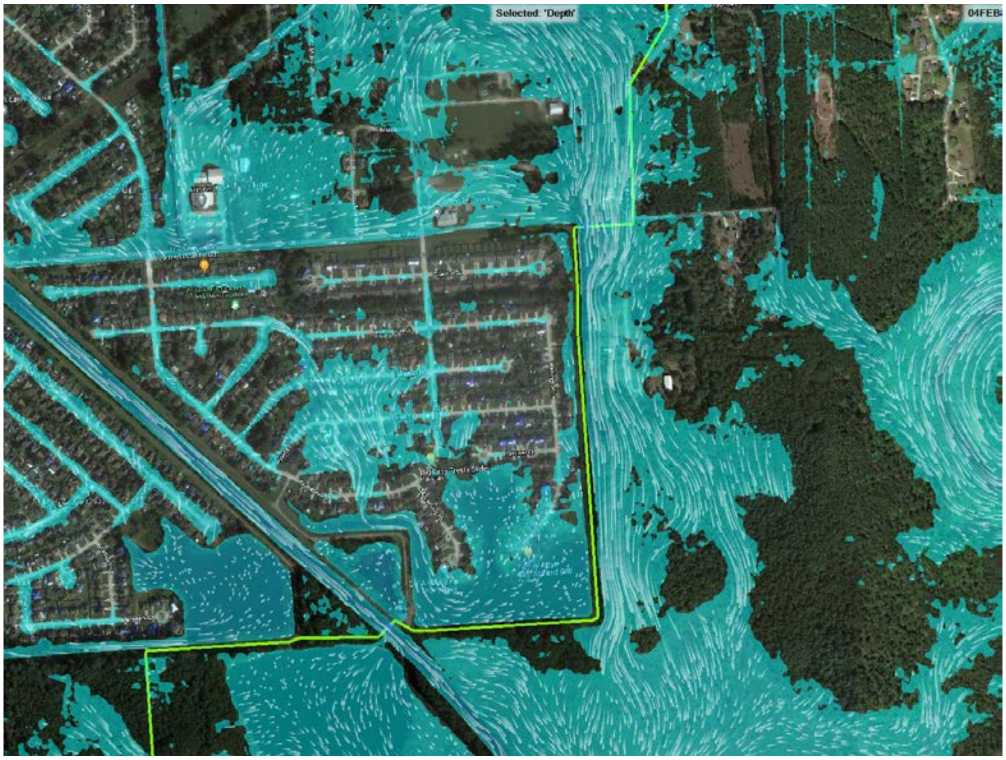


Figure E5:35. Segment 12 Existing Conditions

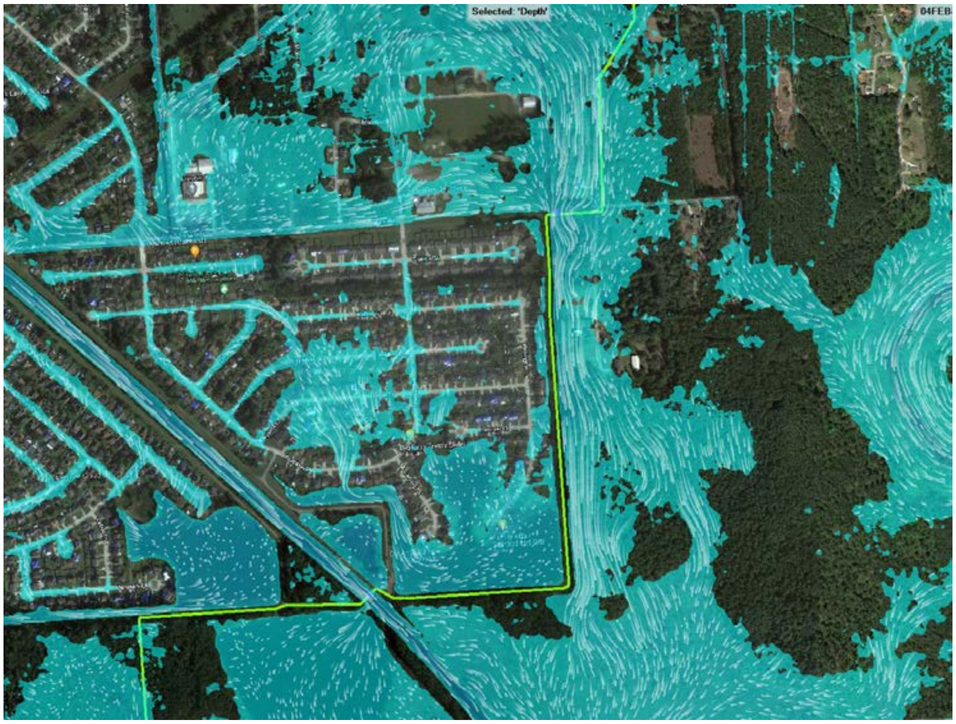


Figure 5:36. Segment 12 With Project

Segment 13

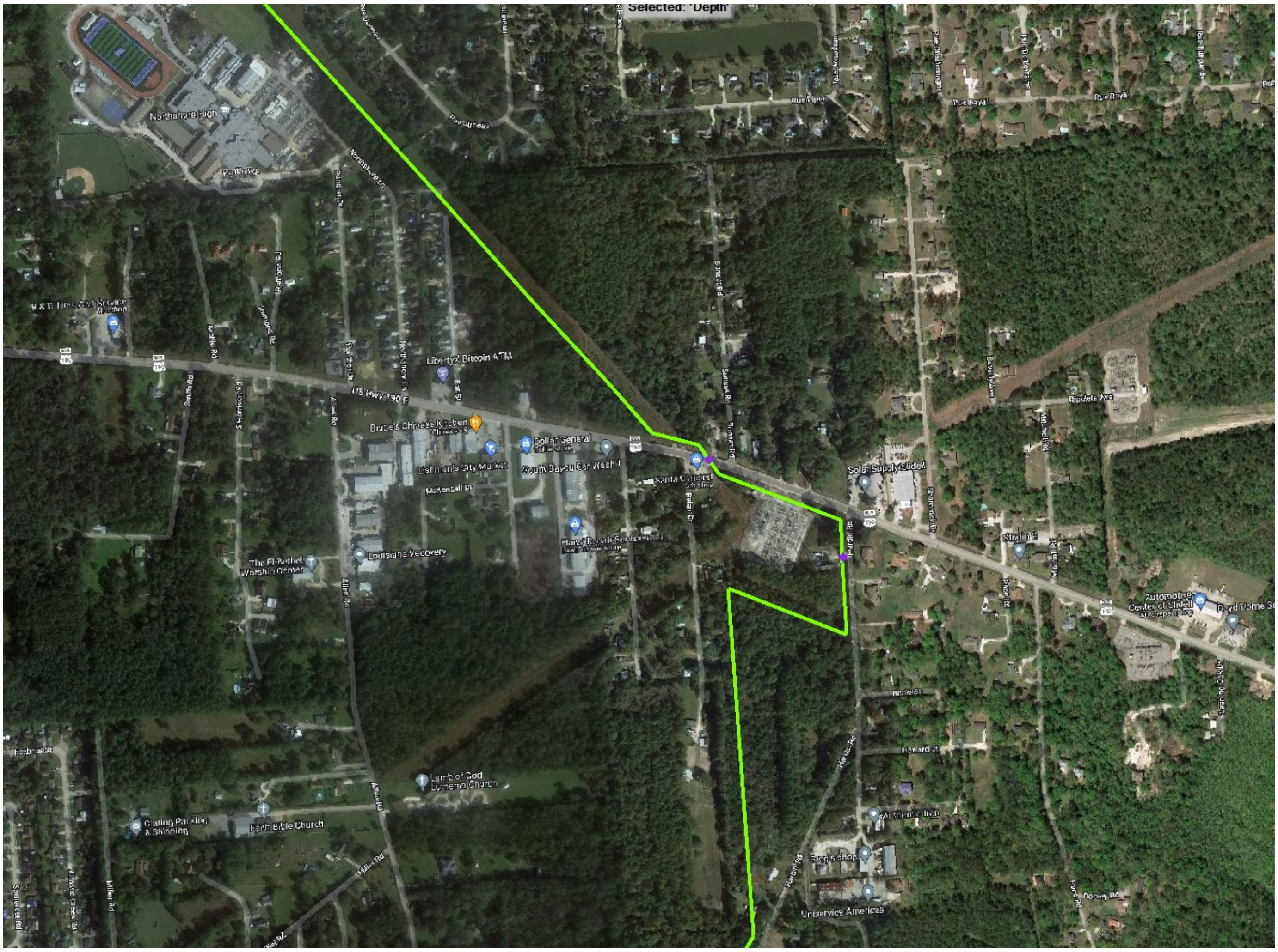


Figure 9. Segment 13

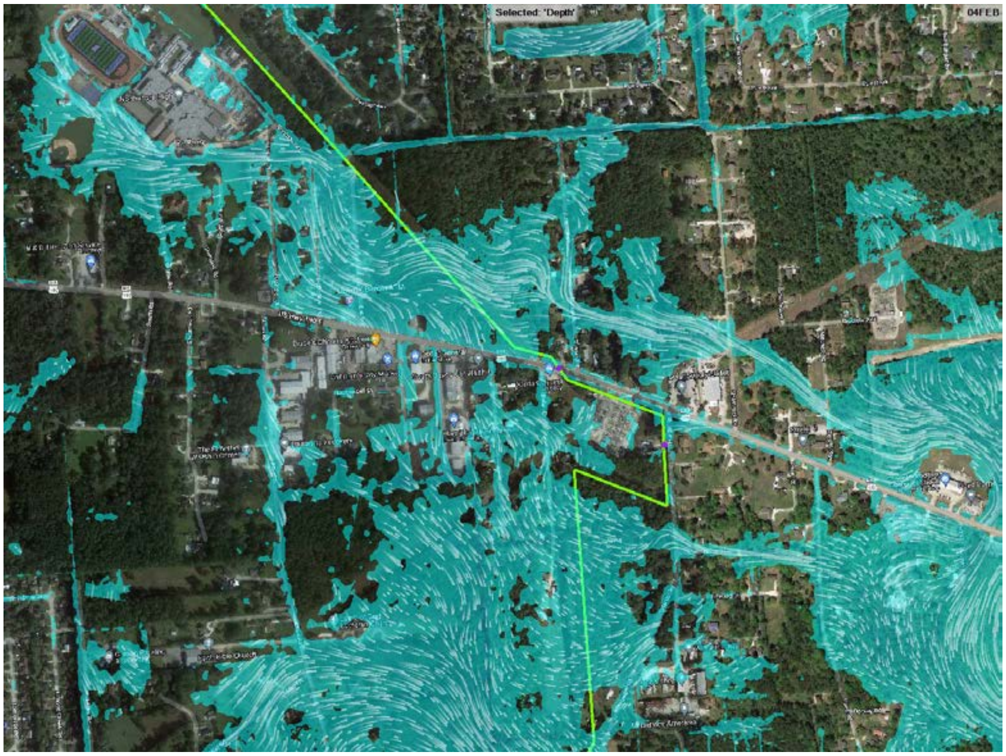


Figure E5:38. Segment 13 Existing Conditions

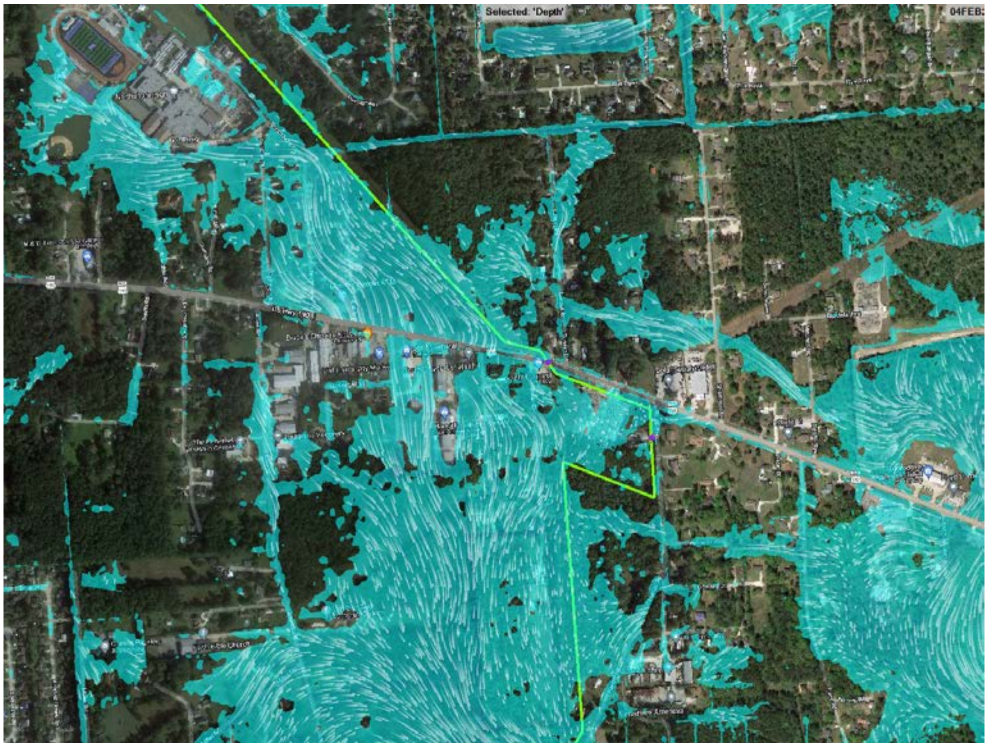


Figure E5:39. Segment 13 With Project

Segment 14

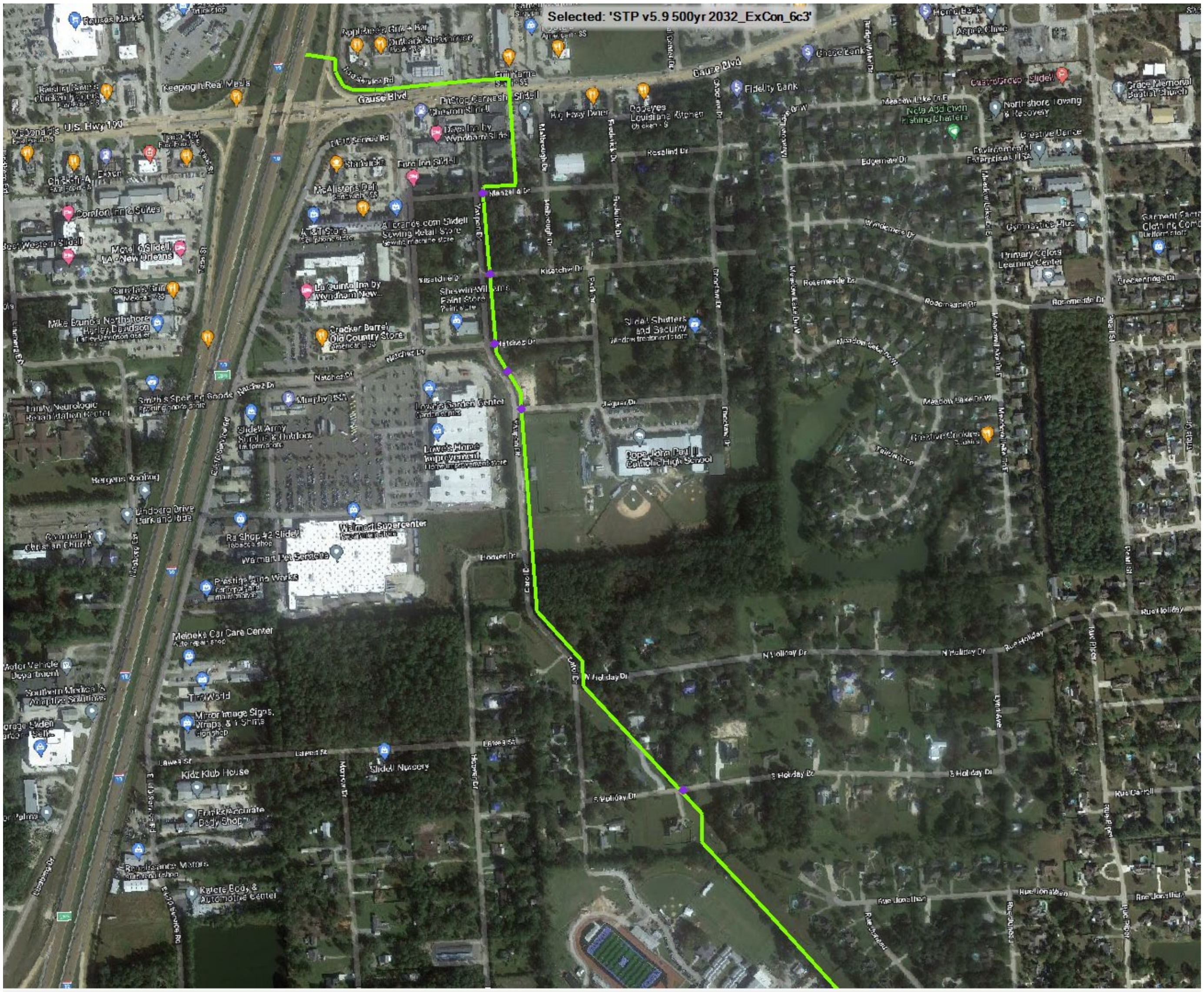


Figure E5:40. Segment 14

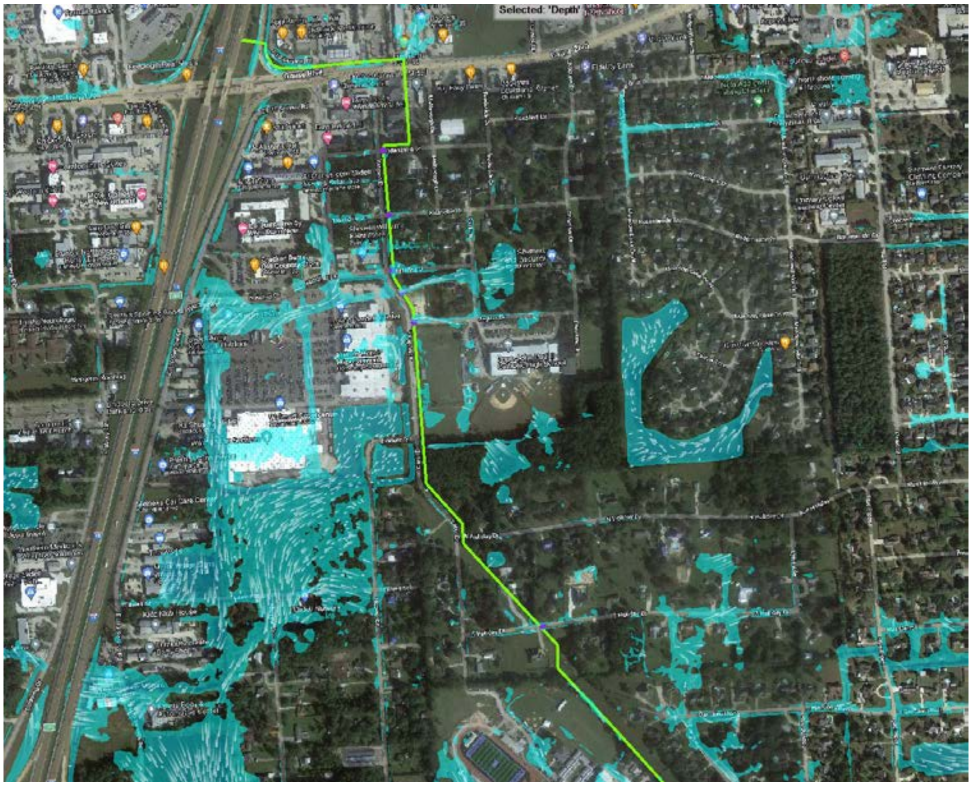


Figure E5:41. Segment 14 Existing Conditions

Figure E5:42. Segment 14 With Project

Segment 15

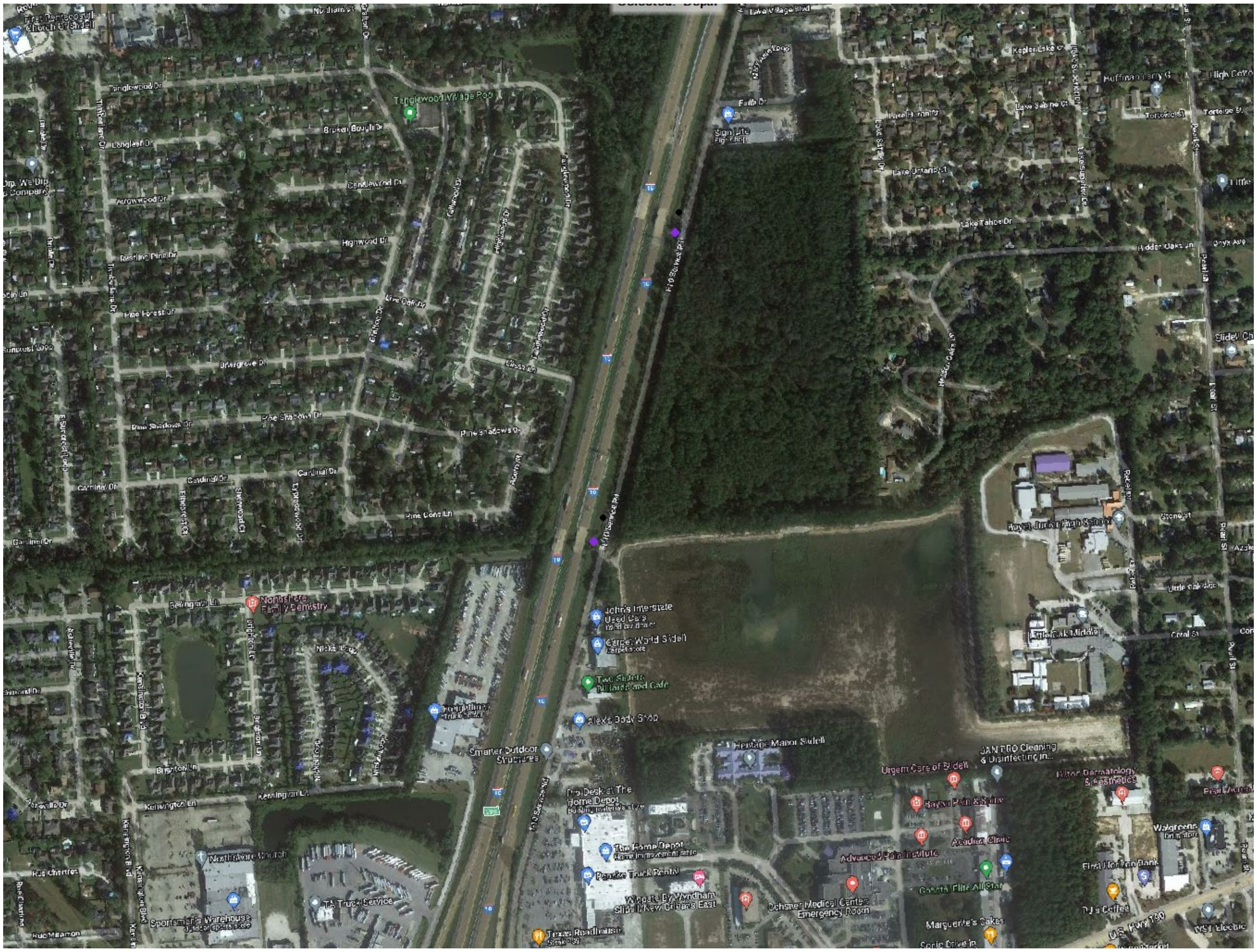


Figure E5:43. Segment 15

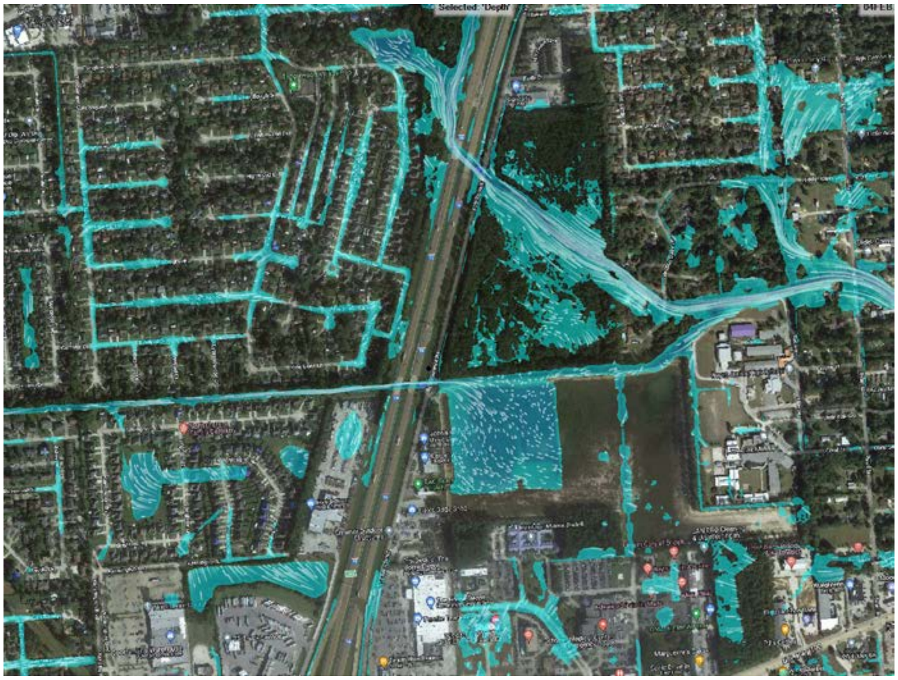


Figure E5:44. Segment 15 Existing Conditions

Figure E5:45. Segment 15 With Project

Annex E-6-Wet Point Hydrographs

Enclosed are WSE plots comparing the 2-year 2032 existing conditions run and with project run using the ISLR. WSE plots were pulled at points of interest provided by Environmental using the “wet points” shapefile. Points are ordered and labeled based on the “ID” field in the Shapefile, not the FID. The dates on the x axis are insignificant – simply a date selected for the modeling simulations, not indicative of a real event. The two lines show the results of the 50 percent AEP (“2 year”), 24-hr rainfall event. The blue line shows without-project conditions; the green line shows with-project conditions. In the with-project simulations shown in this document, Lake Pontchartrain was at a normal level with all drainage gates open for gravity drainage to occur. None of the proposed pumps are operating in the results shown in this document. Given the lack of channel surveys and ditch dimensions, error and uncertainty for the results shown in these plots cannot be ignored. However, trends and the order of magnitude of differences are considered reliable.

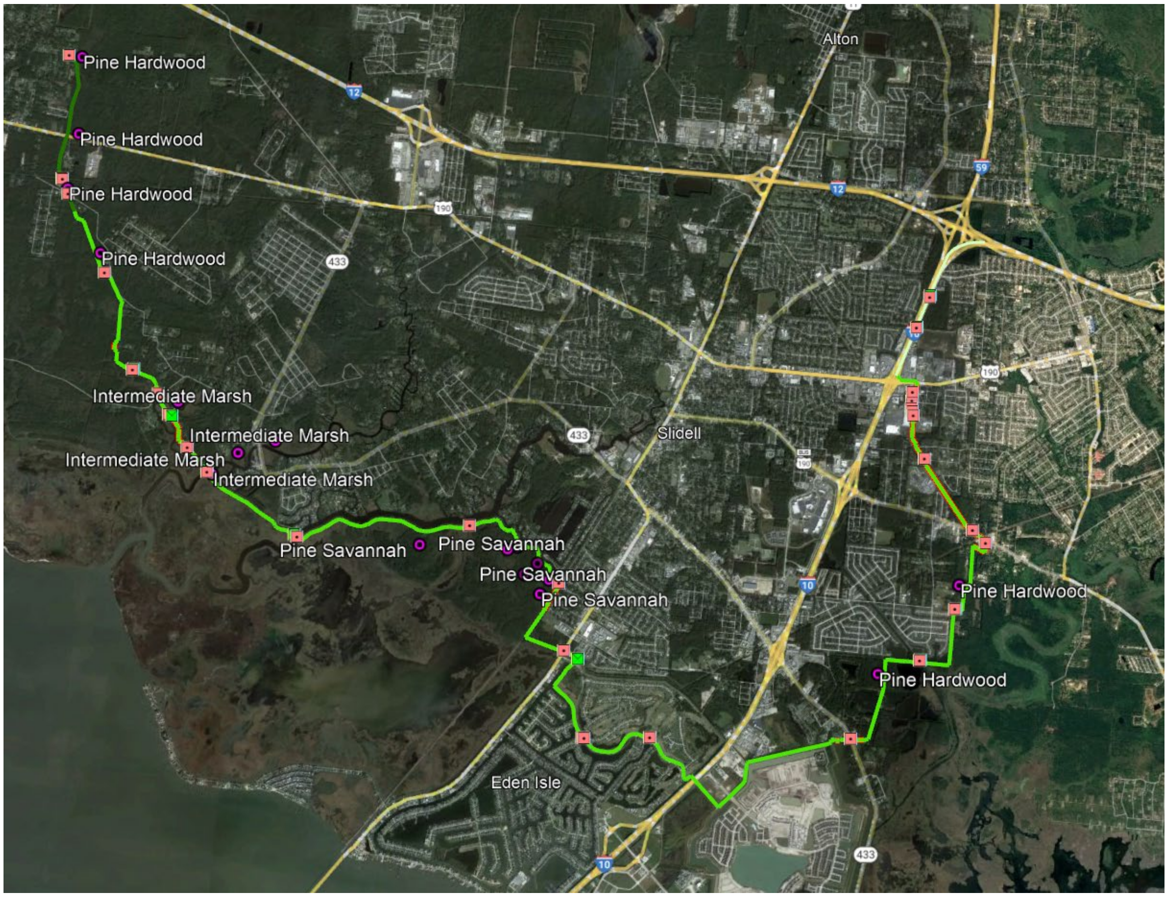


Figure E6:1. Alternative 6c3 RP Alignment

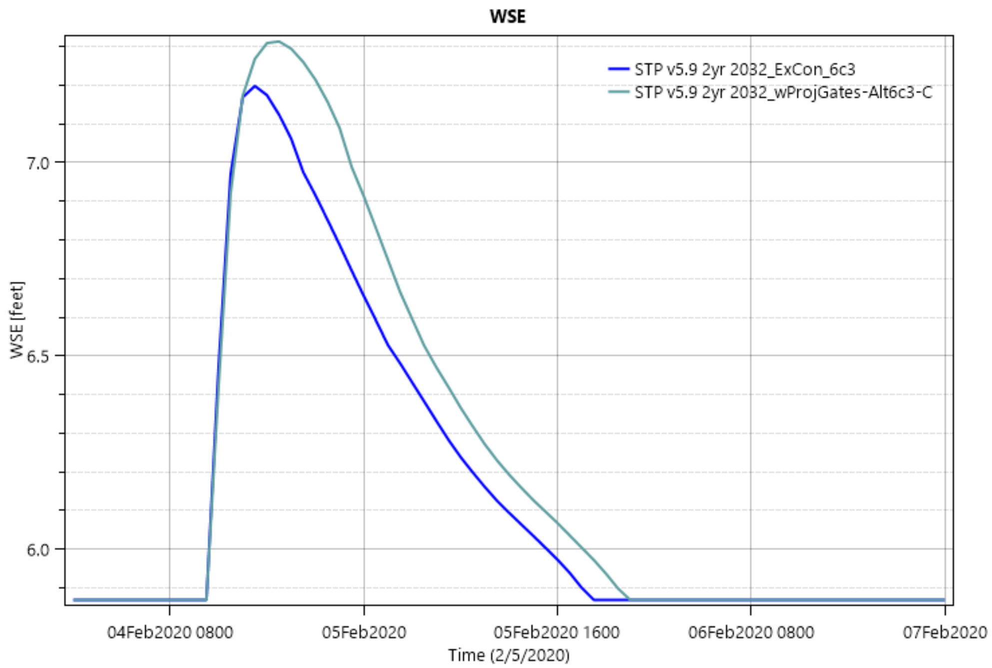


Figure E6:2. Point ID 1 - Pine Hardwood. Point is located on the protected side of the alignment North of Kingspoint Levee. WSE returns to pre-project levels within 36 hours.

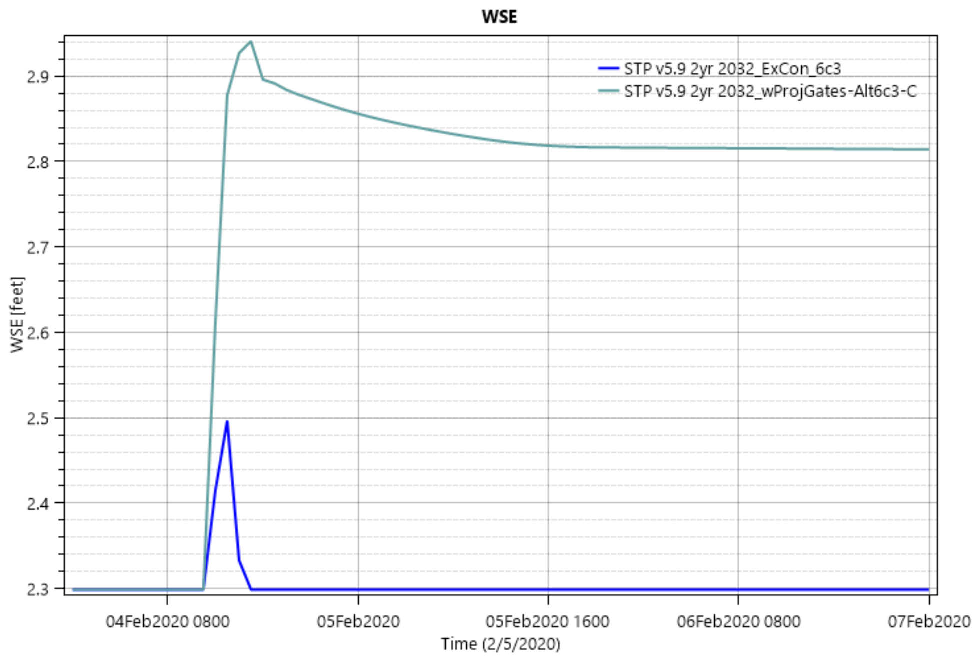


Figure E6:310. Point ID 2 - Pine Hardwood. Point is located on the protected side of the alignment South of Kingspoint Levee. WSE remains elevated through the end of the simulation because an existing drainage path is obstructed. There are no structures in close proximity to this inducement, therefore, a gate was not identified at this location.

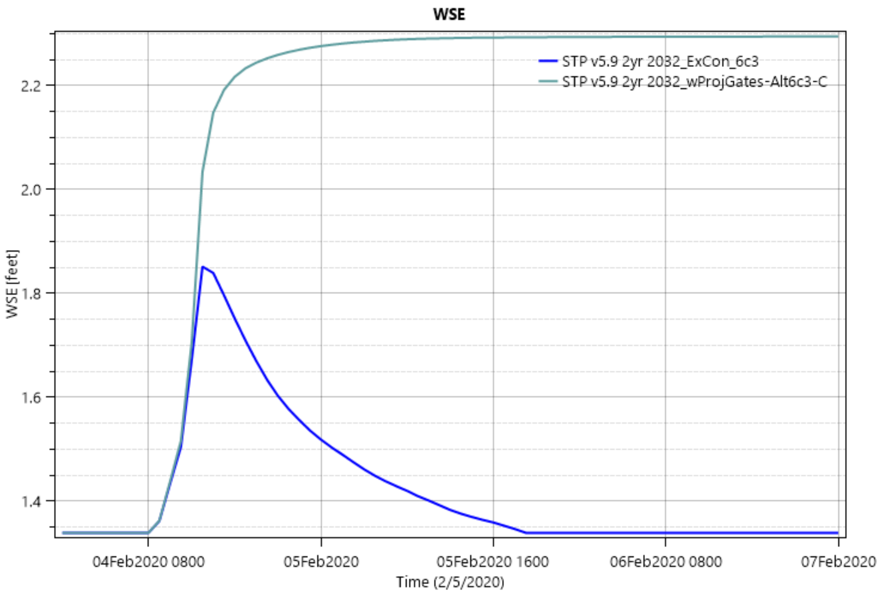


Figure E6:4. Point ID 3 - Pine Savannah. Point is located on the flood side of the alignment West of the Norfolk Southern Railroad. Water in this area moves from South to North and flows into Bayou Bonfouca. WSE remains elevated near the end of the simulation because the levee is obstructing the existing drainage path of water, forcing it to pool on the flood side of the alignment.

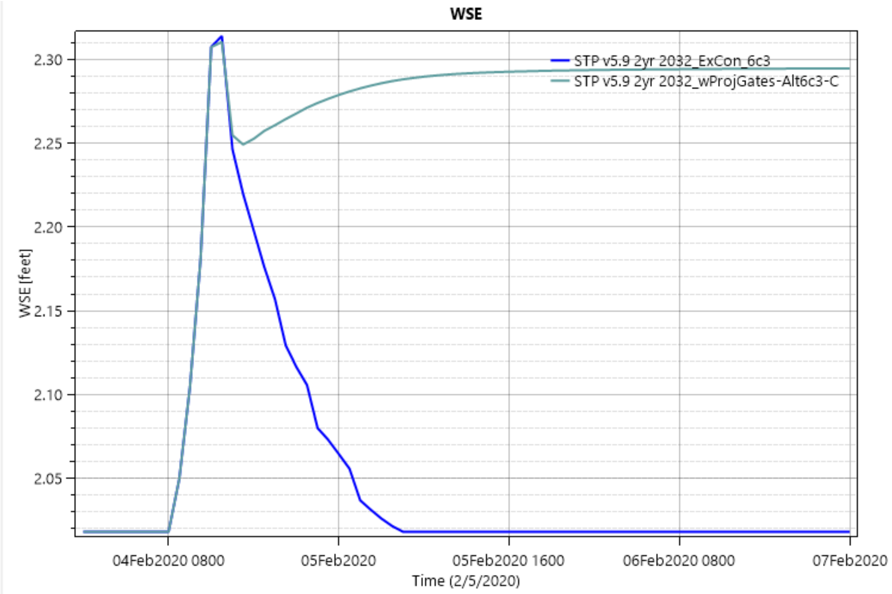


Figure E6:5. Point ID 4 - Pine Savannah. Point is located on the flood side of the alignment West of the Norfolk Southern Railroad. Water in this area moves from South to North and flows into Bayou Bonfouca. WSE remains elevated near the end of the simulation because the levee is obstructing the existing drainage path of water, forcing it to pool on the flood side of the alignment.

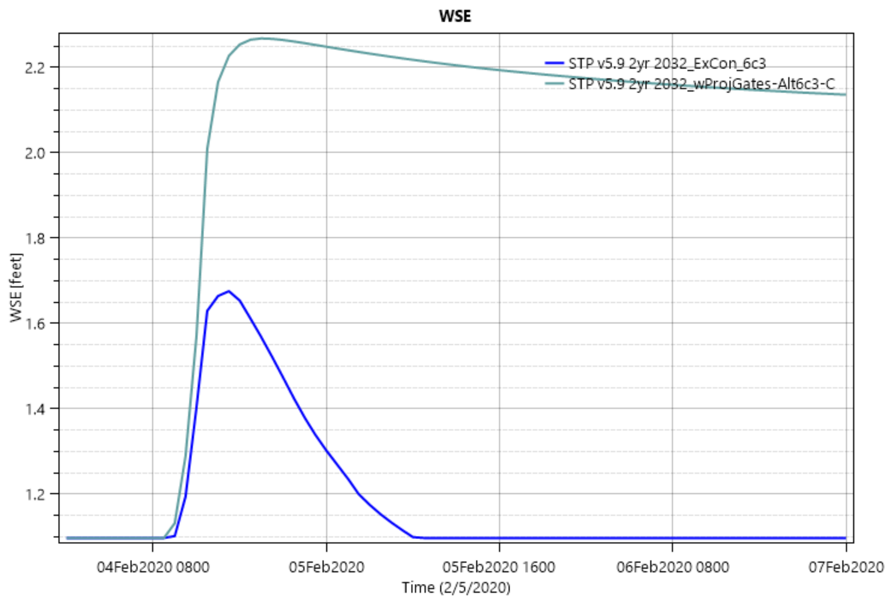


Figure E6:6. Point ID 5 - Pine Savannah. Point is located on the flood side of the alignment West of the Norfolk Southern Railroad. Water in this area moves from South to North and flows into Bayou Bonfouca. WSE remains elevated near the end of the simulation because the levee is obstructing the existing drainage path of water, forcing it to pool on the flood side of the alignment.

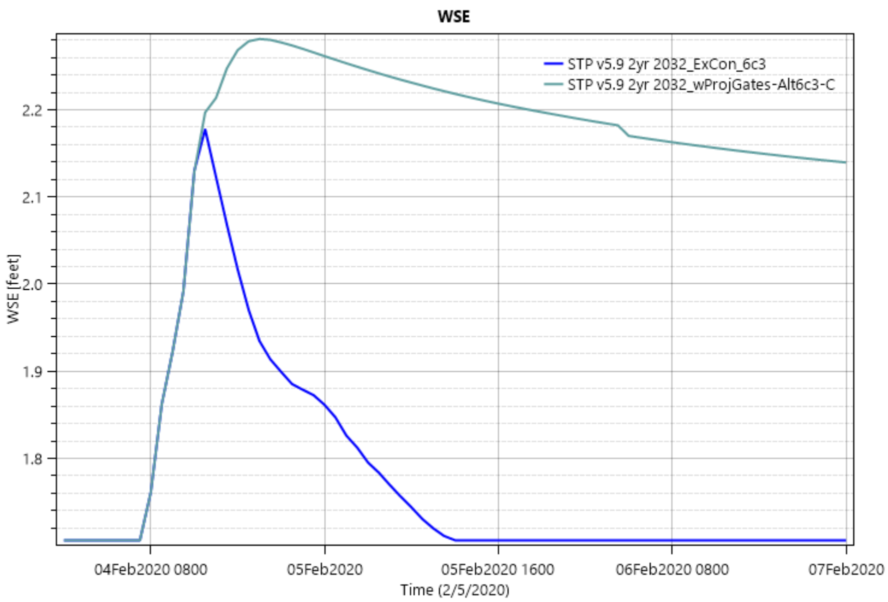


Figure E6:7. Point ID 6 - Pine Savannah. Point is located on the flood side of the alignment West of the Norfolk Southern Railroad. Water in this area moves from South to North and flows into Bayou Bonfouca. WSE remains elevated near the end of the simulation because the levee is obstructing the existing drainage path of water, forcing it to pool on the flood side of the alignment.

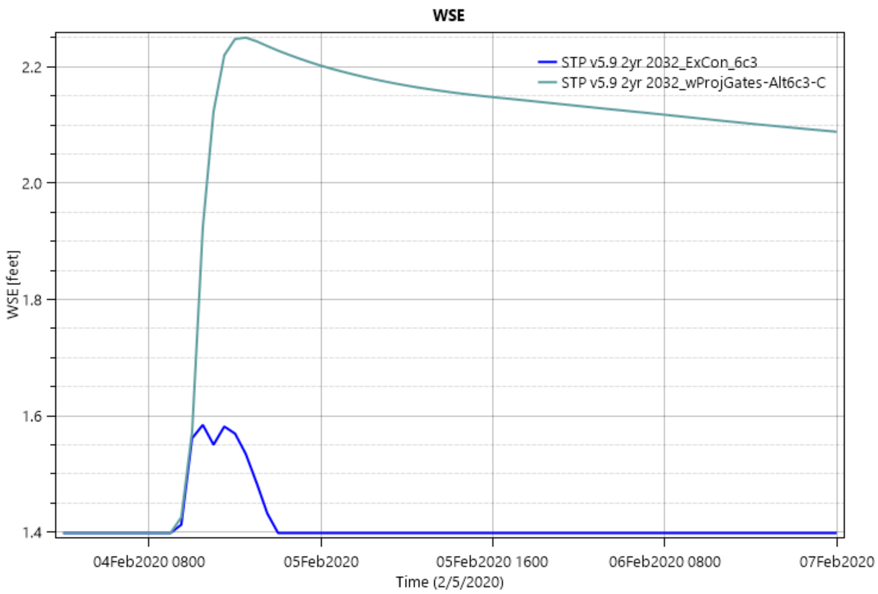


Figure E6:8. Point ID 7 - Pine Savannah. Point is located on the flood side of the alignment West of the Norfolk Southern Railroad. Water in this area moves from South to North and flows into Bayou Bonfouca. WSE remains elevated near the end of the simulation because the levee is obstructing the existing drainage path of water, forcing it to pool on the flood side of the alignment.

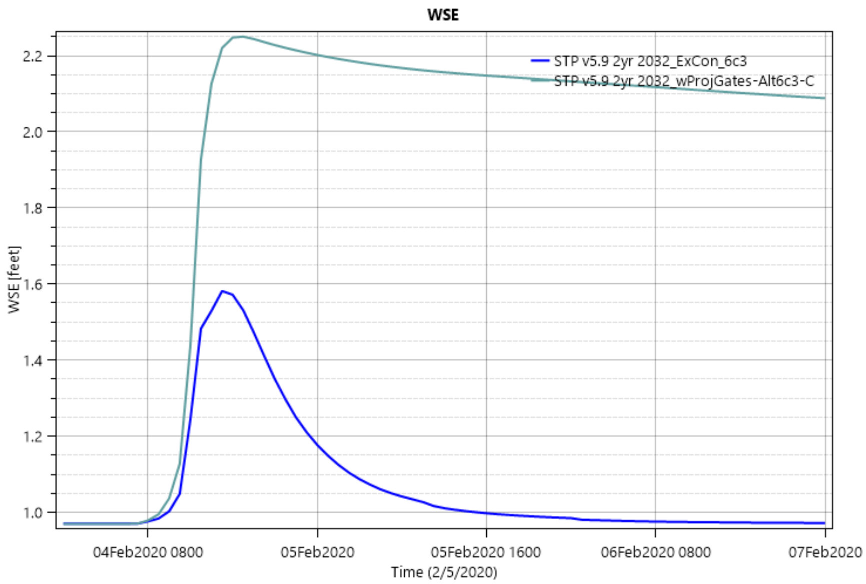


Figure E6:9. Point ID 8 - Pine Savannah. Point is located on the flood side of the alignment West of the Norfolk Southern Railroad. Water in this area moves from South to North and flows into Bayou Bonfouca. WSE remains elevated near the end of the simulation because the levee is obstructing the existing drainage path of water, forcing it to pool on the flood side of the alignment.

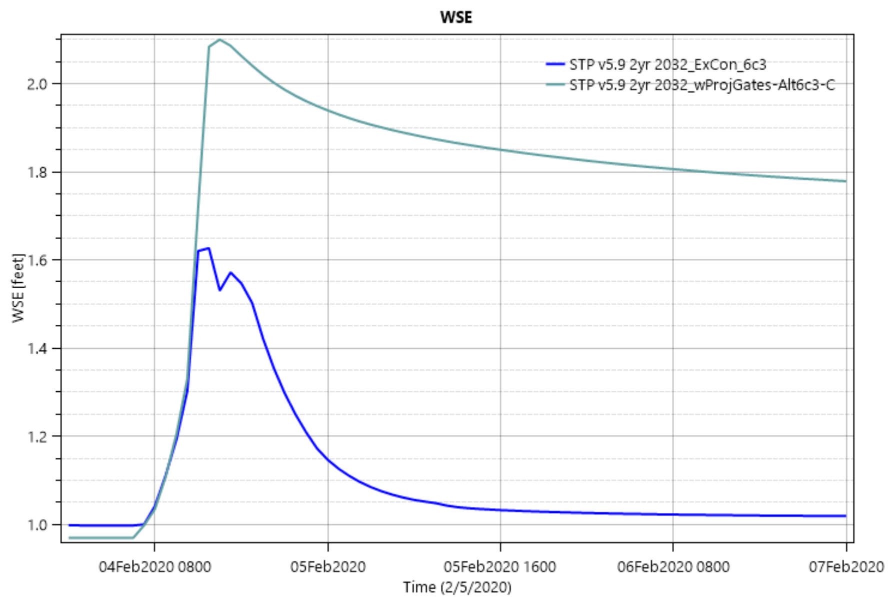


Figure E6:10. Point ID 9 - Pine Savannah. Point is located on the flood side of the alignment West of the Norfolk Southern Railroad and on the left descending bank of Bayou Bonfouca. Water in this location drains into Bayou Bonfouca. WSE remains elevated near the end of the simulation because the levee is obstructing the existing drainage path of water, forcing it to pool on the flood side of the alignment.

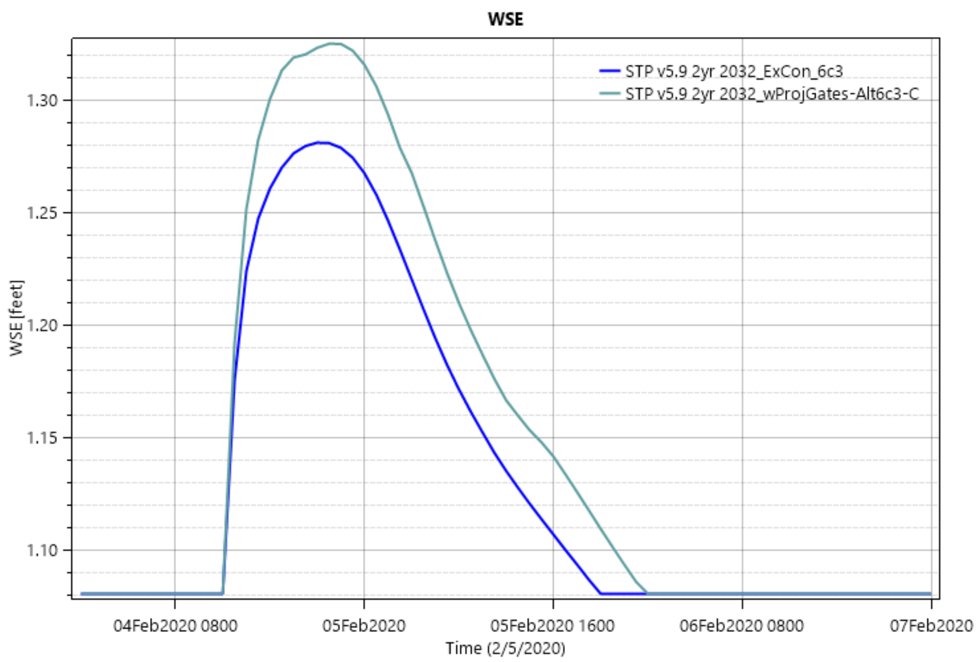


Figure E6:11. Point ID 10 - Intermediate Marsh. Point is located on the protected side of the alignment on the left descending bank of Bayou Liberty. WSE returns to pre-project levels within 36 hours.

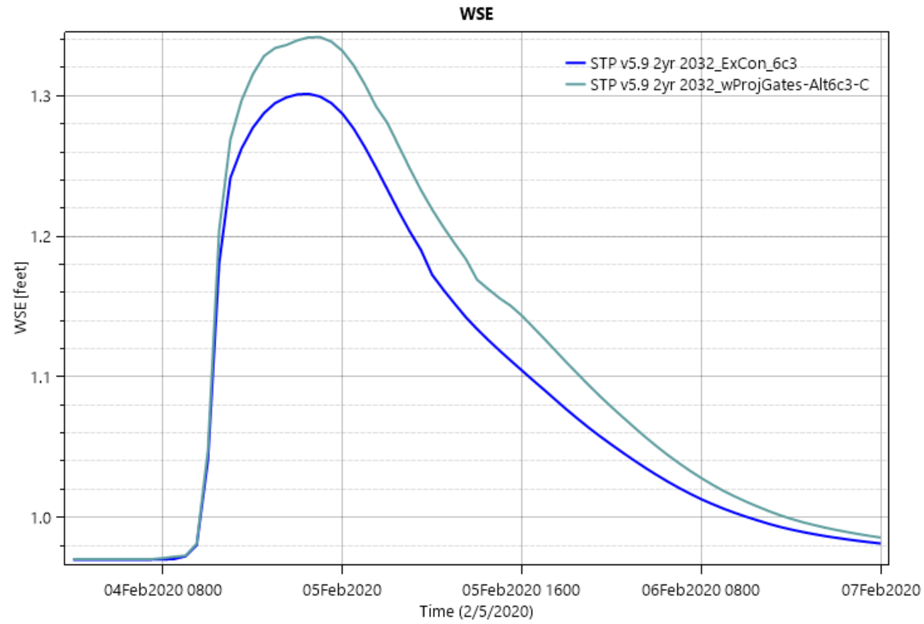


Figure E6:12. Point ID 11 - Intermediate Marsh. Point is located on the protected side of the alignment on the right descending bank of Bayou Liberty approximately 0.4miles upstream of the gate crossing. WSE returns near pre-project levels by the end of the simulation.

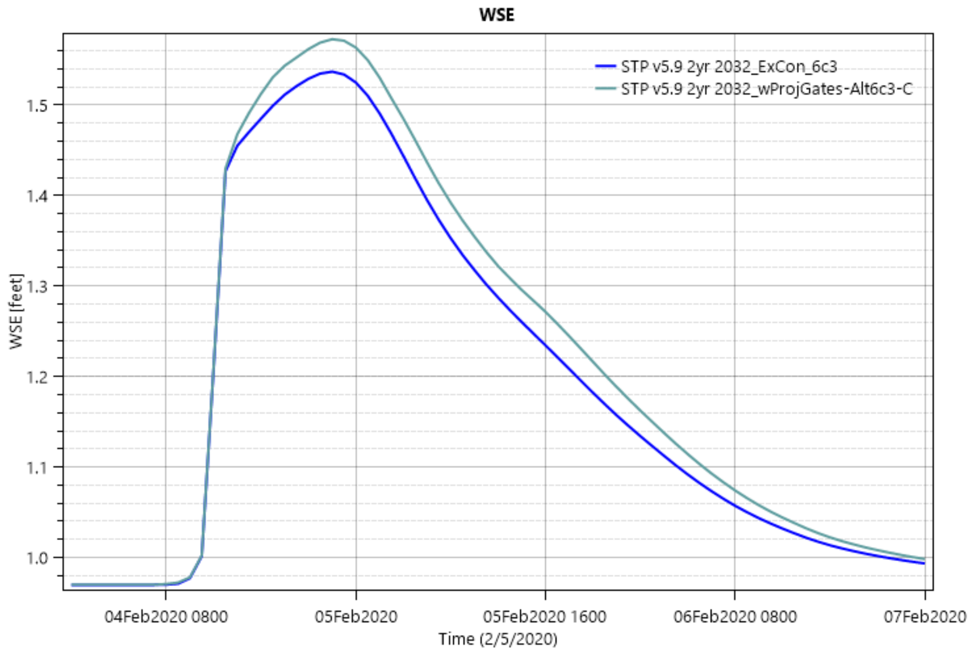


Figure E6:13. Point ID 12 - Intermediate Marsh. Point is located on the protected side of the alignment on the right descending bank of Bayou Liberty approximately 0.7miles upstream of the gate crossing. WSE returns to near pre-project levels by the end of the simulation.

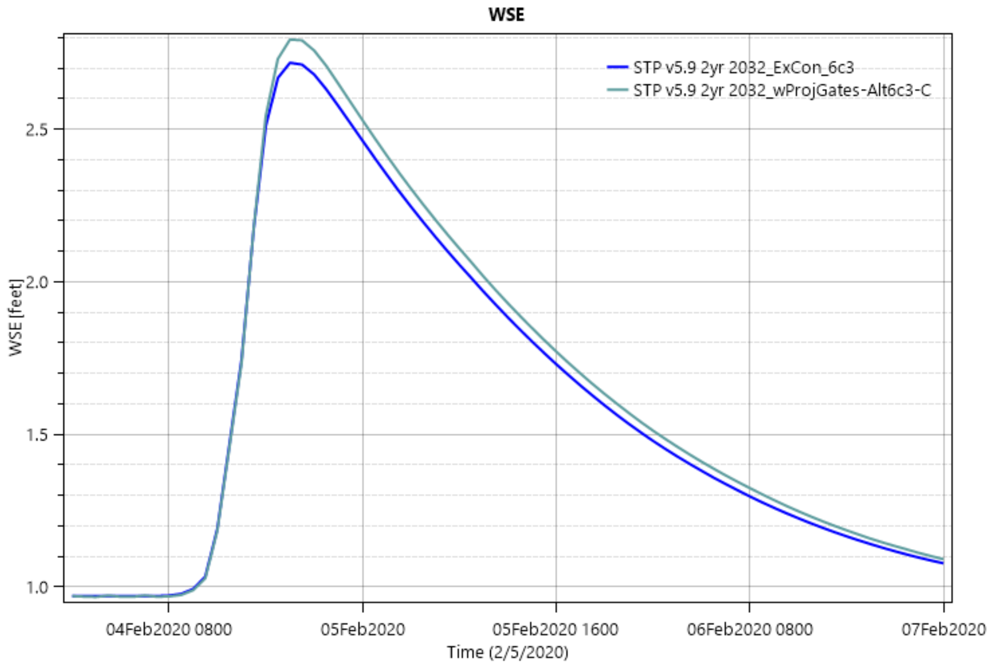


Figure E6:14. Point ID 13 - Intermediate Marsh. Point is located on the protected side of the alignment in the Bayou Paquet floodplain. WSE returns to near pre-project levels by the end of the simulation.

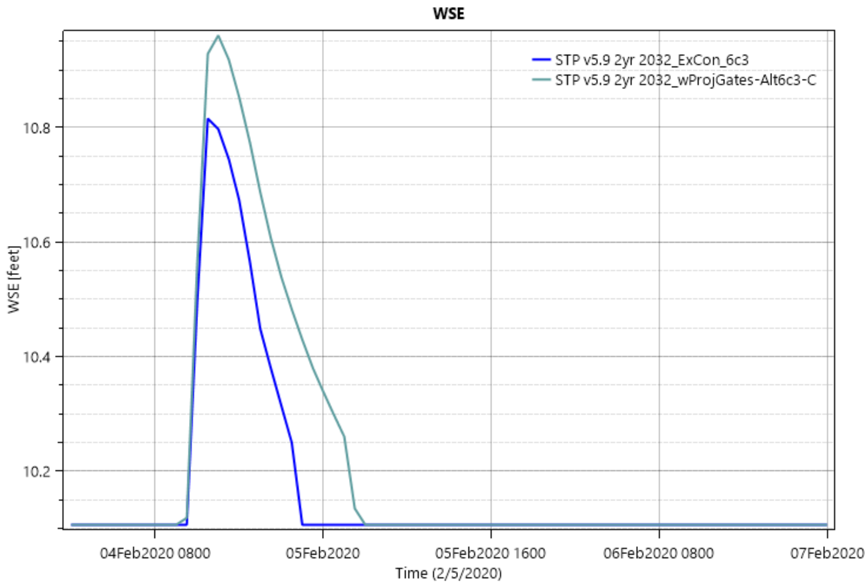


Figure E6:15. Point ID 14 - Pine Hardwood. Point is located on the protected side of the alignment near CC Road. WSE returns to pre-project levels within 36 hours.

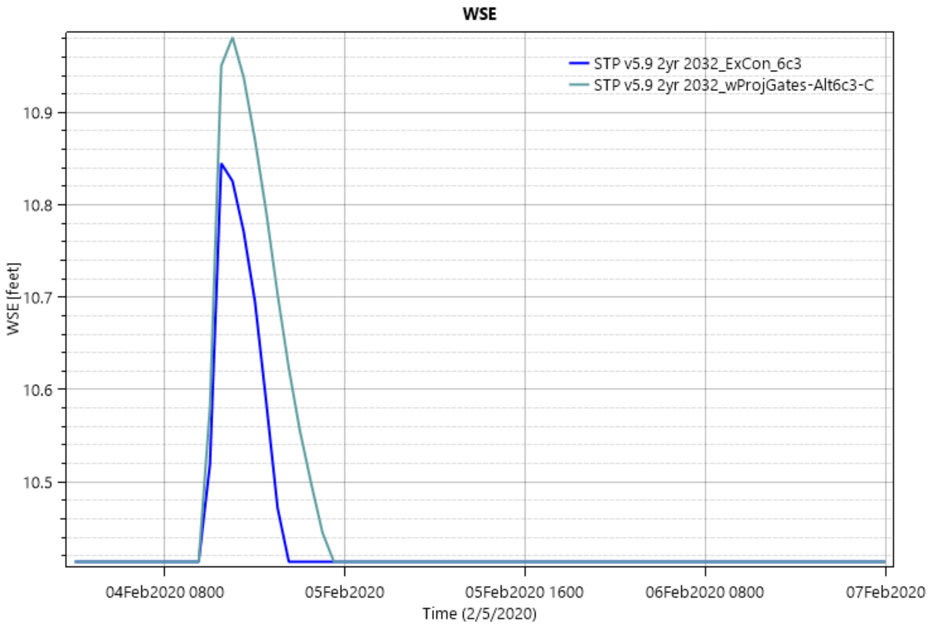


Figure E6:16. Point ID 15 - Pine Hardwood. Point is located on the protected side of the alignment South of the Tammany Trace trail. WSE returns to pre-project levels within 36 hours.

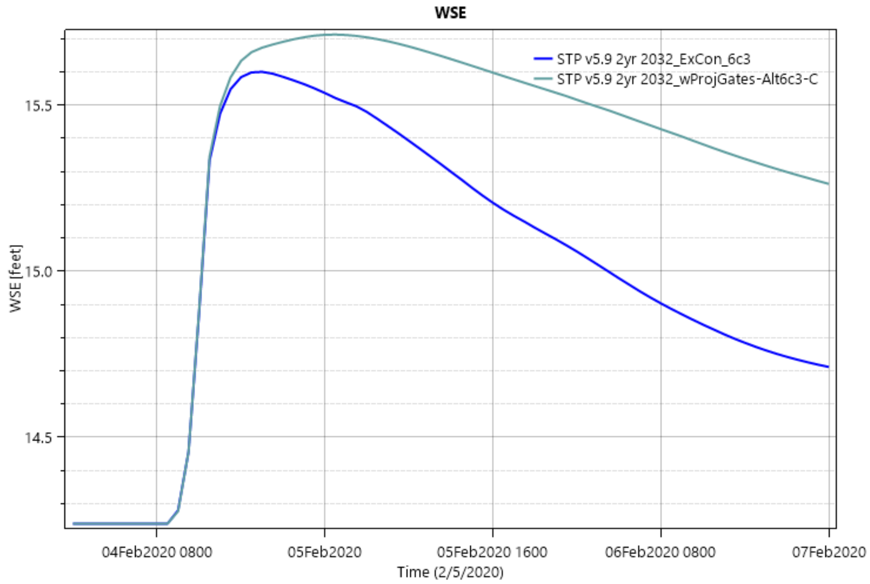


Figure E6:17. Point ID 16 - Pine Hardwood. Point is located on the protected side of the alignment North of the Hwy 190 embankment. WSE remains elevated through the end of the simulation because the highway embankment and levee interface create a pocket where water can pool.

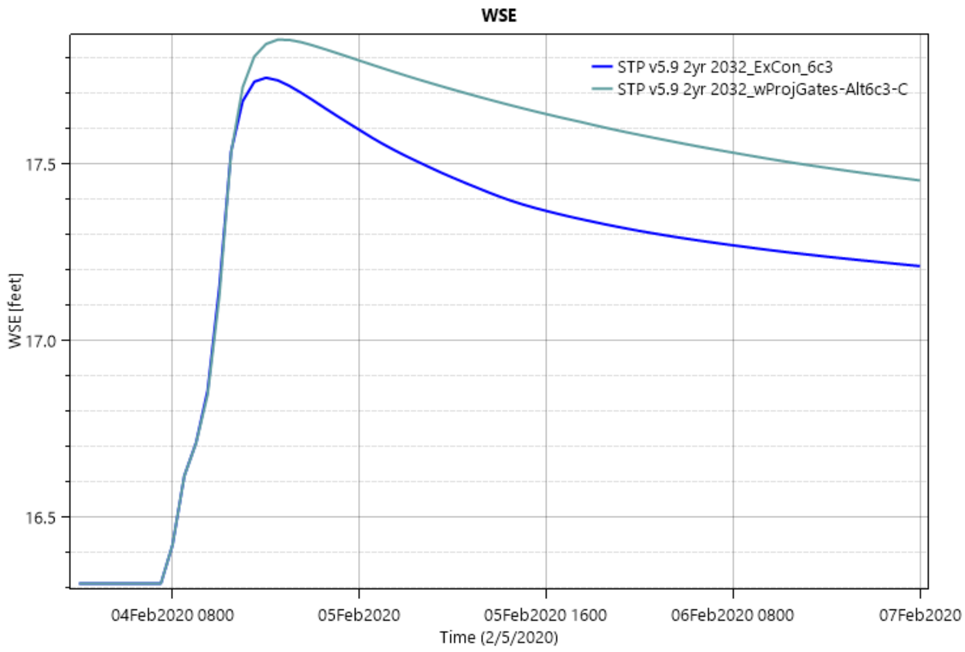


Figure 6:18. Point ID 17 - Pine Hardwood. Point is located on the protected side of the alignment near the Western terminus. WSE remains elevated through the end of the simulation because the drainage path is being obstructed from the North to South. There are no structures in close proximity to this inducement, therefore, a gate was not identified at this location.

Annex E-7-Definitions of HEC-RAS Simulation Plan Titles

Table E7:1. HEC-RAS run descriptions for ISLR runs

HEC-RAS Run Descriptions for Intermediate SLR Runs	
Plan Title	**Run Description**
STP V5.9 2yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 5yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 10yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 25yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 50yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 100yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP V5.9 200yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 500yr 2032_ExCon_6c3-Freq Flows	Existing Condition geometry, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 2yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 5yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 10yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 25yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 50yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 100yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP V5.9 200yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP V5.9 500yr 2082_ExCon_6c3-Freq Flows	Existing Condition geometry, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_wProjGate-6c3-C-FF	With-project geometry-gates open, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 200yr 2032_wProjGate-6c3-C-FF	With-project geometry-gates open, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2032_wProjGate-6c3-C-FF	With-project geometry-gates open, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry-gates open, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2082_wProjGate-6c3-C-FF	With-project geometry-gates open, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 200yr 2082_wProjGate-6c3-C-FF	With-project geometry-gates open, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2082_wProjGate-6c3-C-FF	With-project geometry-gates open, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 200yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2032_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2082_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2082_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2082_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2082_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2082_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 200yr 2082_w/ProjGatess-Alt6c3-C	With-project geometry-gates open, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2082_w/ProjGates-Alt6c3-C	With-project geometry-gates open, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 200yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2032_w/ProjPumps-Alt6c3	With-project geometry-pumping, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 200yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2082_w/ProjPumps-Alt6c3	With-project geometry-pumping, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

Table E7:2. HEC-RAS run descriptions for LSLR and HSLR runs

HEC-RAS Run Descriptions for Low and High SLR Runs	
Plan Title	**Run Description**
STP v5.9 2yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 100yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 200yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2032_ExCon_6c3_LowSLR	Existing condition geometry, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 100yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 200yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2082_ExCon_6c3_LowSLR	Existing condition geometry, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 100yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 200yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2032_ExCon_6c3_HighSLR	Existing condition geometry, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 100yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 200yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2082_ExCon_6c3_HighSLR	Existing condition geometry, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 2yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 5yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 10yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 25yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*

STP v5.9 50yr 2032_wProjGate-Alt6c3-C-FF	With-project geometry, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 100yr 2032_wProjGate-6c3-C-FF	With-project geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 200yr 2032_wProjGate-6c3-C-FF	With-project geometry, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 500yr 2032_wProjGate-6c3-C-FF	With-project geometry, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 2yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 5yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*

STP v5.9 10yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 25yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 50yr 2082_wProjGate-Alt6c3-C-FF	With-project geometry, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 100yr 2082_wProjGate-6c3-C-FF	With-project geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 200yr 2082_wProjGate-6c3-C-FF	With-project geometry, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*
STP v5.9 500yr 2082_wProjGate-6c3-C-FF	With-project geometry, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Intermediate SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions. *These plans have been run in the Intermediate SLR model*

STP v5.9 2yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 200yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the LowSLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2032_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 2yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the LowSLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 200yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2082_wProjGate-Alt6c3-C-FF_LSLR	With-project geometry, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 2yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 2yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 5yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 25yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 50yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 200yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 200yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 500yr 2032_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 500yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 2yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 2yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 5yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 5yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 25yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 25yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 50yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 50yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP 100yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP 200yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 200yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP 500yr 2082_wProjGate-Alt6c3-C-FF_HSLR	With-project geometry, 500yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, calculated coincident frequency inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 10yr 2032_ExCon_6c3-Mean_LSLR	Existing condition geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_ExCon_6c3-Mean_LSLR	Existing condition geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_ExCon_6c3-Mean_LSLR	Existing condition geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2082_ExCon_6c3-Mean_LSLR	Existing condition geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_ExCon_6c3-Mean_HSLR	Existing condition geometry, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_ExCon_6c3-Mean_HSLR	Existing condition geometry, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_ExCon_6c3-Mean_HSLR	Existing condition geometry, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2082_ExCon_6c3-Mean_HSLR	Existing condition geometry, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.

STP v5.9 10yr 2032_w/ProjGates-Mean_LSLR	With-project run, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_w/ProjGates-Mean_LSLR	With-project run, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2082_w/ProjGates-Mean_LSLR	With-project run, 10yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2082_w/ProjGates-Mean_LSLR	With-project run, 100yr Precipitation event, computed future (2082) downstream boundary condition stages along Lake Pontchartrain for the Low SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 10yr 2032_w/ProjGates-Mean_HSLR	With-project run, 10yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
STP v5.9 100yr 2032_w/ProjGates-Mean_HSLR	With-project run, 100yr Precipitation event, computed baseline (2032) downstream boundary condition stages along Lake Pontchartrain for the High SLR scenario, historic mean inflows on the Bogue Chitto and Pearl River inflow boundary conditions.
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Mississippi Valley Division,
Regional Planning and Environment Division South

St. Tammany Parish, Louisiana Feasibility Study

Appendix E, Annex 1 – Adaptation

February 2024

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CONTENTS

SECTION 1

ADAPTATION TRIGGERS, TRACKING, AND STRATEGIES

The main report and associated appendices detail how the Recommended Plan will effectively reduce flood and coastal storm risks to the study area, but the Recommended Plan's effectiveness may change over time given sea level changes (SLC) and/or varying storm season intensities with a warming climate. While EP 1100-2-1 (USACE, 2019) is used to understand a project's overall hazard exposure by

SLC scenarios, it also shows how displaying terrain and expected future water level cross sections at critical transects across the study area can help understand the project's inundation exposure and potential trigger points. Trigger points can be thought of in two ways for this study: either a vertical (which applies to nonstructural and structural features) or horizontal (limited to nonstructural features) threshold exceedance or a point in time where action should be considered.

1.1 ADAPATION TRIGGERS

The predominant coastal flood risk defined in this study is from coastal storm surge, as detailed in Appendix E, Hydrology and Hydrologic. Coastal storm surge is the total water level from sources such as a coastal storm's surge, wave setup/runup, tides, and projected SLC. The latter is especially important for St. Tammany Parish and surrounding communities, which are relatively low lying along the most southern portions of the Parish.

This means small changes in elevated water levels could exponentially increase the inundation exposure area but would likely be limited to the most southern portion of the study area. The exponential increase in coastal inundation risk, where the extreme SLC (high rate) in this study's analysis – 1% annual exceedance probability (AEP) still water level (SWL) – coupled with the mean higher water tide (MHHW) is shown for the 100 years from the base year (2032). The difference is roughly two feet of total water level (from 6.5 to 8.5 feet NAD88).

In Tables 1 and 2 the locations and threshold have been identified based on current gauge locations that are actively monitored using the trigger threshold of SLC greater than the intermediate rate based on calendar year which would mean the Recommended Plan may be less effective in reducing coastal storm risk. Additional gauge locations may be added during construction activities and O&M.

Table 1

Lake Pontchartrain at Mandeville Gauge (ID: 85575) Trigger (Western Portion of the Study Area)	
Years	Elevation NAVD 88 feet
2025	0.8
2026	0.8
2027	0.9
2032	1.0

Table 2

Rigolets at Hwy 90 at Slidell Gauge Trigger (Eastern Portion of the Study Area)	
Years	Elevation NAVD 88 feet
2025	0.6
2026	0.6
2027	0.6
2032	0.8

1.2 ADAPATION TRACKING AND STRATEGY

If the triggers are met, the NFS will contact USACE for notification. USACE would determine if significantly changed conditions have been identified and reevaluation of the Recommended Plan is required.