Mississippi Valley Division,
Regional Planning and Environment Division South

Tangipahoa Parish, Louisiana Feasibility Study

Appendix B – Tangipahoa Parish Feasibility Study Hydrology and Hydraulics Appendix

August 2024

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SECTION 1
General

1.1 DESCRIPTION OF WORK

The U.S. Army Corps of Engineers (USACE), Mississippi Valley Division (MVD), St. Louis District (CEMVS), with support from the New Orleans District (CEMVN), performed hydrologic and hydraulic modeling for the Tangipahoa 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) within the 823 square miles of Tangipahoa Parish. The focus of the proposed measures is on riverine flooding only. Coastal surge impacts are considered, but only used in the non-structural floodproofing alternatives in the zones of storm surge.

Hydraulic modeling was performed for the 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% annual exceedance probability (AEP) rainfall events for existing condition, base year (year 2033), and future condition (year 2083). Riverine flooding was a primary focus in the design of the proposed alternatives. However, coastal storm surge was accounted for as frequency-based water levels at the lower model downstream boundary. Coastal storm surge and wave modeling were used in determining surge water levels for the 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% AEP events. Water surface elevation results for each frequency were extracted and provided to the Project Delivery Team (PDT) for use in economic, environmental, and engineering analyses.

SECTION 2
Software and Model Development

2.1 HYDROLOGIC ENGINEERING CENTER – HYDROLOGIC MODELING SOFTWARE 4.11

USACE Hydraulic Engineering Center's (HEC)-Hydrologic Modeling System (HMS) version 4.11 (Beta 11) was used for the hydrologic modeling. Existing hydrologic models, created by Dewberry Engineers Inc., were used for the Tangipahoa River watershed. A new hydrologic model for the Natalbany River and Selser’s Creek watersheds was created by USACE for this study. These hydrologic models cover the entire Tangipahoa and Natalbany River watersheds.

2.2 HYDROLOGIC ENGINEERING CENTER – RIVER ANALYSIS SYSTEM 6.3.1

USACE Hydraulic Engineering Center's (HEC)-River Analysis System (RAS) version 6.3.1 was used for the hydraulic modeling. For the Tangipahoa watershed, the HEC-RAS models developed for this study began from three existing partially constructed models created by Dewberry Engineers Inc. These models cover the Tangipahoa River watershed starting at Osyka, MS, and ending where the Tangipahoa River terminates at Lake Pontchartrain. USACE finished building these models for this study.

An additional hydraulic model covering the Natalbany River and Selser’s Creek watersheds was created for this study. Starting at the upper reaches of their watersheds, this model ends where the rivers terminate at Lake Maurepas downstream. USACE built this model in its entirety.

2.3 ADVANCED CIRCULATION (ADCIRC) MODEL

Coastal models ADCIRC+SWAN were used to simulate storm surge and waves, respectively. Results from the 2017 CPRA ADCIRC+SWAN study (Roberts and Cobell, 2017) were utilized for the study. No ADCIRC model runs were completed. CEMVN’ 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 in the 2017 study.

SECTION 3
Hydrologic Modeling

3.1 BASIN HYDROLOGY

Tangipahoa Parish is comprised of several major watersheds which include the Tangipahoa River, Natalbany River, Yellow Water River, Chappepeela Creek, Bedico Creek, Ponchatoula Creek, and Selser's Creek, to name a few. USGS delineated watersheds, identified by Hydrologic Unit Codes (HUC), were used to identify the hydrologic divisions of the study area. The Tangipahoa Parish boundary extents cover 30 HUC-12 basins. A comprehensive list is provided in Table B: 3-1. and Figure B: 3-1.

The study area was split up into four main basins for HMS modeling. The Upper Tangipahoa River model starts at the headwaters of the Tangipahoa River and terminates at Osyka, MS. The Middle Tangipahoa River model starts at Osyka, MS and terminates at Robert, LA. The Lower Tangipahoa River model starts at Robert, LA and terminates where the river meets Lake Pontchartrain. The Natalbany River watershed and the Selser's Creek watershed were combined into one HMS model. Beginning at the upper most part of the watershed, The Salser's Creek and Natalbany River model terminates at Lake Maurepas. Terminating close to each other, Salser's Creek and the Natalbany River share the same downstream boundary condition in the HEC-RAS model. Figure B: 3-2 provides the map coverage of these four models.

The study area experiences flood risk from two primary sources: coastal storm surge and waves, and localized rainfall. Following the analysis of existing documentation from previous studies, the PDT was able to accurately assess the hydrology and hydraulics of the study area.

The HEC-HMS models were run for a simulation time period of ten days. They were calibrated to the March 2016, August 2016, and August 2021 rain events.

Table B: 3-1. List of Tangipahoa Parish HUC 12 Basins

Name	HUC 12 Code
Anderson Canal	80702040502
Beaver Creek	80702050201
Bedico Creek	80702050402
Big Creek	80702050203
Black River	80902010205
Bull Branch-Tchefuncta River	80902010202
Chappepeela Creek	80702050302
East Fork Big Creek	80702050202
East Ponchatoula Creek-Ponchatoula Creek	80702030303

Name	HUC 12 Code
Gorman Creek-Tchefuncta River	80902010201
Irving Branch-Tangipahoa River	80702050108
Killian Bayou-Tickfaw River	80702030403
Line Creek-Terrys Creek	80702050107
Little Chappepeela Creek	80702050301
Little Silver Creek-Silver Springs Creek	31800050502
Lower Bala Chitto Creek	80702050106
Natalbany Creek-Natalbany River	80702030301
North Pass-Pass Manchac	80702040504
Ponchatoula Creek	80702030305
Savannah Branch-Tchefuncta River	80902010203
Selsers Creek	80702040501
Skulls Creek-Tangipahoa River	80702050403
Snell Branch-Silver Creek	31800050501
Spring Creek-Tangipahoa River	80702050204
Still Branch-Natalbany River	80702030306
Sweetwater Creek-Tangipahoa River	80702050303
Taylor Branch-Little Natalbany River	80702030302
Town of Osyka-Tangipahoa River	80702050104
Washley Creek	80702050401
Yellow Water River	80702030304

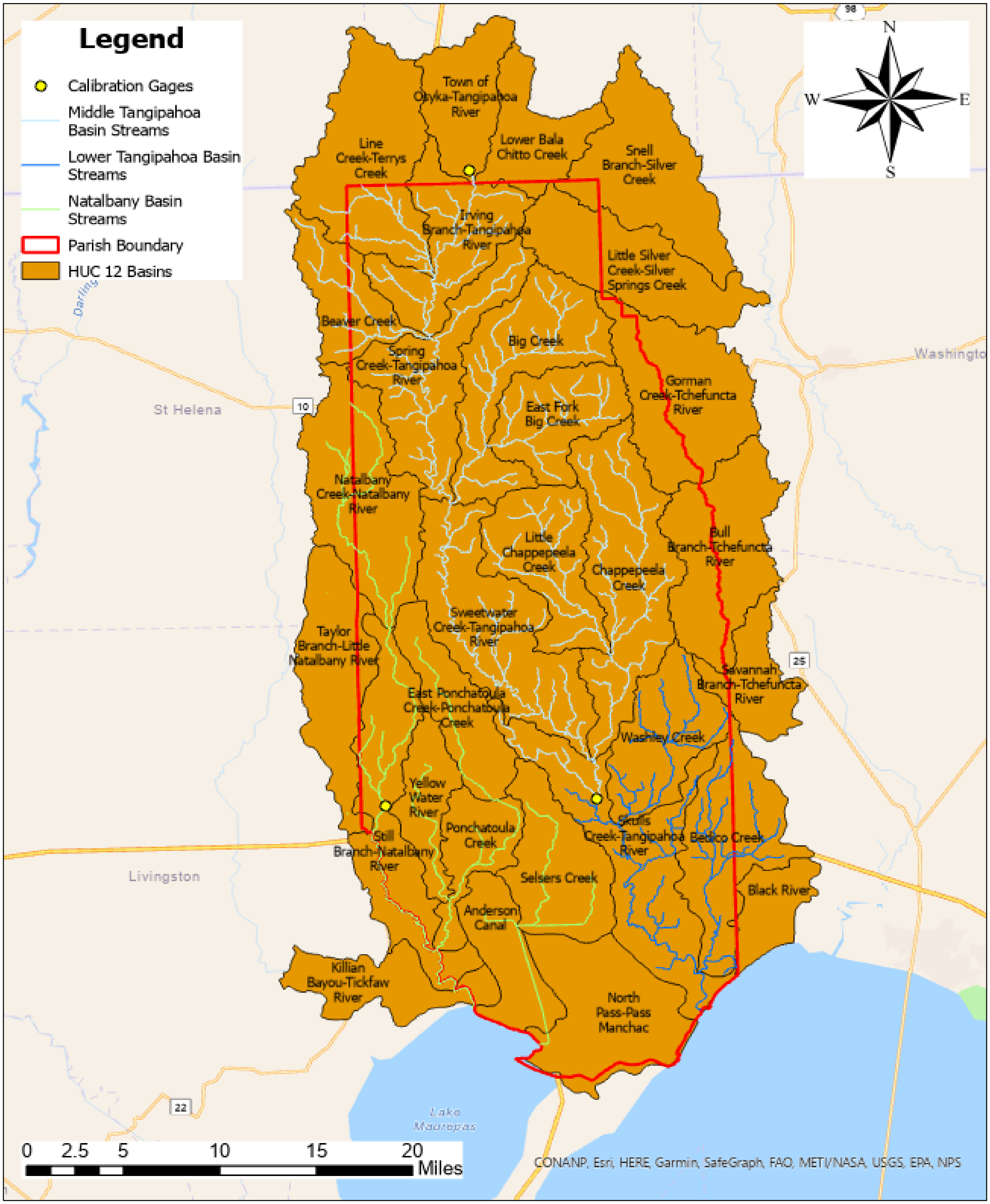


Figure B: 3-1. Tangipahoa Parish Hydrologic Unit Codes (HUC) 12 Basins

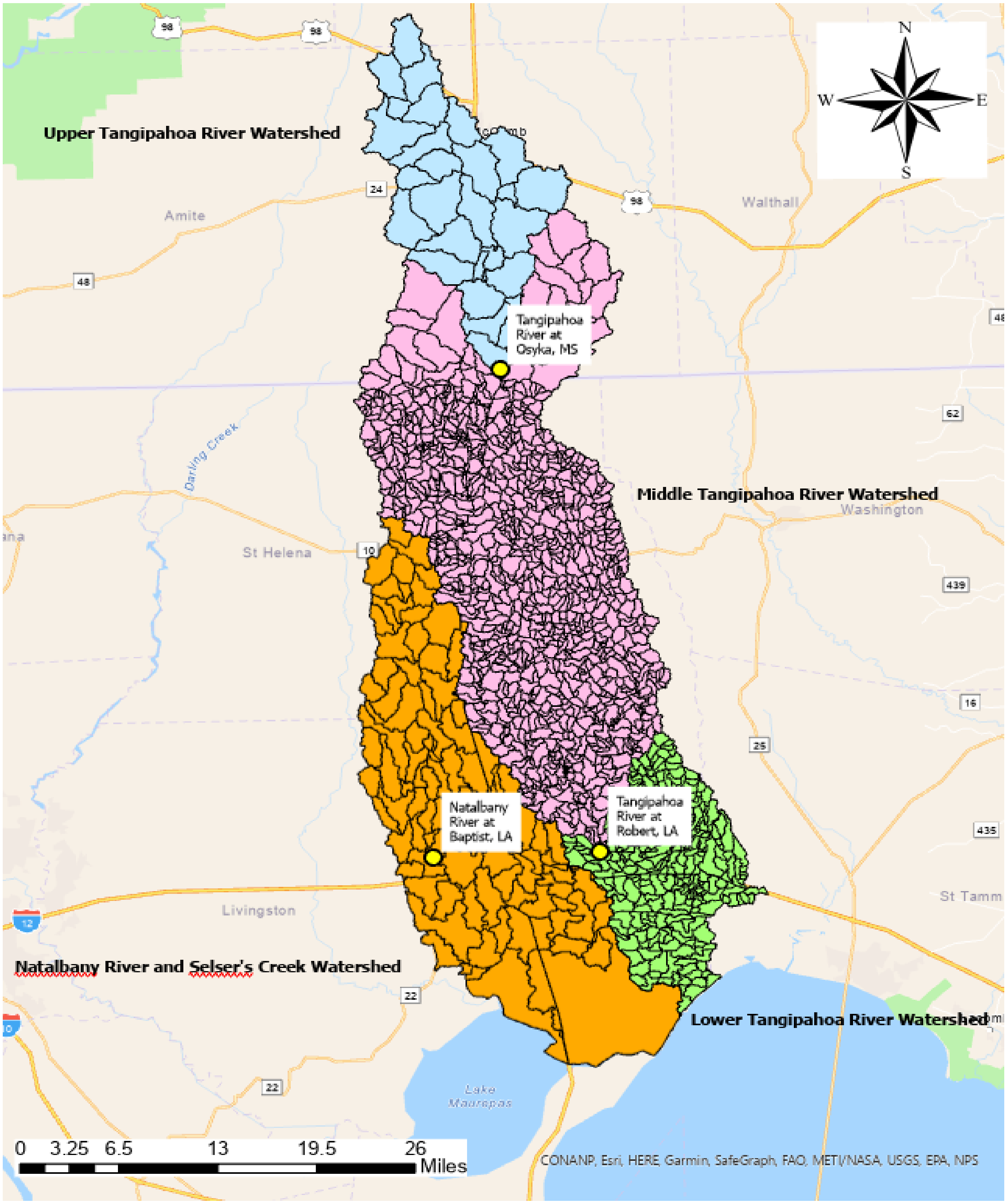


Figure B: 3-2. Tangipahoa Parish Study Hydrologic Basin Map

3.2 FREQUENCY PRECIPITATION

Eight precipitation events were evaluated. They are the 50% annual exceedance probability (AEP) (2-year), 20% AEP (5-year), 10% AEP (10-year), 4% AEP (25-year), 2% AEP (50-year), 1% AEP (100-year), 0.5% AEP (200-year), and 0.2% AEP (500-year) storm events.

To determine the duration of rainfall for the frequency storms, time of concentration was examined. The time of concentration for the entire Tangipahoa watershed is approximately 3 days. The time of concentration for the Natalbany watershed is approximately 1 day. A 96-hour storm event duration was used to ensure that time is sufficiently long enough so that the entirety of the watersheds contribute to the peak runoff.

Frequency storm precipitation hyetographs were developed for each of the AEP events, based on rainfall intensities from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 Volume 9 Point Precipitation Frequency Estimates. The annual maximum series was selected. This ensures that the precipitation statistics use the largest precipitation amounts in a continuous 12-month period for a specified duration. Figure B: 3-3 and Table B: 3-2 depict NOAA Atlas 14 Precipitation frequency depth-duration and depth-frequency, respectively. Annual Maximum Series data was used for a site near Robert, LA (Latitude: 30.5114, Longitude: -90.3395, Elevation: 31 ft) for the Tangipahoa River watershed, and a site near Hammond, LA (Latitude: 30.5007, Longitude: -90.4617, Elevation: 35 ft) for the Natalbany River watershed.

For the frequency storm event definition in HEC-HMS, the annual to partial duration ratio was set to 1.0. This aligns with USACE project requirements to use annual maximum precipitation in determination of the rainfall frequency depth and hydrologic discharge computation. A rainfall intensity position of 50% was used. This is like a NRCS Type II/Type III temporal distribution of rainfall. This ideal distribution centers the highest intensity of rainfall at the middle of the storm. An intensity duration of 5 minutes was used, as this was equal to the simulation computation interval.

Area reduction was applied using the TP-40 method on the watershed areas above the observed gages. This utilized the gage's watershed contributing area in determining the TP-40 reduction. Though smaller reduced area segments would be ideal, this would not necessarily decrease discharges significantly. It also would not be practicable due to the large number of subbasins in the models.

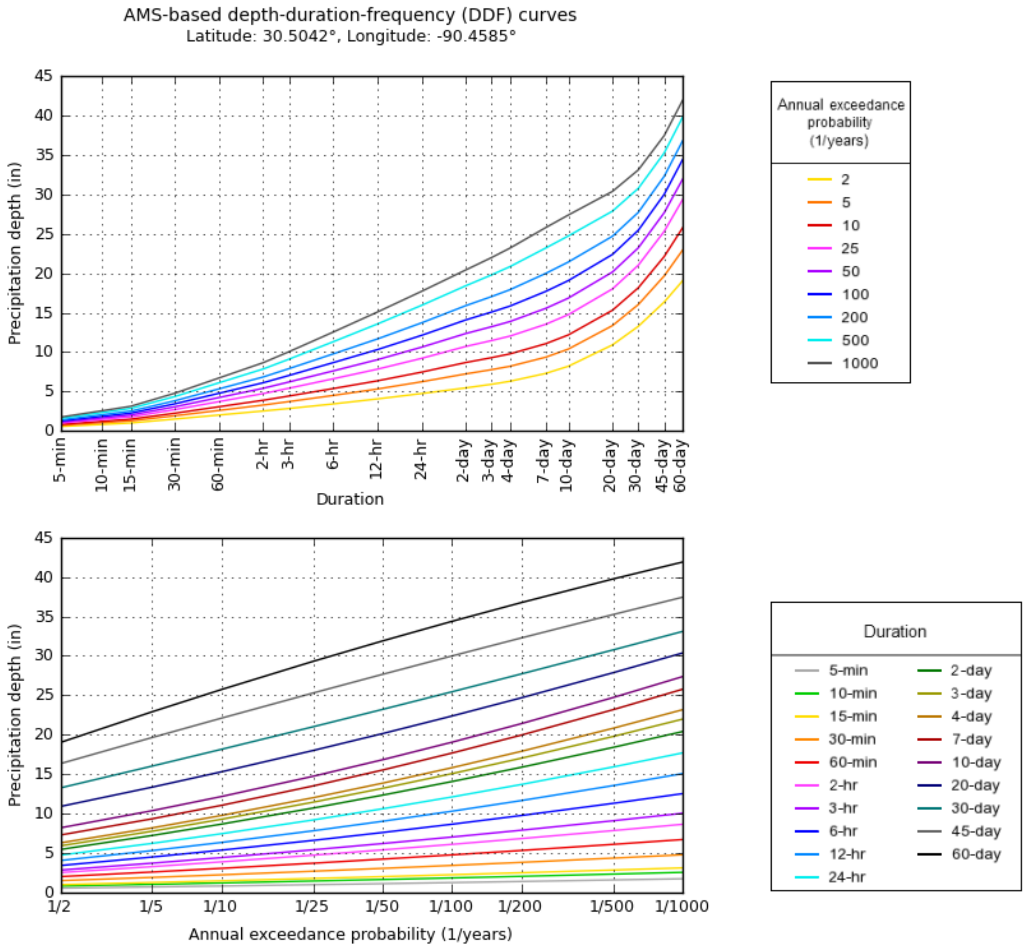


Figure B: 3-3. NOAA Atlas 14 Precipitation Data by Annual Exceedance and Duration

Table B: 3-2. Precipitation Frequency for Hammond, LA (Central Location of Modeling)

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	**0.567** (0.453-0.713)	**0.717** (0.571-0.903)	**0.836** (0.663-1.06)	**1.00** (0.769-1.30)	**1.13** (0.849-1.48)	**1.27** (0.918-1.68)	**1.41** (0.978-1.90)	**1.60** (1.07-2.19)	**1.75** (1.14-2.42)
10-min	**0.830** (0.663-1.04)	**1.05** (0.836-1.32)	**1.23** (0.970-1.55)	**1.47** (1.13-1.90)	**1.66** (1.24-2.16)	**1.86** (1.34-2.46)	**2.06** (1.43-2.78)	**2.34** (1.57-3.21)	**2.57** (1.67-3.54)
15-min	**1.01** (0.809-1.27)	**1.28** (1.02-1.61)	**1.49** (1.18-1.89)	**1.79** (1.37-2.31)	**2.02** (1.52-2.64)	**2.26** (1.64-3.00)	**2.51** (1.75-3.39)	**2.86** (1.91-3.92)	**3.13** (2.03-4.32)
30-min	**1.51** (1.21-1.90)	**1.93** (1.53-2.43)	**2.25** (1.79-2.85)	**2.71** (2.08-3.51)	**3.07** (2.30-4.00)	**3.44** (2.49-4.56)	**3.83** (2.66-5.16)	**4.37** (2.92-5.99)	**4.79** (3.11-6.61)
60-min	**2.02** (1.62-2.55)	**2.61** (2.08-3.29)	**3.07** (2.44-3.88)	**3.72** (2.86-4.82)	**4.24** (3.18-5.54)	**4.78** (3.46-6.33)	**5.34** (3.71-7.20)	**6.11** (4.08-8.38)	**6.72** (4.37-9.28)
2-hr	**2.53** (2.05-3.15)	**3.29** (2.65-4.10)	**3.90** (3.12-4.87)	**4.74** (3.68-6.08)	**5.41** (4.10-6.99)	**6.12** (4.48-8.02)	**6.85** (4.81-9.14)	**7.86** (5.31-10.7)	**8.66** (5.69-11.8)
3-hr	**2.85** (2.32-3.52)	**3.73** (3.02-4.61)	**4.43** (3.57-5.50)	**5.42** (4.24-6.91)	**6.22** (4.74-7.98)	**7.04** (5.19-9.18)	**7.91** (5.60-10.5)	**9.10** (6.20-12.3)	**10.1** (6.66-13.7)
6-hr	**3.43** (2.81-4.19)	**4.51** (3.68-5.51)	**5.38** (4.37-6.60)	**6.62** (5.23-8.36)	**7.62** (5.88-9.69)	**8.67** (6.47-11.2)	**9.77** (7.01-12.8)	**11.3** (7.81-15.1)	**12.5** (8.41-16.9)
12-hr	**4.07** (3.37-4.91)	**5.32** (4.39-6.43)	**6.36** (5.22-7.71)	**7.83** (6.27-9.80)	**9.04** (7.06-11.4)	**10.3** (7.79-13.2)	**11.7** (8.47-15.2)	**13.6** (9.49-18.0)	**15.1** (10.3-20.1)
24-hr	**4.75** (3.97-5.66)	**6.24** (5.21-7.45)	**7.46** (6.19-8.94)	**9.21** (7.45-11.4)	**10.6** (8.39-13.2)	**12.1** (9.27-15.3)	**13.7** (10.1-17.7)	**15.9** (11.3-20.9)	**17.7** (12.2-23.3)
2-day	**5.46** (4.62-6.44)	**7.24** (6.11-8.54)	**8.68** (7.28-10.3)	**10.7** (8.75-13.1)	**12.4** (9.87-15.2)	**14.1** (10.9-17.6)	**15.9** (11.8-20.2)	**18.4** (13.2-23.9)	**20.4** (14.2-26.6)
3-day	**5.92** (5.04-6.93)	**7.77** (6.60-9.11)	**9.29** (7.85-10.9)	**11.5** (9.44-13.9)	**13.2** (10.6-16.2)	**15.1** (11.7-18.7)	**17.0** (12.8-21.6)	**19.8** (14.3-25.5)	**22.0** (15.5-28.5)
4-day	**6.30** (5.39-7.34)	**8.20** (6.99-9.56)	**9.77** (8.29-11.4)	**12.0** (9.96-14.5)	**13.9** (11.2-16.9)	**15.8** (12.4-19.6)	**17.9** (13.5-22.6)	**20.8** (15.2-26.7)	**23.2** (16.4-29.9)
7-day	**7.29** (6.29-8.41)	**9.35** (8.04-10.8)	**11.1** (9.46-12.8)	**13.5** (11.3-16.2)	**15.5** (12.7-18.7)	**17.7** (14.0-21.7)	**20.0** (15.2-24.9)	**23.2** (17.1-29.5)	**25.8** (18.4-33.0)
10-day	**8.21** (7.12-9.40)	**10.4** (8.98-11.9)	**12.2** (10.5-14.0)	**14.7** (12.4-17.5)	**16.8** (13.8-20.2)	**19.1** (15.2-23.2)	**21.4** (16.4-26.6)	**24.7** (18.3-31.3)	**27.4** (19.7-34.8)
20-day	**10.9** (9.57-12.3)	**13.4** (11.7-15.1)	**15.3** (13.3-17.4)	**18.0** (15.3-21.0)	**20.2** (16.7-23.7)	**22.4** (18.0-26.8)	**24.7** (19.2-30.2)	**27.9** (20.9-34.8)	**30.4** (22.2-38.2)
30-day	**13.3** (11.7-14.9)	**16.0** (14.1-18.0)	**18.2** (15.9-20.5)	**21.0** (17.9-24.2)	**23.2** (19.4-27.1)	**25.5** (20.6-30.2)	**27.7** (21.6-33.6)	**30.8** (23.2-38.0)	**33.1** (24.4-41.4)
45-day	**16.3** (14.5-18.2)	**19.7** (17.4-21.9)	**22.1** (19.5-24.8)	**25.3** (21.6-28.8)	**27.7** (23.2-31.9)	**30.0** (24.4-35.2)	**32.3** (25.4-38.7)	**35.2** (26.8-43.1)	**37.4** (27.8-46.5)
60-day	**19.0** (17.0-21.1)	**22.9** (20.4-25.5)	**25.7** (22.8-28.7)	**29.3** (25.1-33.1)	**31.9** (26.8-36.5)	**34.4** (28.1-40.1)	**36.8** (29.0-43.8)	**39.7** (30.3-48.3)	**41.9** (31.3-51.8)

[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.

3.3 HYDROLOGIC MODELING PARAMETERIZATION

HEC-HMS was utilized to model the hydrology. Hydrology for the calibration and frequency storm events were computed based on subbasin area, infiltration, transform properties, baseflow, and hydrologic routing.

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. Initial Deficit values were estimated from the Soil Survey Geographic

Database (SSURGO) for the state of Louisiana by calculating the average available water storage for the first 25cm of soil in each basin, and the halving it for initial parameterization. The second parameter, maximum deficit, specifies the maximum amount of water that can be held in the soil layer. A maximum deficit of 5.0 inches was used for all subbasins in the Tangipahoa model and 2.0 inches for all the subbasins in the Natalbany/Selser's Creek model. The constant rate defines how quickly water enters the soil while it is saturated, and precipitation is occurring. Constant rate values, which were calculated from the Louisiana SSURGO database by assigning an infiltration rate to each soil classification, were averaged for each subbasin in the model domain. Impervious area values were calculated using the National Land Coverage Database (NLCD) 2016 dataset. An illustration of the parish hydrologic soil groupings as shown in the Louisiana SSURGO database can be found in Figure B: 3-4.

The Mod Clark transform method was chosen for all four HMS models. The reason Mod Clark was chosen was because gridded precipitation was used to calibrate the models and the time of concentration (Tc) could be easily calculated. The equation used for time of concentration was taken from an HEC-HMS workshop and is as follows:

$$T_c = 2.2 * \frac{(L * L_C)}{\sqrt{Slope_{10-85}}}^{0.3}$$

L is the length of the longest flow path. Lc is the flow path length to the basin centroid. Slope(10-85) is the slope of the watershed at 10% and 85% lengths of L.

The ratio of R/Tc+R was used to estimate the storage coefficient (R). Ratios were taken from previous modeling efforts on the Atchafalaya River watershed.

Baseflow methods differ between the models. The Natalbany River and Salser's Creek model utilize the Recession method. Standard variables were chosen but were adjusted through calibration. The Tangipahoa River basin models utilize Linear Reservoir method for baseflow approximation. Linear Reservoir method ground water coefficients were computed from the Mod Clark storage coefficients using the equations documented in the HEC-HMS manual.

Hydrologic routing methods chosen were dependent on the watershed. The Tangipahoa River models used the Mod-Puls routing method, and the Natalbany River and Selser's Creek model used the Muskingum-Cunge routing method. The reason different methods were used was because the Mod-Puls parameters were readily available in the Tangipahoa watershed model. Dewberry Engineers Inc, created a 1-D hydraulic model of the Tangipahoa watershed and used it to create the Mod-Puls storage-discharge relationships. Muskingum-Cunge was chosen for the Natalbany River and Selser's Creek model because the parameters required could be easily estimated from LiDAR data. The Modified-Puls method would be better suited for use on both watersheds as the basins are flat with ample storage. Therefore, there is an inherent risk in relying on Muskingum-Cunge in areas with high surface storage. To mitigate this risk, the PDT relies on the HEC-RAS routing for final determination of calibration to the observed events at the gage locations.

HEC-HMS computes the subbasin infiltration from the total precipitation depth at each computation interval. Transform parameters account for attenuation and timing of the peak runoff discharge. The direct runoff hydrographs produced for each sub-basin were used as the input on the 2D Areas in the HEC-RAS model. They were also applied to the 1D channel segments as lateral and reach inflows.

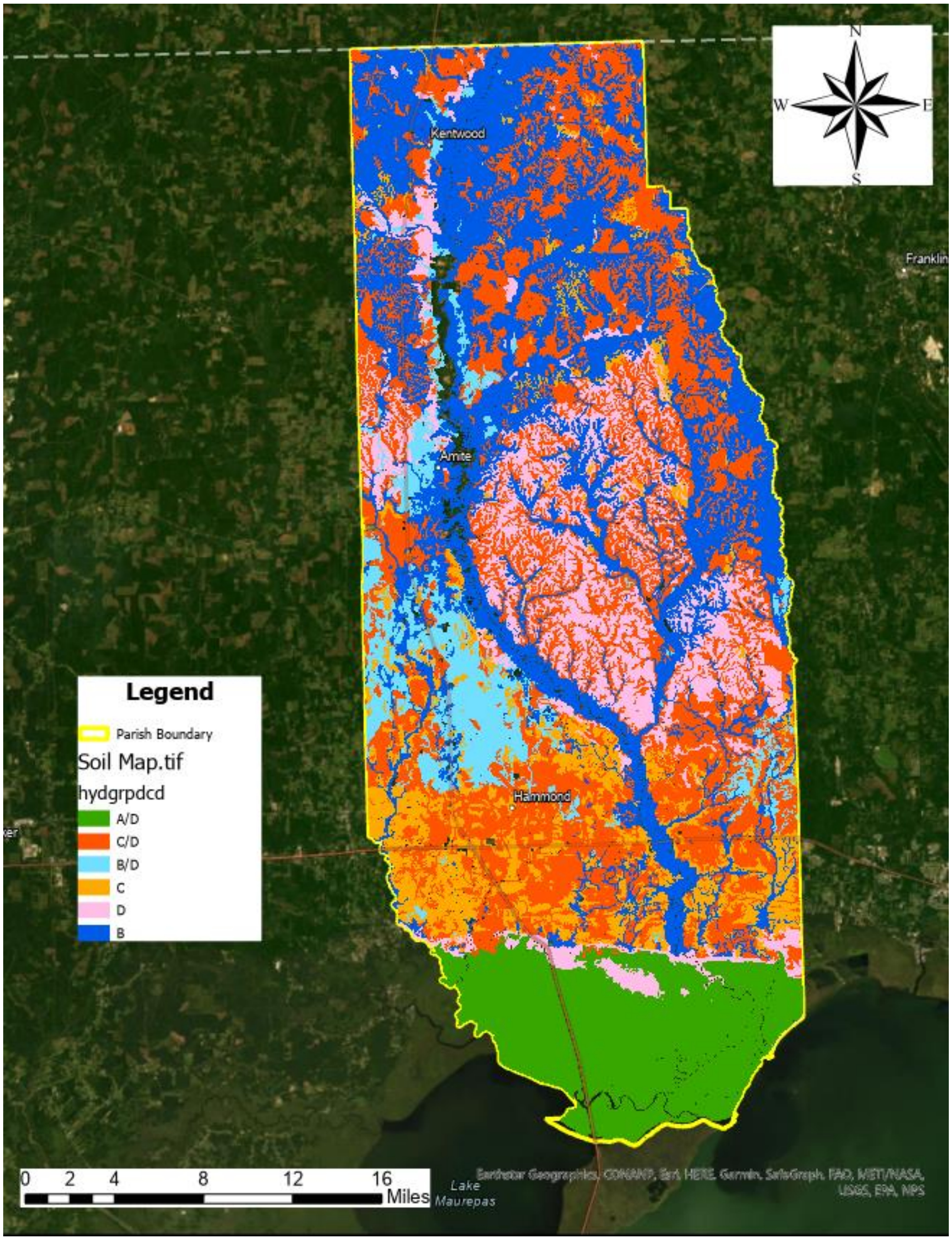


Figure B: 3-4. SSURGO Soil Classifications for Tangipahoa Parish

3.4 HYRDROLOGIC MODELING CALIBRATION

3.4.1 Observed Event Calibration

Model calibration of the HMS models was completed to improve the accuracy of the model. Three events were chosen to calibrate the models: March 2016, August 2016, and August 2021. These three events all marked historic high river flows for the Tangipahoa and Natalbany Rivers within the Parish.

Existing USGS gages were utilized to evaluate the calibration runs of the models. A list of gages utilized for each calibration event may be seen in Table B: 3-3 and locations of the gages may be seen in Figure B: 3-5. Annex B of this appendix contains calibration plots comparing the March 2016, August 2016, and August 2021 events at the gage locations listed in Table B: 3-3 with flows in the final calibrated hydrology models.

Constant loss rate, initial deficit, time of concentration, storage coefficient, and baseflow parameters were changed to calibrate to these events. Tables B: 3-4 through 3-6 show the deficit constant parameter averages for the pre-calibrated and calibrated models. Table B: 3.7 shows the transform R/Tc+R relationships between the pre-calibrated and calibrated models.

Several factors were considered to determine if the calibration was adequate. Nash-Sutcliffe coefficient, timing of peak flow, magnitude of peak flow, and volume of precipitation captured were all considered. The results of the HEC-HMS model calibration to the observed 2013, 2016, and 2021 events can be found in Tables B: 3-8 through 3-10.

The calibration event's final basin parameters were evenly averaged. These averaged parameters were used in the final frequency runs in HEC-HMS. For basins that were located downstream of gages and therefore could not be calibrated directly, such as the Lower Tangipahoa River model and lower basins in the Natalbany River/Sesler's Creek model, the factors applied to the parameters in the upstream basins were applied to these basins downstream.

Because the March and August 2016 floods were both predominately driven by riverine flooding and had similar antecedent flooding conditions, the post-calibration parameters for these events ended up being similar. The post-calibration parameters for the August 2021 event differed from the 2016 events since the 2021 event was Hurricane Ida. And since the antecedent and flooding conditions were different for this event, it reflects in the calibrated parameters. It is also worth noting that the March 2016 event had slightly lower initial deficit parameters than both August events. This could be because the antecedent soil conditions could have been more saturated since there is generally more precipitation in the springtime.

Table B: 3-3. Hydrologic Calibration Gages for Tangipahoa Parish

Gage Name	Gage ID	Gage Link
Tangipahoa River at Osyka, MS	USGS 07375280	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07375280
Tangipahoa River at Robert, LA	USGS 07375500	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07375500
Natalbany River at Baptist, LA	USGS 07376500	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07376500

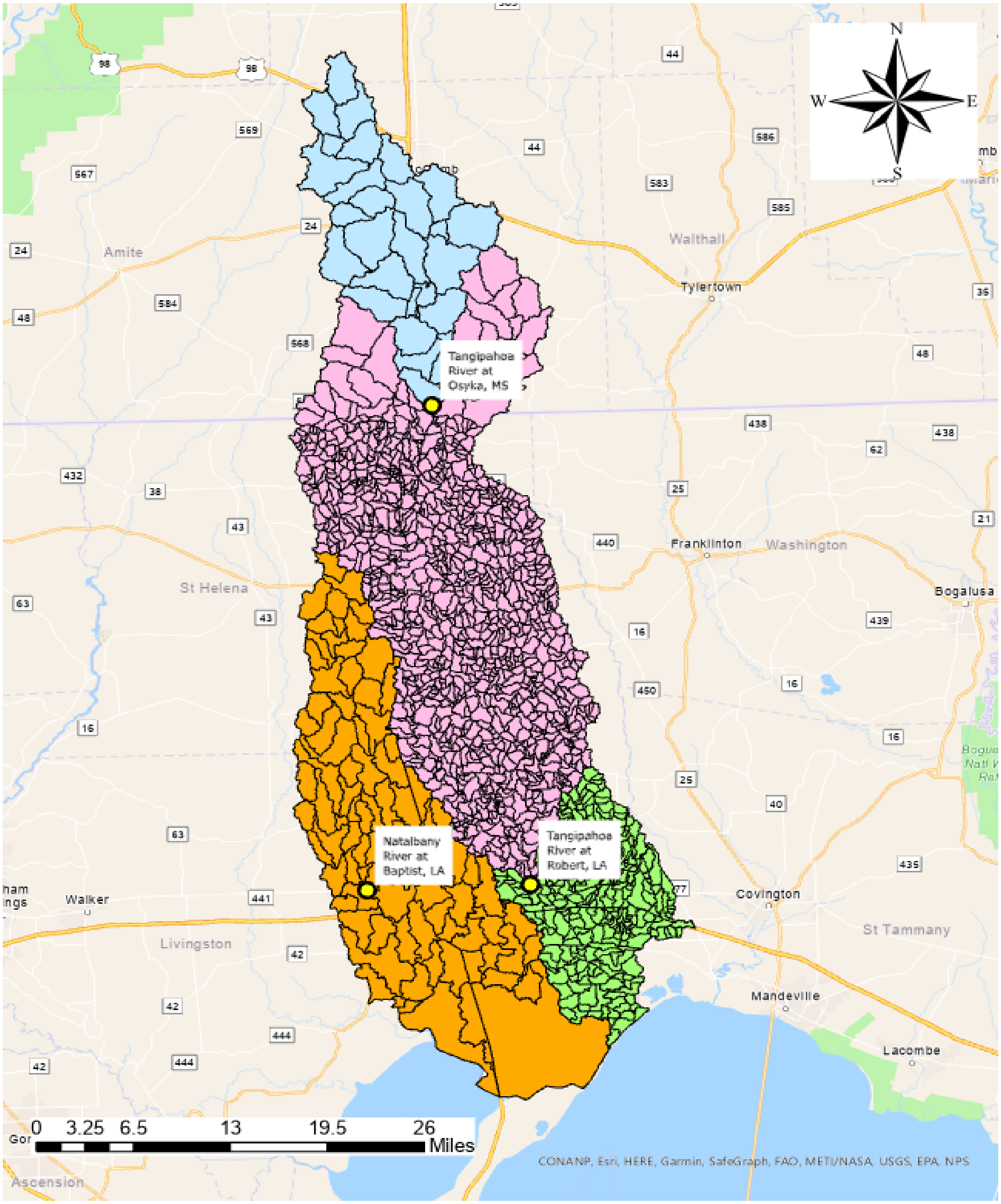


Figure B: 3-5. Calibration Gage Locations

Table B: 3-4. Initial Deficit Calibration - Base and Calibrated Model Averages

Calibration Event	Upper Tangipahoa (inches)	Middle Tangipahoa (inches)	Lower Tangipahoa (inches)	Natalbany (inches)
Pre-Calibration	1.98	0.25	0.20	0.95
Mar-2016	0.66	0.15	0.17	0.20
Aug-2016	2.31	0.30	0.17	0.10
Aug-2021	1.65	0.30	0.17	0.30
Jan-2013	1.98	0.49	0.17	0.40

Table B: 3-5. Maximum Deficit Calibration - Base and Calibrated Model Averages

Calibration Event	Upper Tangipahoa (inches)	Middle Tangipahoa (inches)	Lower Tangipahoa (inches)	Natalbany (inches)
Pre-Calibration	5.0	5.0	5.0	2.0
Mar-2016	5.0	5.0	5.0	2.0
Aug-2016	5.0	5.0	5.0	2.0
Aug-2021	5.0	5.0	5.0	2.0
Jan-2013	5.0	5.0	5.0	2.0

Table B: 3-6. Constant Loss Rate Calibration - Base and Calibrated Model Averages

Calibration Event	Upper Tangipahoa (in/hr)	Middle Tangipahoa (in/hr)	Lower Tangipahoa (in/hr)	Natalbany (in/hr)
Pre-Calibration	0.56	0.44	0.57	0.083
Mar-2016	0.56	0.44	0.57	0.046
Aug-2016	0.56	0.44	0.57	0.026
Aug-2021	0.56	0.44	0.57	0.026
Jan-2013	0.84	0.88	0.78	0.013

Table B: 3-7. Mod-Clark Transform Calibration - Base and Calibrated Model Averages

Calibration Event	Upper Tangipahoa (inches)	Middle Tangipahoa (inches)	Lower Tangipahoa (inches)	Natalbany (inches)
Pre-Calibration	0.30	0.55	0.79	0.65
Mar-2016	0.30	0.64	0.92	0.85
Aug-2016	0.46	0.64	0.92	0.24
Aug-2021	0.30	0.64	0.92	0.79
Jan-2013	0.63	0.82	0.92	0.57

Table B: 3-8. HMS Calibration Results for Upper Tangipahoa Model at Osyka, LA

Calibration Event	Peak Discharge Difference (cfs)	Volume Difference (inches)	Nash Sutcliffe	Flood Type
Mar-2016	-597	-0.02	0.91	Rainfall

Calibration Event	Peak Discharge Difference (cfs)	Volume Difference (inches)	Nash Sutcliffe	Flood Type
Aug-2016	133	-0.70	0.81	Rainfall
Aug-2021	1,111	-1.00	0.88	Hurricane Ida
Jan-2013	1,104	-0.49	0.74	Rainfall

Table B: 3-9. HMS Calibration Results for Middle Tangipahoa Model at Robert, LA

Calibration Event	Peak Discharge Difference (cfs)	Volume Difference (inches)	Nash Sutcliffe	Flood Type
Mar-2016	1,614	-2.39	0.87	Rainfall
Aug-2016	3,745	-2.73	0.81	Rainfall
Aug-2021	-4,151	-1.67	0.86	Hurricane Ida
Jan-2013	8,900	-0.41	0.80	Rainfall

Table B: 3-10. HMS Calibration Results for Natalbany River Model at Baptist, LA

Calibration Event	Peak Discharge Difference (cfs)	Volume Difference (inches)	Nash Sutcliffe	Flood Type
Mar-2016	260	0.86	0.90	Rainfall
Aug-2016	160	0.55	0.79	Rainfall
Aug-2021	73	-3.72	0.65	Hurricane Ida
Jan-2013	25	-1.27	0.92	Rainfall

3.4.2 Bulletin 17C Flow Frequency Analysis

The Bulletin 17C flow frequency analysis was performed on yearly annual maximum discharges at the gage locations on the Tangipahoa and Natalbany Rivers. Hydrologic Engineering Center Statistical Software Package (HEC-SSP) was used to compute the gage statistics. The gages period of record is listed in Table B: 3-11.

Table B: 3-11. Gage Period of Record

Gage	Period of Record
Tangipahoa River at Osyka, MS	1997 – 2023
Tangipahoa River at Robert, LA	1939 – 2023
Natalbany River at Baptist, LA	1944 - 2023

To compute statistics and confidence limits, the Bulletin 17C methodology was chosen. As part of the Bulletin 17C methodology, the moments/parameters of the Log Pearson Type III distribution are estimated using uses the expected moments algorithm. It estimates the distribution parameters based on sample moments in an integrated manner that incorporates standard, censored, or historical data at once rather than as a series of adjustment procedures. Within the Bulletin 17C methodology, every annual peak flow in the analysis period, whether observed or not, is represented by a flow range. That range might simply be limited to the gaged observation when one exists. This analysis used gage observed yearly maximum flows over ranges.

For the generalized skew, a regional skew was used. The source of the regional skew was from a study conducted by the USGS titled Methods for Estimating Annual Exceedance Probability Discharges for Streams in Arkansas, Based on Data Through Water Year 2013 (USGS 2013) (Source: https://pubs.usgs.gov/sir/2016/5081/sir20165081.pdf). In this study gages in Arkansas, Missouri, and Louisiana were included and used in computation of regional skewness. The study determined that the best regional skew for the area is -0.17 with a regional skew mean squared error of 0.11. With this setting the skew of the computed curve was weighted by the regional skew from the data points contained in the set.

For the Tangipahoa River at Robert, LA, a historical flood event stage (27 feet) was recorded in 1921. With the stage converted by rating curve, a flow of 112,000 cfs was added to the EMA data set as a historical record. It was given a historic low value of 110,000 cfs and a high value of 130,000 cfs. A low perception threshold was also set spanning the years 1921 through 1938 since there were no observations that exceeded the 1921 during those years. The low perception threshold was set at 110,000 cfs. The EMA data set as shown in HEC-SSP, plotted by year, is illustrated in Figure B: 3-7.

For the Tangipahoa River at Osyka, MS gage, the gage at Robert, LA was used to estimate annual maximum flows for years prior to 1997. HEC-SSP's record extension analysis was used to extend the Osyka, MS gage period of record to improve the Bulletin 17C estimates of flow frequency. The record extension analysis yielded a concurrent record linear correlation of 0.786. This is lower than the HEC-SSP minimum recommended value of 0.8. Since this was close to 0.8, the period of record extension was still relied upon in the Bulletin 17C analysis. Figure B: 3-6 shows a plot of the Osyka (secondary) extended record compared with the primary Robert record.

The expected probability curves were computed using Bulletin 17B procedures. The expected probability adjustment is a correction for bias in the computed frequency curve. This bias is due to the shortness of the data record. The expected probability curves are shown on the frequency plots for use in establishing design flood criteria.

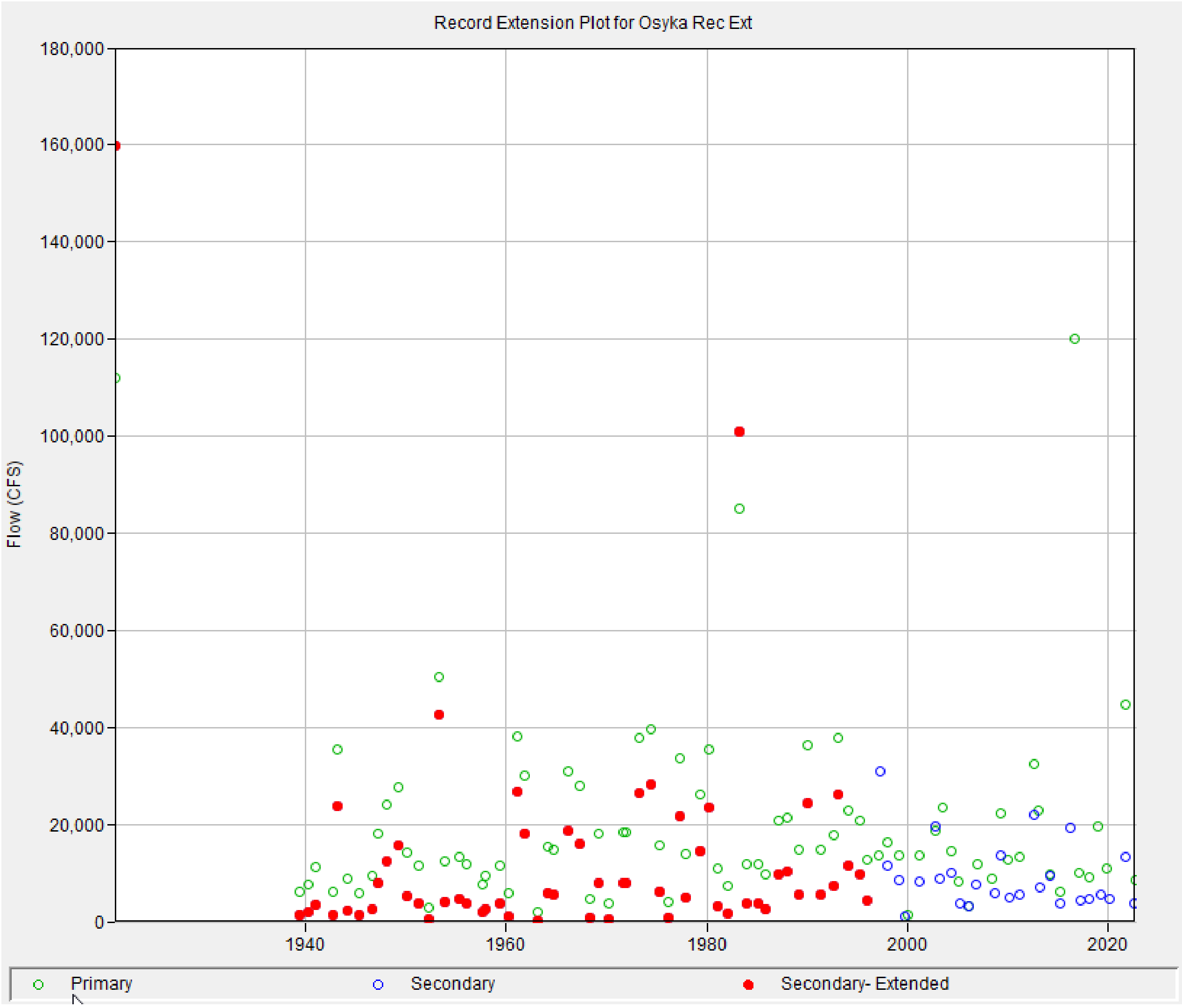


Figure B: 3-6. HEC-SSP Extended Record at Osyka, LA (Secondary)

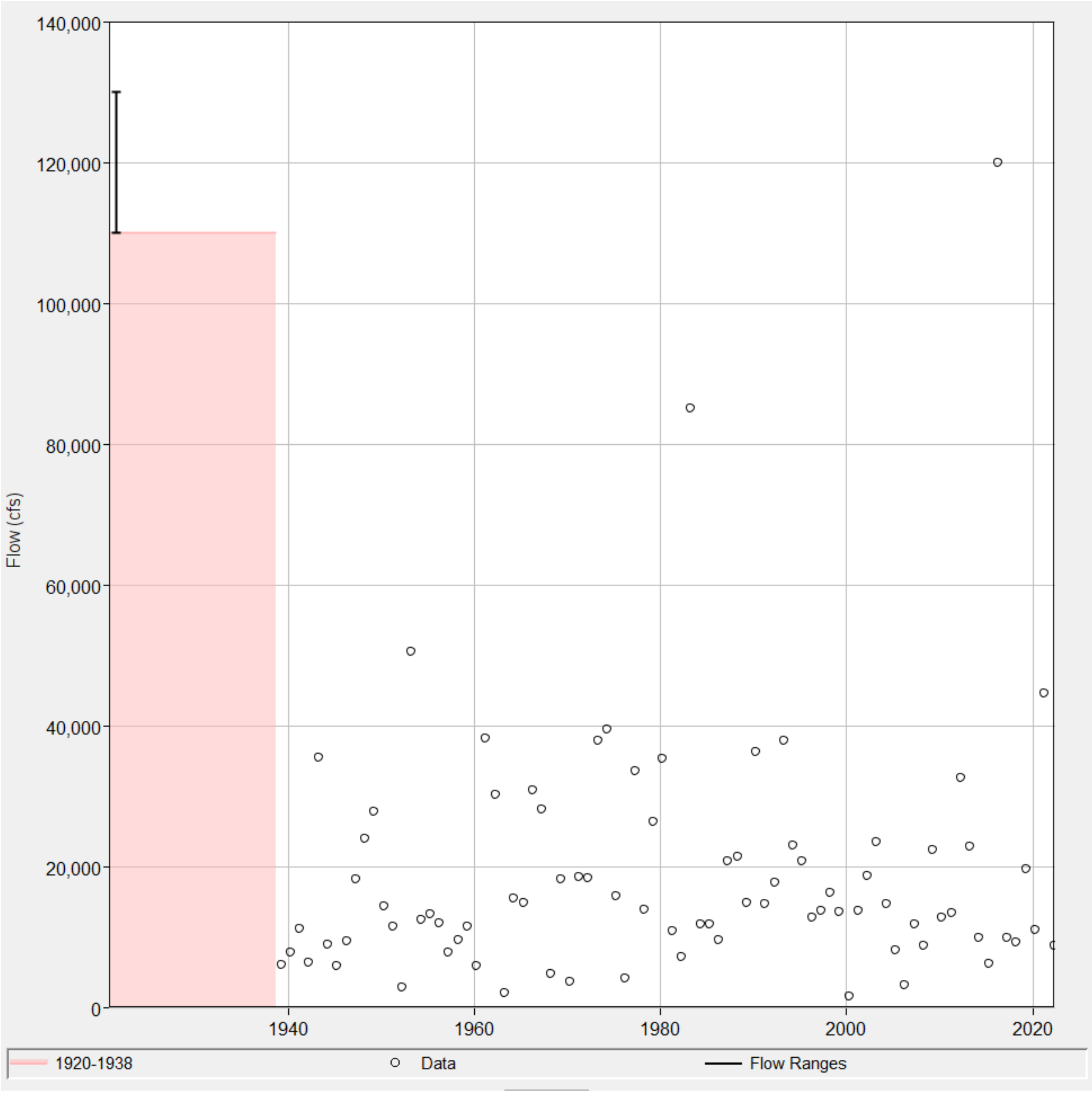


Figure B: 3-7. HEC-SSP EMA Dataset at Robert, LA

Multiple Grubbs-Beck low outlier testing is used to discount outliers and the Hirsch/Stedinger plotting position was used for plotting the input flow data set on a probability scale along with the computed, expected, confidence limit curves.

To better produce the frequency estimates between hurricane induced flooding and rainfall induced flooding a mixed population analysis should be considered. The PDT lacked time, funding, and data to take the mixed population into account. Since the Bulletin 17C analysis is shown for comparison purposes only, the results of the HEC-HMS calibration will solely rely on the gage calibration results.

The Bulletin 17c frequency analysis at the gages on the Tangipahoa and Natalbany Rivers, deviate from the HEC-HMS computed discharges. The lower frequency events discharge deviations are reasonable, but for the higher frequencies the computed discharges are high. This adds to the uncertainty in frequency water surface elevation or flood inducements computed in the HEC-RAS model. This uncertainty also impacts the economics. Computation of damages at these frequencies would be predicted high as well. The PDT recognizes this uncertainty and will rely on the validity of the calibrated models to the observed gages. Less weight will be given to the Bulletin 17c results.

3.4.3 Flow Frequency Comparison – Tangipahoa River

Frequency discharges were obtained from the simulation of the frequency precipitation events through the HEC-HMS model. The flows computed at Osyka, MS and Robert, LA were compared to a Bulletin 17C analysis done with the HEC-SSP.

The calculated frequency flows for the Robert, LA gage were higher than the flows calculated by HEC-SSP. The Osyka, MS frequency results were within an acceptable tolerance. Part of the reason for the deviation at Robert, LA could be with how the HEC-HMS models were calibrated. Though a higher frequency event was used in calibration, three lower frequency events were the primary focus of the calibration. The deviation at the lower frequency events is acceptable and this study relies on predicted water levels for the lower frequency events. Though non-structural measures do capture higher frequency flooding in the final array alternatives, the HEC-HMS computed flows will produce conservative water level estimates at those frequencies.

Table B: 3-12 shows the HEC-HMS computed discharges at various locations on the Tangipahoa River. Table B: 3-13 and 3-14 compare the Bulletin 17C results with the computed frequency discharges for the Robert, LA and Osyka, MS gages, respectively. Figures B: 3-8 and 3-10 show the Bulletin 17C frequency plots for the Robert, LA and Osyka, MS gages, respectively. Figures B: 3-9 and 3-11 show the Bulletin 17C frequency results versus the HEC-HMS computed discharges at the Robert, LA and Osyka, MS gages, respectively.

Table B: 3-12. Tabulation of Return Period Calculations for Inflow Boundary Condition Lines at Upper, Middle, and Lower Tangipahoa River HEC-HMS Models

Annual Exceedance Probability (%)	Tangipahoa River near Osyka, MS (cfs)	Tangipahoa River near Shiloh, LA (cfs)	Tangipahoa River near Robert, LA (cfs)
50	7,000	27,000	35,500
20	11,400	33,300	47,300
10	14,900	38,400	56,100
4	19,700	46,000	69,200
2	24,700	52,300	77,900
1	30,300	59,000	93,100

Annual Exceedance Probability (%)	Tangipahoa River near Osyka, MS (cfs)	Tangipahoa River near Shiloh, LA (cfs)	Tangipahoa River near Robert, LA (cfs)
0.5	36,000	66,000	104,900
0.2	43,700	75,600	123,600

Table B: 3-13. Bulletin 17C Analysis Results - Robert, LA

Annual Exceedance Probability (%)	HEC-HMS Tangipahoa River near Robert, LA (cfs)	Bulletin 17c Computed Curve (cfs)	Bulletin 17C Confidence Limits: 0.05 Tangipahoa River near Robert, LA (cfs)	Bulletin 17C Confidence Limits: 0.95 Tangipahoa River near Robert, LA (cfs)
50	35,500	14,860	17,413	12,620
20	47,300	28,540	33,722	24,432
10	56,100	39,650	48,965	33,456
4	69,200	55,760	75,080	44,251
2	77,900	69,150	100,857	51,566
1	93,100	83,640	133,349	58,330
0.5	104,900	99,270	174,218	64,646
0.2	123,600	121,740	244,635	72,409

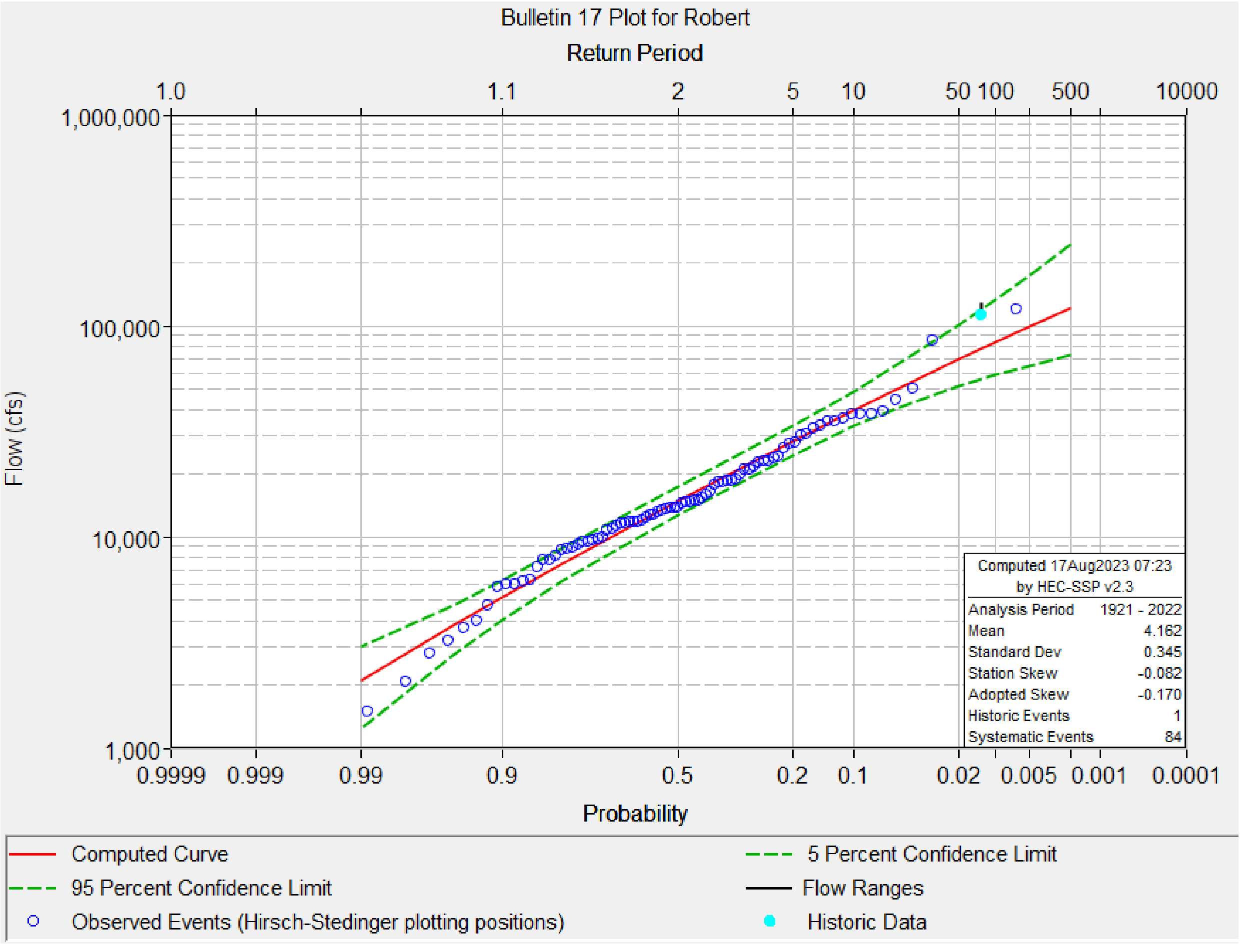


Figure B: 3-8. Bulletin 17C Frequency Plot - Robert, LA

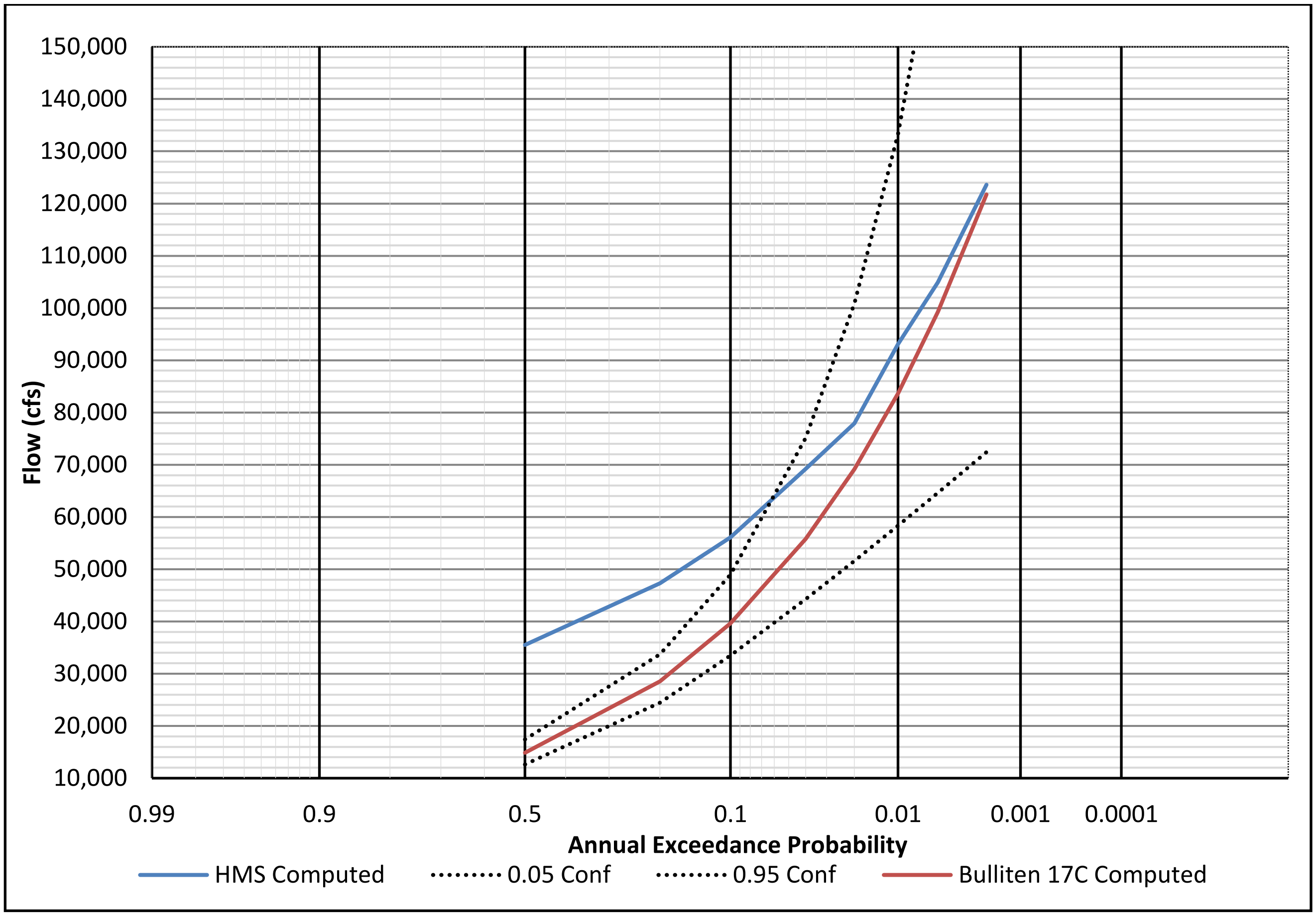


Figure B: 3-9. Bulletin 17C versus HMS Computed Discharges - Robert, LA

Table B: 3-14. Bulletin 17C Analysis Results - Osyka, MS

Annual Exceedance Probability (%)	HEC-HMS Tangipahoa River near Osyka, MS (cfs)	Bulletin 17c Computed Curve (cfs)	Bulletin 17C Confidence Limits: 0.05 Tangipahoa River near Osyka, MS (cfs)	Bulletin 17C Confidence Limits: 0.95 Tangipahoa River near Osyka, MS (cfs)
50	7,000	7,880	8,870	6,970
20	11,400	12,840	14,540	11,440
10	14,900	16,420	19,210	14,460
4	19,700	21,200	26,450	17,810
2	24,700	24,900	32,990	19,970
1	30,300	28,720	40,660	21,890
0.5	36,000	32,640	49,670	23,640
0.2	43,700	38,030	64,000	25,730

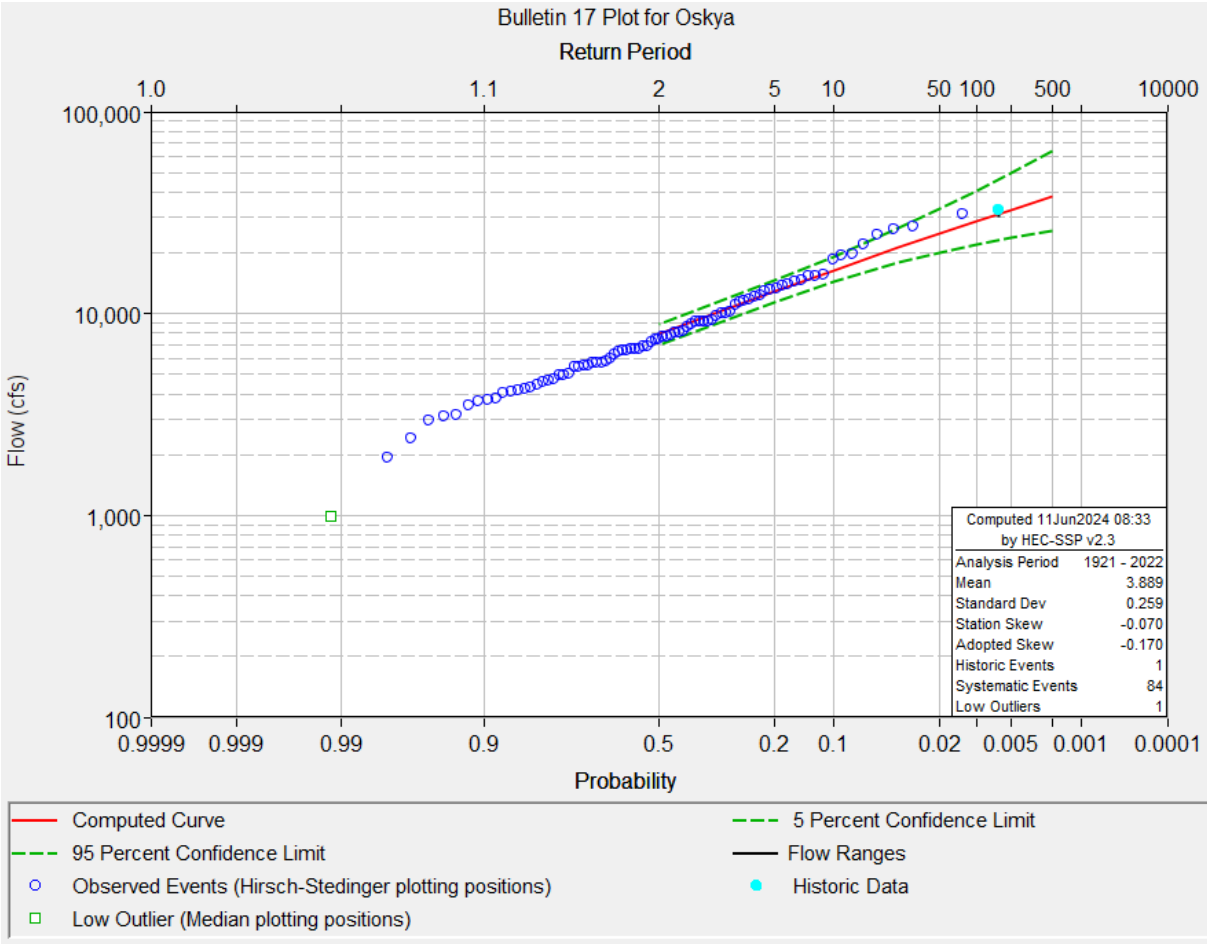


Figure B: 3-10. Bulletin 17C Frequency Plot - Osyka, MS

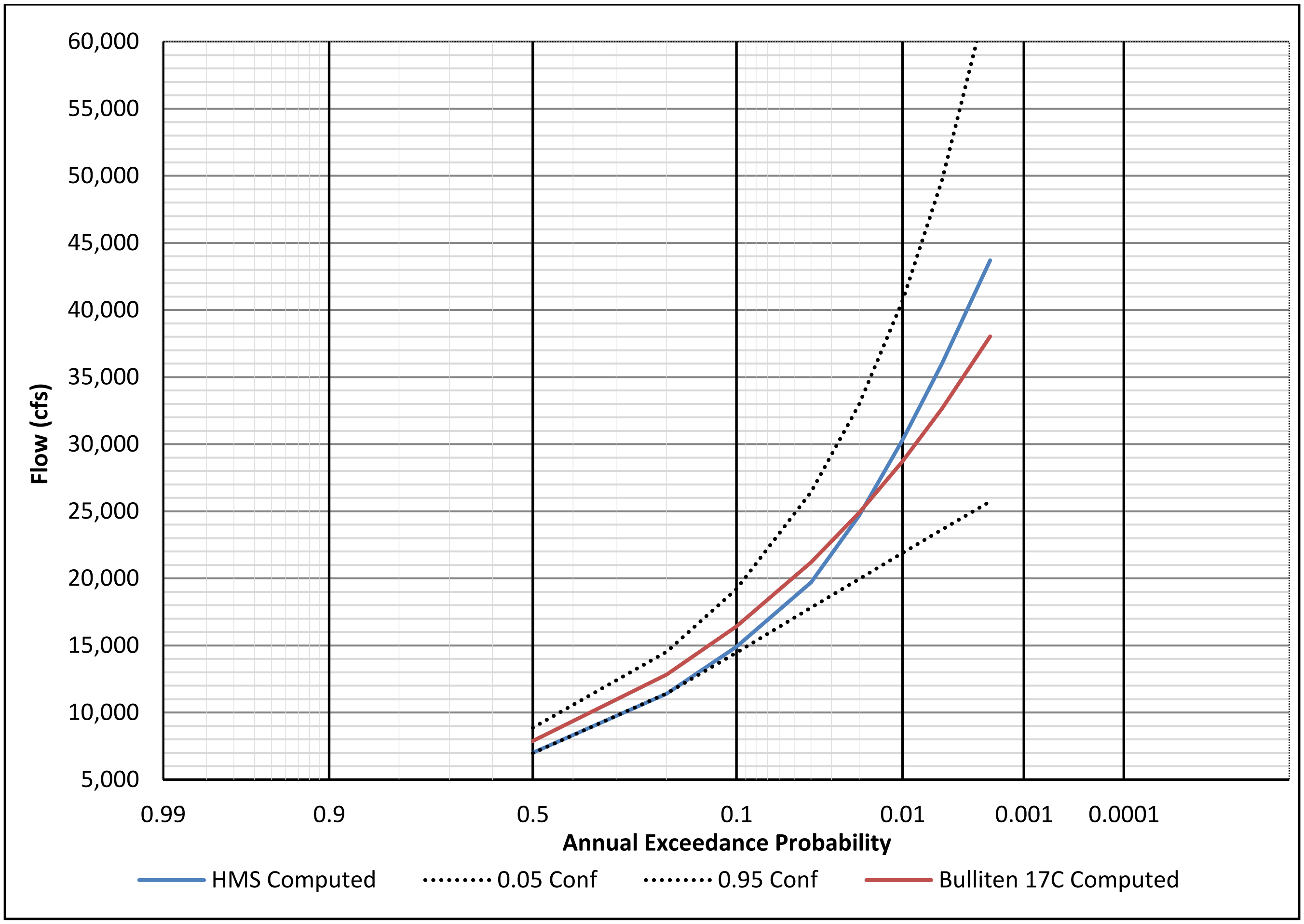


Figure B: 3-11. Bulletin 17C versus HMS Computed Discharge - Osyka, MS

3.4.4 Flow Frequency Comparison – Natalbany River

Frequency discharges were obtained from the simulation of the frequency precipitation events through the HEC-HMS model. The flows computed at Baptist, LA were compared to a Bulletin 17C analysis done with the HEC-SSP.

The calculated frequency flows for this location were higher than the flows calculated by HEC-SSP. Similar to the reasoning behind deviations at Robert, LA, this study relies on predicted water levels for the lower frequency events. Though non-structural measures do capture higher frequency flooding in the final array alternatives, the HEC-HMS computed flows will produce conservative water level estimates at those frequencies.

Table B: 3-15 shows the HEC-HMS computed discharges at various locations on the Natalbany River. Figure B: 3-11 shows the Bulletin 17C computed frequency plot. Figures B: 3-12 show the Bulletin 17C frequency results versus the HEC-HMS computed discharges.

Table B: 3-15. Bulletin 17C Analysis Results – Baptist, LA

Annual Exceedance Probability (%)	HEC-HMS Tangipahoa River near Baptist, LA (cfs)	Bulletin 17c Computed Curve (cfs)	Bulletin 17C Confidence Limits: 0.05 Tangipahoa River near Baptist, LA (cfs)	Bulletin 17C Confidence Limits: 0.95 Tangipahoa River near Baptist, LA (cfs)
50	4,750	3,070	3,458	2,709
20	6,525	4,960	5,644	4,404
10	7,809	6,320	7,451	5,556
4	9,653	8,120	10,230	6,839
2	11,258	9,520	12,723	7,663
1	12,919	10,950	15,635	8,396
0.5	14,297	12,420	19,044	9,060
0.2	16,815	14,440	24,464	9,852

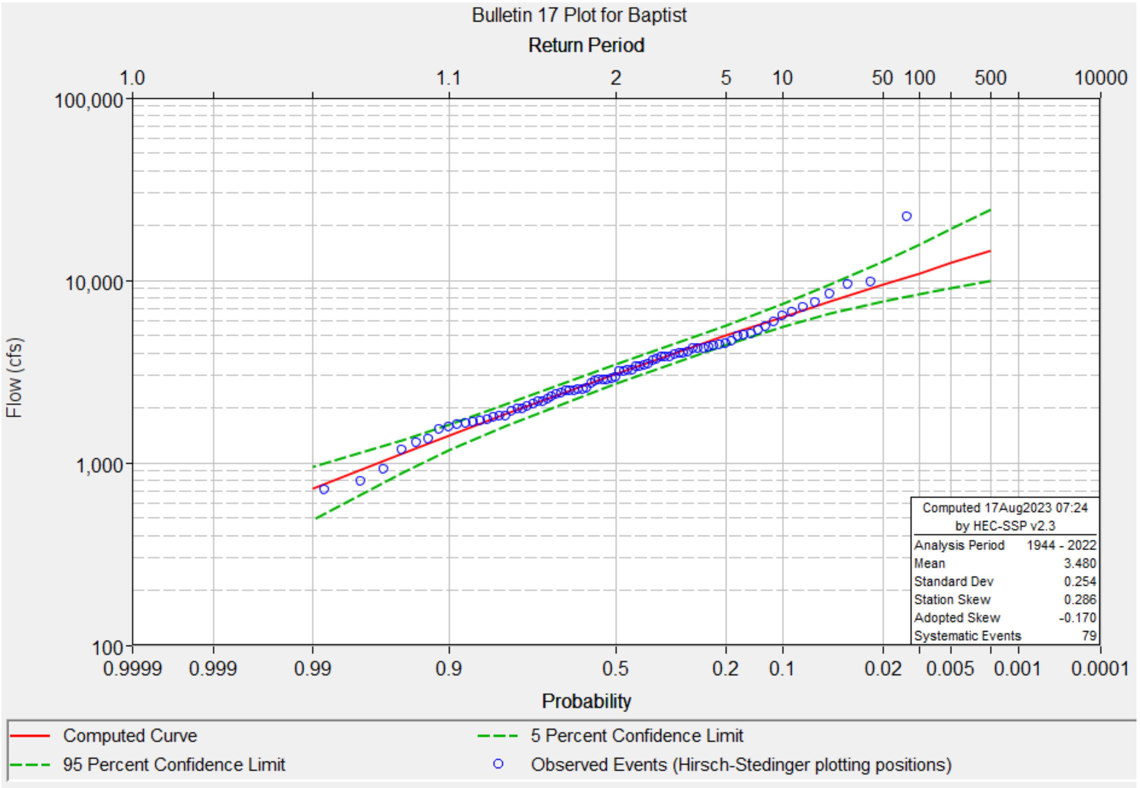


Figure B: 3-12. Bulletin 17C Analysis Plot - Baptist, LA

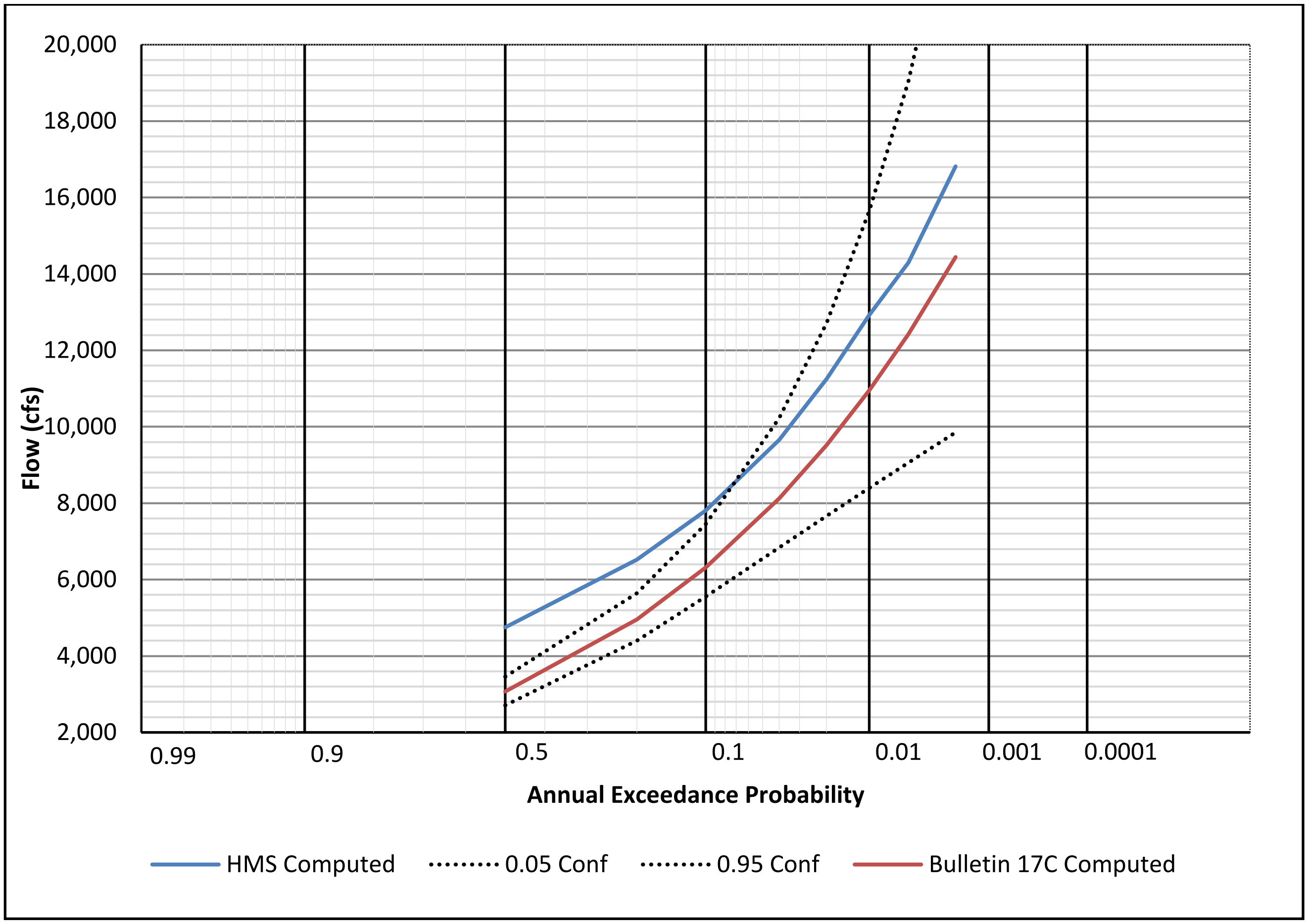


Figure B: 3-13. Bulletin 17C versus HMS Computed Discharges - Baptist, LA

SECTION 4
Hydraulic Modeling

4.1 MODELING SUMMARY

Hydraulic modeling was performed using a mixture of two-dimensional (2D) and one-dimensional (1D) unsteady flow capabilities of HEC-RAS. The hydraulic model covers the extents of the Middle Tangipahoa, Lower Tangipahoa, and Natalbany/Selser's Creek hydrologic models. The area covered by the Upper Tangipahoa HEC-HMS model was excluded for hydraulic modeling because that area of the watershed lies outside of the parish boundary. The outflow of the Upper Tangipahoa River hydrologic model was used as the inflow for the Middle Tangipahoa hydraulic model. The area covered by the Middle Tangipahoa River hydrologic model was split at Shiloh, LA into two separate hydraulic models: the Upper Middle and Lower Middle Tangipahoa River hydraulic models. These models were calibrated to existing conditions.

Because some of the structural alternatives proposed had impacts that spanned the model boundaries, the 2D portions of the Lower Middle and Lower Tangipahoa models were joined together into a single composite model. The 1D reaches were added in as inflows points into the 2D composite model. This composite model was used to produce existing and proposed condition results for the base year and future year simulations.

The vertical datum of elevations in the models is NAVD 88 (Geoid 12B). The horizontal projection used in this study is NAD 1983 Louisiana State Plane South (feet).

4.2 MODEL GEOMETRY

The geometry for the Upper Middle and Lower Middle Tangipahoa River models is a mixture of 2D around the mainstem Tangipahoa River and floodplain, and 1D reaches representing the tributaries. The Lower Tangipahoa River as well as the Natalbany River/Selser's Creek hydraulic models are completely 2D models. Elements of stream bathymetry were integrated into the terrain for this model where the data was available. Figure B: 4-1 depicts the existing conditions model domain.

Both the existing conditions and with-project geometries utilize the 1D/2D unsteady flow equations in HEC-RAS. The 1D/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 30 feet by 30 feet. Outside of these waterways and in areas of lesser impact, the cell definition increases with a cell range between 200 and 500 feet on each grid cell side. Smaller cells were also used to allow better model stability and accuracy nearby model features such as culverts, lateral structures, 2D area connections, and 2D inflow points.

Because of time constraints, bridge definition was not incorporated in most of the modeling footprint the exception being the Lower Tangipahoa model, as the model was completed in its entirety by Dewberry Engineers, Inc. Encroachments were added at bridge locations in all 1D channel reaches to mimic the effects of the bridge embankments.

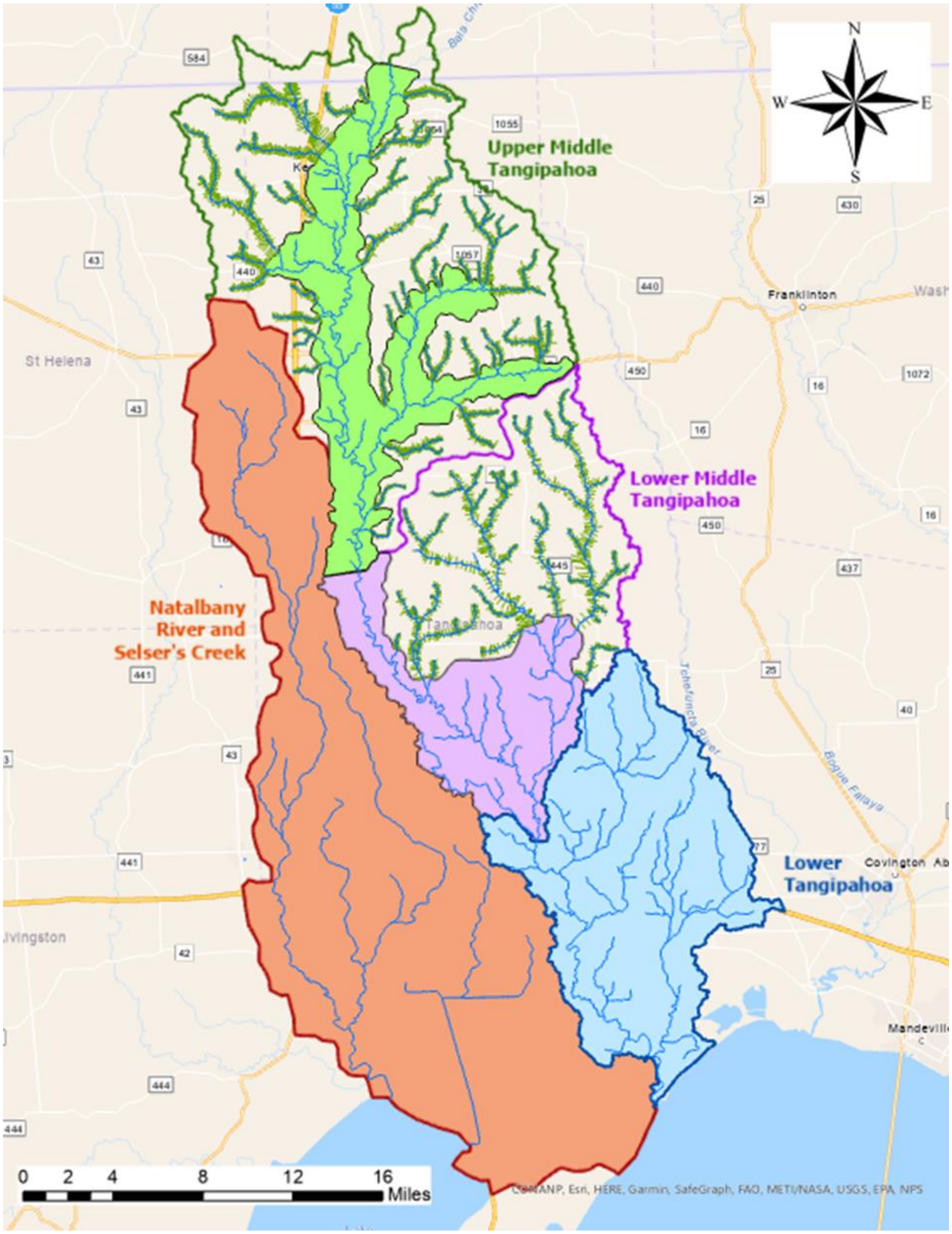


Figure B: 4-1. Existing Condition Model Extents. Solid Color Represents 2D Area.

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 a single source: The USGS National Elevation Dataset. The terrain obtained is a 5 x 5-foot digital elevation model (DEM) that covers the entire study area.

For the Tangipahoa River and some of its tributaries, as well as part of the Natalbany River, bathymetry data was collected by Dewberry Engineers Inc. It was merged with the USGS terrain data to create the final model terrain. The bathymetry data spans the mainstem Tangipahoa River from Lake Pontchartrain upstream to the Mississippi state line. Bathymetry data for the Natalbany River spans from State Highway 22 in Springfield, LA upstream to State Highway 40, just west of Independence, LA. Bathymetry data for several major Tangipahoa River downstream tributaries was also incorporated. Figure B: 4-2 shows the extent of the terrain for the study area, as well as the extents of the incorporated bathymetry data.

The Tangipahoa River portion of the watershed is mostly covered with bathymetry data of the channel. However, channel data was not available for the entire Natalbany River, and no channel data was available for Salser's Creek at all. This will affect the model accuracy in the larger segments of river without bathymetry. This could potentially lead to over predicted flood stages in areas where water was present in the channel at the time of DEM survey collection. Channel conveyance area is reduced due to the lack of bathymetry.

The terrain used in the project had bridge decks captured. This will not allow water to flow in the 2D segments of the model. In segments where channel bathymetry did not exist, channel sections were driven through the bridge decks in the DEM, opening a path for water to move. Channel dimensions were estimated from downstream and upstream sections of the river close to the bridge location.

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 Landcover Database (NLCD). An appropriate Manning's roughness coefficient was selected for each land cover type that is found in the study area. HEC-RAS has a built-in land cover to Manning's n value conversion when importing in the NLCD grid. The conversion values are discussed in the HEC-RAS user's manual. Table B: 4-1 lists the Manning's n values for each land cover type used in the models.

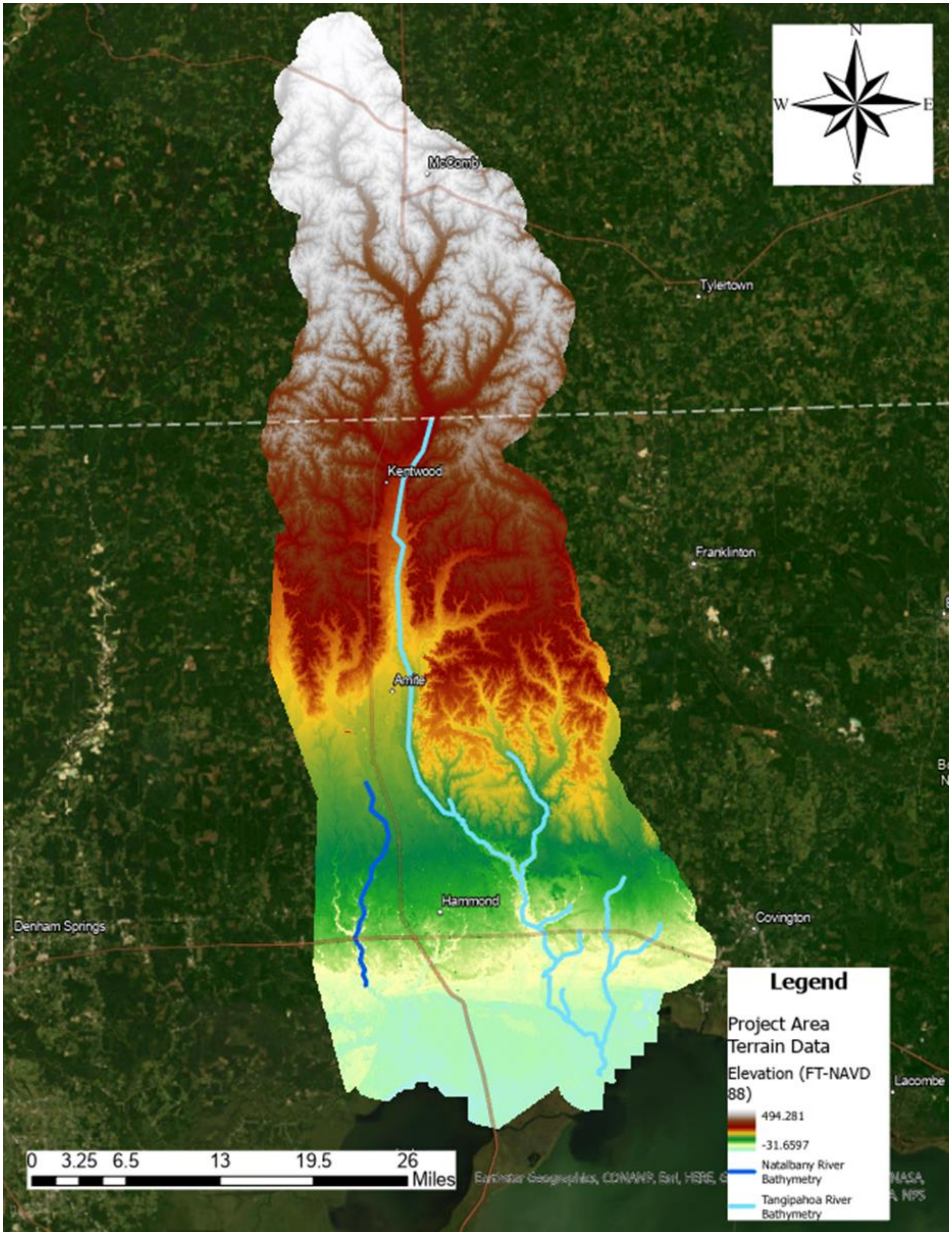


Figure B: 4-2. LiDAR Dataset with Bathymetry Data Extents

Table B: 4-1. Manning's Roughness Coefficients for Each NLCD Land Cover Type

Land Cover Type	Manning’s N
No Data	0.06
Shrub-Scrub	0.05
Deciduous Forest	0.12
Woody Wetlands	0.15
Mixed Forest	0.15
Evergreen Forest	0.15
Pasture-Hay	0.04
Developed, Open Space	0.04
Developed, Low Intensity	0.08
Developed, Medium Intensity	0.10
Developed, High Intensity	0.12
Grassland-Herbaceous	0.04
Cultivated Crops	0.05
Open Water	0.03
Emergent Herbaceous Wetland	0.1
Barren Land Rock-Sand-Clay	0.03

4.4 BOUNDARY CONDITIONS

4.4.1 Tangipahoa River Models

Inflow boundary conditions were applied throughout the hydraulic model. The 2D area inflow boundary conditions for the Upper and Lower Middle Tangipahoa models are hydrographs that represent runoff into the Tangipahoa River. Flow and lateral inflow hydrographs are defined at cross-sections for the 1D river segments. The downstream boundary condition for these models is normal depth.

For the lower Tangipahoa River model, there are four boundary condition lines that define the southern boundary influenced by Lake Pontchartrain. For the calibration events, downstream boundary conditions at Lake Pontchartrain are gage observations recorded by the USGS Lake Pontchartrain gage. For riverine flood frequency events, the downstream boundary condition is the MHW level.

Several outflow boundary condition lines were drawn on both the east and west sides of the Lower Tangipahoa River model. The ones on the west side capture higher flows that leave the Tangipahoa River watershed and flow into the Selser’s Creek watershed. These lateral outflow boundary conditions assume normal depth.

Figures B: 4-3 through 4-5 graphically show the boundary condition lines for the Tangipahoa River models.

4.4.2 Natalbany River and Selser’s Creek Model

Inflow boundary conditions were applied to the hydraulic model for each simulation. The inflow boundary conditions for the Natalbany River and Selser’s Creek models are also

HEC-HMS computed hydrographs that represent runoff into the 2D area. Figure B: 4-6 graphically shows the layout of the boundary condition lines.

Inflow boundary conditions lines were defined where the flow from the Tangipahoa River watershed flows into the Selser's Creek watershed. The computed Lower Tangipahoa outflow at these boundaries are inflow boundary conditions to the Natalbany River and Selser's Creek model. An outflow boundary condition is also used where the flow form the Natalbany River watershed flows in to the Tickfaw River watershed during high flows on the west side of the model. This lateral outflow boundary condition assumes normal depth.

The downstream boundary condition for the Natalbany River and Selser's Creek is the MHW level for the frequency events. For the calibration events, there was no data from the USGS Lake Maurepas gage, so elevation data from the USGS Lake Pontchartrain gage was used. A constant elevation shift was applied to account for the average elevation difference between Lake Pontchartrain and Lake Maurepas. The shift was the average difference computed from the lake gage observations from May 2022 through present (January 2023). The estimated elevation difference of 0.33 ft. This lake level shift has little impact on inundation or flood depths upstream of the Lake Maurepas when compared to using the unconverted Lake Pontchartrain level. This is especially true in the parish area where proposed measures are anticipated.

In the Natalbany River model, inflow from the Tickfaw River is not captured. This is because it falls within the coastal surge boundary. Within this realm, the water levels produced by coastal surge dominate. In Annex E, the results of a sensitivity analysis where inflow from the Tickfaw River was added into the model and the resulting water surface level effects were examined. As a result of this sensitivity analysis, the Tickfaw River portion of inflow near Lake Maurepas and upstream of the confluence with the Natalbany River was not incorporated into the Natalbany and Salser's Creek model.

4.4.3 2D Inflow Hydrographs

For each of the hydraulic models, inflow boundary conditions lines were created that represent the outflow of the basins or junctions from the HEC-HMS models. Each HEC-HMS basin or junction has a corresponding flow hydrograph boundary condition.

Inflow hydrographs are also applied to the 2D portions of the models at 2D boundary condition lines. Inflow boundary condition lines are used at the northern boundary of each RAS model. The Upper Middle Tangipahoa boundary is the Tangipahoa River at Osyka, MS, the Lower Middle Tangipahoa boundary is the Tangipahoa River at Shiloh, LA, and the Lower Tangipahoa boundary is the Tangipahoa River at Robert, LA. Inflow for the 0.2 to 50% AEP events were applied to the Tangipahoa River. The inflow boundary condition lines cover the entire width of the 0.2% AEP event floodplain for each river.

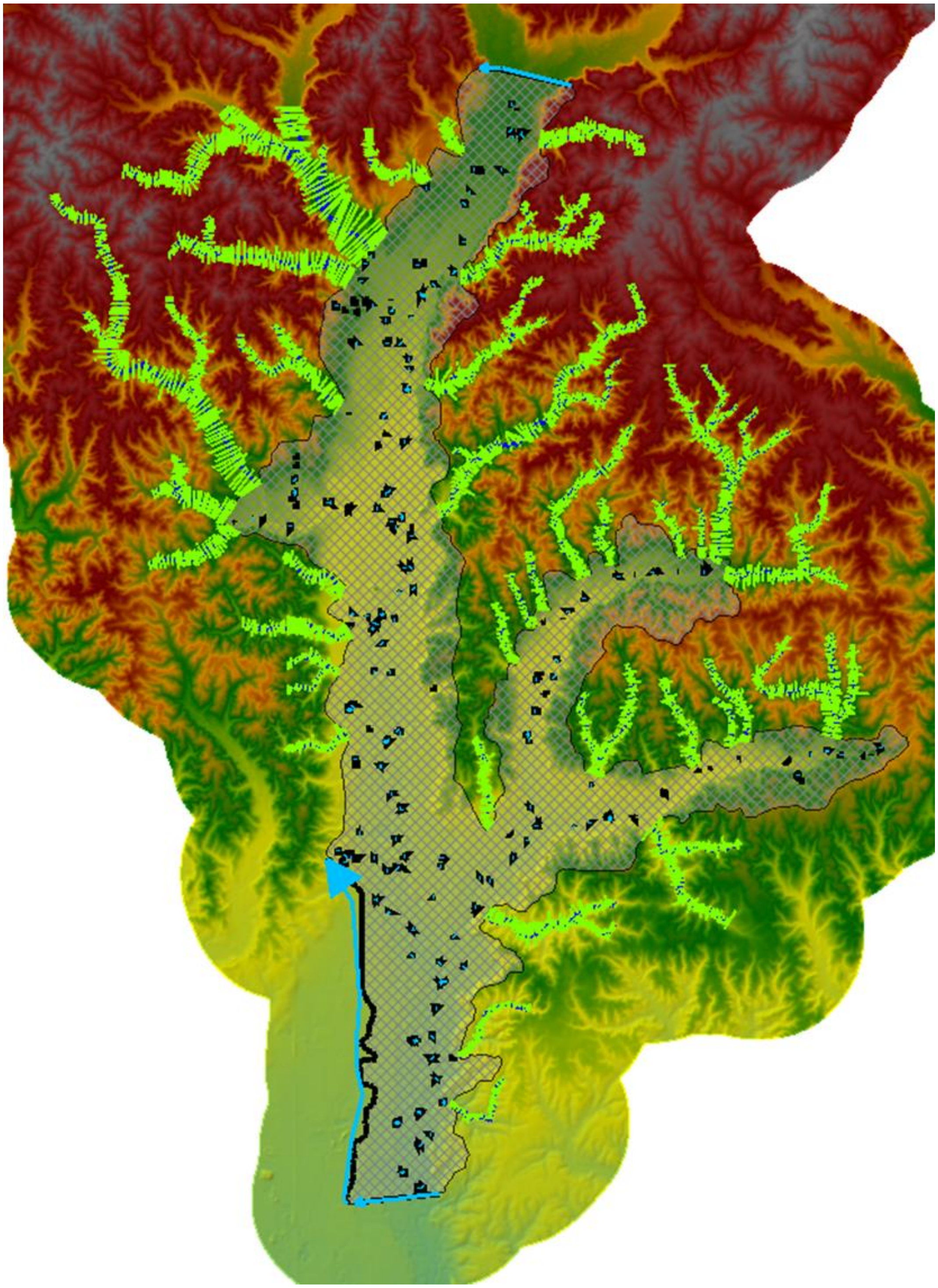


Figure B: 4-3. 2D Boundary Condition Lines for the Upper Middle Tangipahoa River

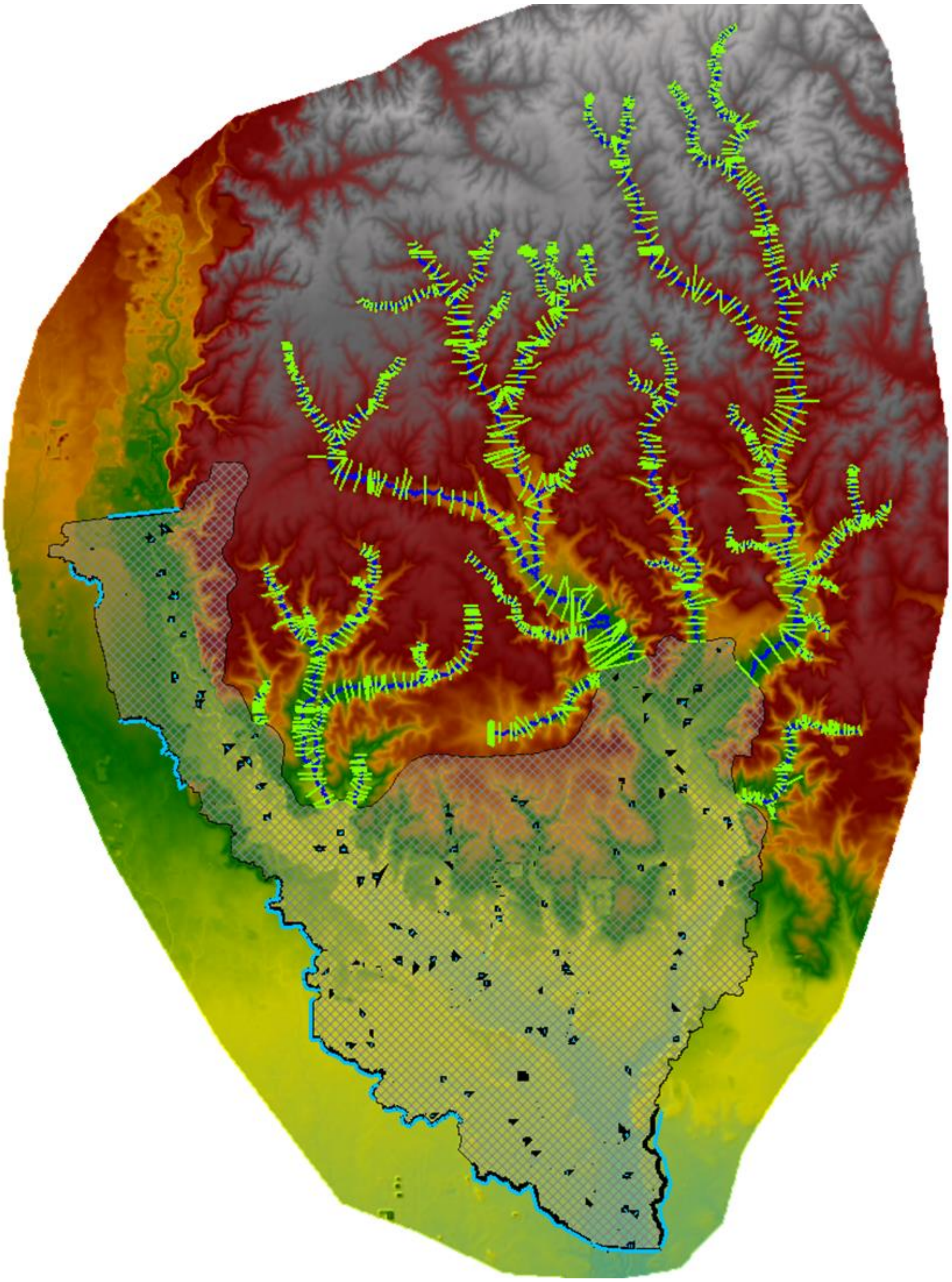


Figure B: 4-4. 2D Boundary Condition Lines for the Lower Middle Tangipahoa River

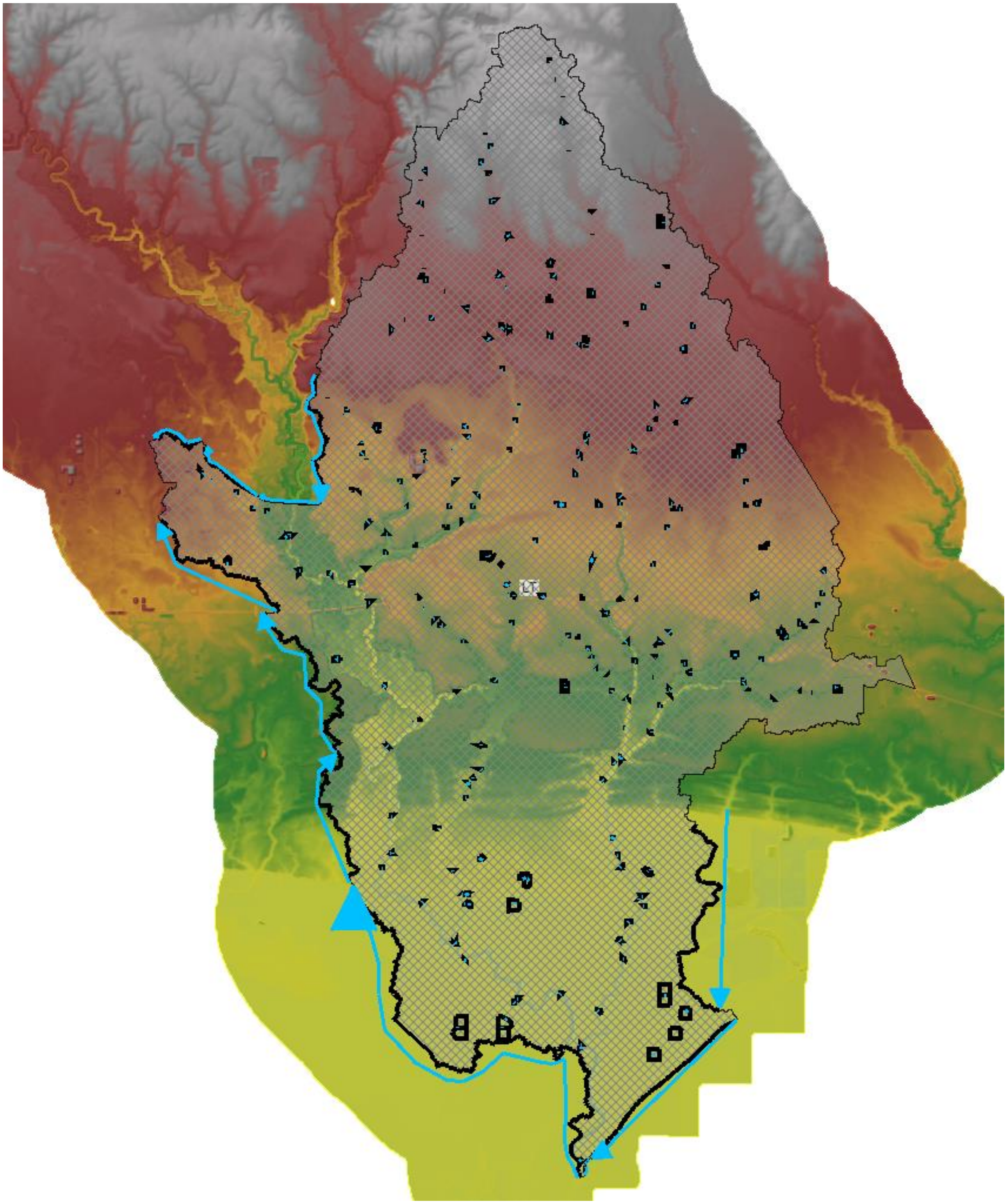


Figure B: 4-5. 2D Boundary Condition Lines for the Lower Tangipahoa River

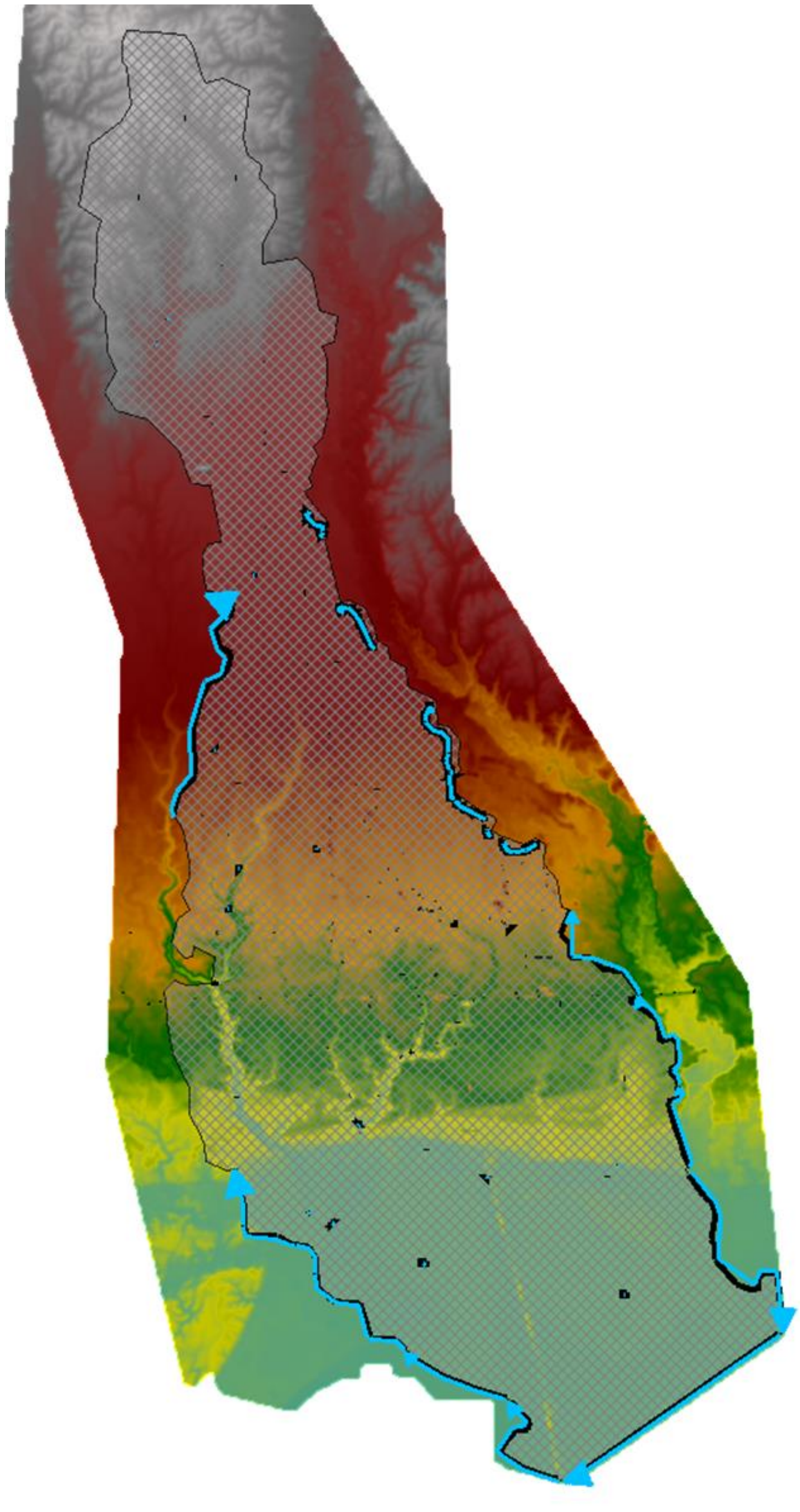


Figure B: 4-6. 2D Boundary Condition Lines for the Natalbany River and Selser's Creek

4.5 HYDRAULIC MODELING CALIBRATION

Calibration of the HEC-RAS models was completed to improve the accuracy of the models. Four events were chosen to calibrate the models. The events that occurred in January 2013, March 2016, August 2016, and August 2021 were selected as they produced heavy flooding in the Parish.

Existing USGS gages were utilized to evaluate the calibration runs of the model geometry and terrain. A complete list of gages utilized for each calibration event may be seen in Table B: 4-2. Observed versus computed stage plots depicting the January 2013, March 2016, August 2016, and August 2021 events at the gage locations listed in Table B: 4-2 are shown in Annex B of this appendix.

Table B: 4-2. Hydraulic Calibration Gages for Tangipahoa Parish

Gage Name	Gage ID	Gage Link
Tangipahoa River at Osyka, MS	USGS 07375280	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07375280
Tangipahoa River at Robert, LA	USGS 07375500	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07375500
Tangipahoa River at Amite, LA	USGS 07375430	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07375430
Tangipahoa River at Ponchatoula, LA	USGS 07375650	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07375650
Tangipahoa River at Kentwood, LA	USGS 07375300	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07375300
Natalbany River at Baptist, LA	USGS 07376500	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07376500
Lake Pontchartrain at Crossover 4 near Mandeville, LA	USGS 301200090072400	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=301200090072400

To ensure the model produces credible results, a few adjustments were required to adequately align the model and gages with the January 2013, March 2016, August 2016, and August 2021 event observations. A warm-up period on the 2D area was applied to all events to ensure flow was established at the beginning of the simulation.

Downstream boundary conditions for the Tangipahoa River, Natalbany River, and Selser's Creek were linked to the Lake Pontchartrain Mandeville gage (USGS 301200090072400). An elevation shift of +0.33 ft was applied to the Lake Pontchartrain elevation to adjust for the elevation difference at Lake Maurepas. For each calibration event, the HEC-RAS simulation was run for enough days to ensure a peak was reached for the entire model domain. A 10 second computation interval was used for all events.

Revisions were also made to the roughness coefficients that represent the channel and floodplain areas. Manning's n override regions were applied to most waterways to supersede the default landcover-based Manning's n value. This achieved a more accurate calibration to observed gage records. Following analysis of the first few simulations, it was determined that the roughness coefficients of the Woody Wetlands landcover and Open Water should be increased throughout the entire model domain to more accurately represent those landcover categories.

4.6 COMPOUND FLOODING SENSITIVITY ANALYSIS

Compound flooding is a concern at the boundaries of the storm surge influence and the riverine flood influence. The boundaries of storm surge and riverine flooding for the 1% AEP storm event is shown in Figure B: 4-7. Red denotes the area dominated by riverine flooding and purple is the area dominated by coastal surge flooding. The extent of the coastal surge impact falls just south of Highway 22.

Shown in the Annex B are observed lake and river flood hydrographs for time to peak comparisons, coincident flooding profile plots, and the extents of compound flooding for each model. The compound flooding extents are also shown in Figure B: 4-8. Yellow denotes a water level difference of 0.0 to 0.1 feet and the red denotes difference greater than 0.1 feet. The compound flooding zones are small in comparison to the extents of riverine and storm surge flooding. Not many structures reside in this zone and due to the magnitude of stage increase predicted to occur during coincident surge and river flood events, damage costs do not drastically differ. The coincident flood profiles for the 1% AEP event are shown in Annex B. They show a 1% riverine flood coincident with MHW at the lake, a 1% AEP surge event coincident with a 50% AEP riverine flood, and a 1% AEP riverine flood coincident with a 1% AEP surge event.

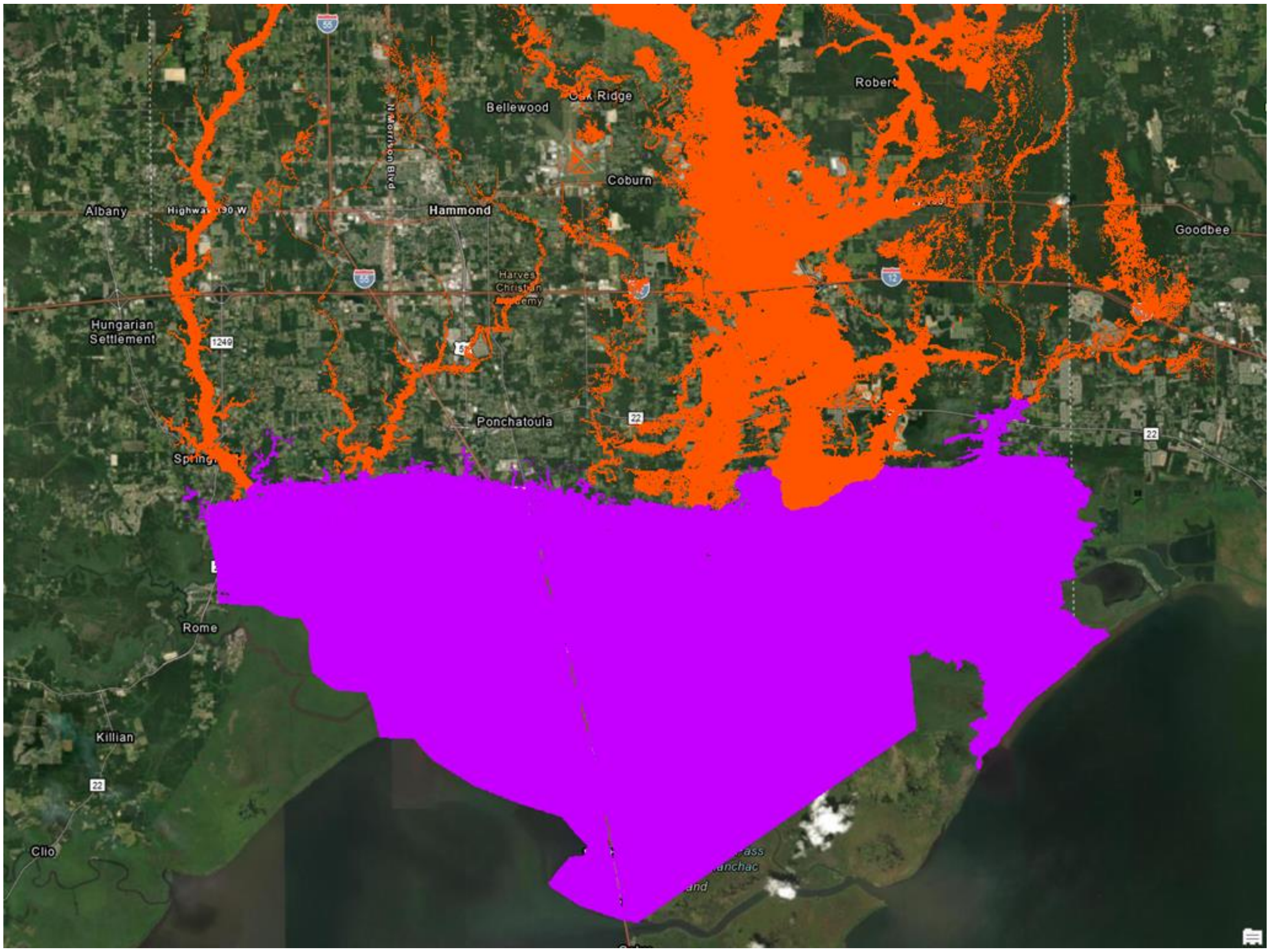


Figure B: 4-7. 1% AEP Event - Riverine (Red) and Coastal Surge (Purple) Inundation Extents Base Year 2033

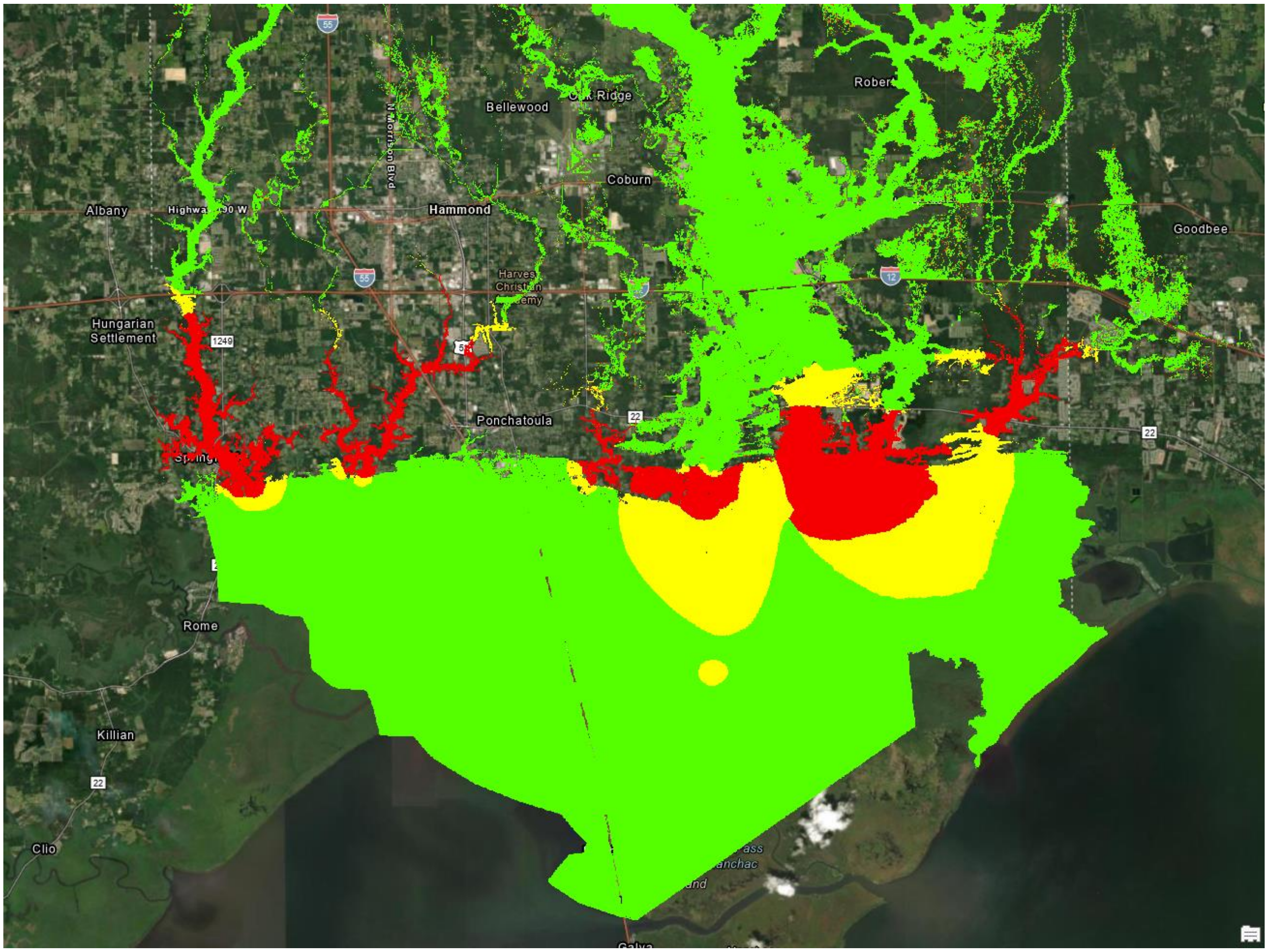


Figure B: 4-8. 1% AEP Event - Extents of Compound Flooding (Yellow 0.0-0.1; Red > 0.1 feet) Base Year 2033

4.6.1 Flood Peak Timing

To understand the likelihood of coincident flood events between the lakes and rivers, the degree of stage independence was examined. To analyze the effect of the flood coincidence, a comparison was made between the peak timing of lake and river gage stages for four selected tropical events.

Plots of observed stages on Lake Pontchartrain and the Natalbany and Tangipahoa Rivers are shown in Annex B for multiple storm events. These plots focus on the differences in peak coincidence on Lake Pontchartrain and the river gages at Baptist, LA on the Natalbany River and at Robert, LA on the Tangipahoa River. From comparing the lake and river peak coincidence gage correlation can be inferred.

Lake Pontchartrain levels are shown for both comparisons to the river gages because Lake Maurepas levels were not recorded during the examined events. There will be more time to the peak of the Lake Maurepas stage. Since Lake Maurepas and Pontchartrain were not modeled, an exact time difference was not determined. It is assumed that time to peak of Lake Pontchartrain and Lake Maurepas are the same for the purposes of this correlation.

For each of the events examined, the time differences in stage peaks are shown in Table B: 4-3 and 4-4. The difference in time of these peak stages is referred to as the lag time. To translate the gages to the lakes, river travel time from Baptist, LA to Lake Maurepas is estimated at 12 hours (0.5 days) and river travel time from Robert, LA to Lake Pontchartrain is estimated at 20 hours (0.8 days). This additional lag time between the gages and the lakes would shift the corresponding river peaks by this additional time. The table reports the peak stages at the gage locations.

Table B: 4-3. Peak Stage Correlation at Lake Pontchartrain and Robert, LA

Event	Year	Lag Time (days)
Hurricane Ida	2021	2.3
Hurricane Isaac	2012	2.0
Tropical Storm Lee	2011	1.0
Tropical Storm Cristobal	2020	1.8

Table B: 4-4. Peak Stage Correlation at Lake Maurepas and Baptist, LA

Event	Year	Lag Time (days)
Hurricane Ida	2021	0.6
Hurricane Isaac	2012	2.0
Tropical Storm Lee	2011	1.0
Tropical Storm Cristobal	2020	0.6

As shown in Table B: 4-3, the river gage peak timing follows the storm surge peak timing by an average of 1.8 days for the Tangipahoa River. As shown in Table B: 4-4, the river gage peak timing follows the storm surge peak timing by an average of 1.1 days for the Natalbany River. With the time shift to the Lakes, the actual peak coincidence at the lakes would be 2.6 days on the Tangipahoa River and 1.6 days on the Natalbany River. Based on the magnitude of the lag times, the river and storm surge peak stage occurrence are assumed to be relatively independent. The one caveat is that the lake levels do appear to be elevated during river peak stages which could affect compound flooding risk. Since this adds to uncertainty, a sensitivity analysis of river flood coincidence with lake surge was performed.

Note that a true measure of gage independence is to perform a gage correlation analysis. However, a sufficient gage period of record does not exist at the gages.

4.6.2 Coincident Frequency

EM 1110-2-1415 defines the coincident frequency of flows in USACE hydrologic design. It states that it is necessary to consider river flood coincidence with storm surge flooding. Because of limited data availability, a full coincident frequency analysis may not be adequate. In some cases where river and lake events are not highly correlated, indirect use of non-coincident data in order to establish frequency profiles of coincident events can be done.

A sensitivity analysis on the range of the actual conditional exceedance frequency profiles was performed. To capture the difference in the upper and lower bounds of dependent frequency profiles in the zone of compound flooding, the 1% AEP and 10% AEP storm events were examined. Plots of the computed profiles for 1% AEP event for rivers and creeks in the Lower Tangipahoa and Natalbany River/Selser's Creek HEC-RAS models are shown in Annex B. The plots focus on the zones of compound flooding.

The upper profile in the plots have the 1% AEP river event coincident with a 1% AEP lake surge event. The lower lines that join in the area of compound flooding are the 1% AEP river event coincident with the MHW level on the lake and 1% AEP lake surge event coincident with the 50% AEP river flood event. Falling within this triangle of profiles will be the actual 1% AEP river profile. To clarify, the actual profile within this compound flooding zone would be computed through a more complex coincident frequency analysis.

Through flood peak timing analysis of select storm events it was determined that river and lake levels during storm events are relatively independent. Therefore, a simpler approach is warranted to capture coincident river stages to lake surge stage. The approach that the PDT determined acceptable is that the design frequency event river flow will be coincident with the MHW level for riverine flooding. The design frequency storm surge level will be coincident with a normal river flow (50% AEP event).

For the 1% AEP coincident storm events, there is a low probability of occurrence. The actual 1% AEP event profile will fall below this profile in the compound flooding. The determined area of compound flooding is small, and the risk potential from underestimating the actual frequency profile in this zone is low. This would push the actual 1% AEP frequency profile closer to the lower profile range.

Through economic analysis, damage costs were examined for the profiles upper and lower frequency profiles. Using the frequency inundation grids, depths from each scenario were extracted to structures using the default NSI 2022 database for structure details. Developed in 2009 and revised in 2013, damage curves were used in tandem with the base NSI structures and content values to determine the total damage in dollars per structure. These per-structure values were then summed for each inundation scenario so that total aggregate damage for each scenario could be compared for the purposes of analyzing the differences in compound flooding magnitude. The 1% AEP and 10% AEP frequency events were the primary focus of this analysis. Table B: 4-5 and 4-6 show the resulting costs associated with using the different frequency event combinations.

Table B: 4-5. Tangipahoa River Basin Coincident Event Cost Analysis

Frequency Combination	10% AEP Event	1% AEP Event
Frequency River and MHW event coincident with Frequency Surge and River 50% Flow event	$77,993,710	$223,611,240
Frequency River event coincident with Frequency Surge event	$79,460,250	$226,429,440
DIFFERENCE	$1,466,540	$2,818,200
PERCENT DIFFERENCE	1.9%	1.3%

Table B: 4-6. Natalbany River Basin Coincident Event Cost Analysis

Frequency Combination	10% AEP Event	1% AEP Event
Frequency River and MHW event coincident with Frequency Surge and River 50% Flow event	$60,011,490	$209,757,190
Frequency River event coincident with Frequency Surge event	$61,420,030	$214,045,590
DIFFERENCE	$1,408,550	$4,248,400
PERCENT DIFFERENCE	2.3%	2.0%

It can be seen that the additional damage results to using the lower profile (frequency event river-MHW lake versus frequency event lake-50% AEP river) is low compared to the overall damage costs. Percent difference between the averages of the coincident frequency damages are below 2.3%.

The risk for error in relying on the river profile computed from a merger of the 1% AEP river profile tying into MHW and the 1% AEP lake level tying into a 50% AEP river event is low. Also, because the economic analysis shows no significant additional damage within the analyzed range of profiles, the overall risk associated with this approach to computing frequency water surface elevations in the areas of compound flooding is acceptable. Figure B: 4-9 shows an example of the two different water surface profiles considered. Through the section of compound flooding the lower profile (blue line) has been selected.

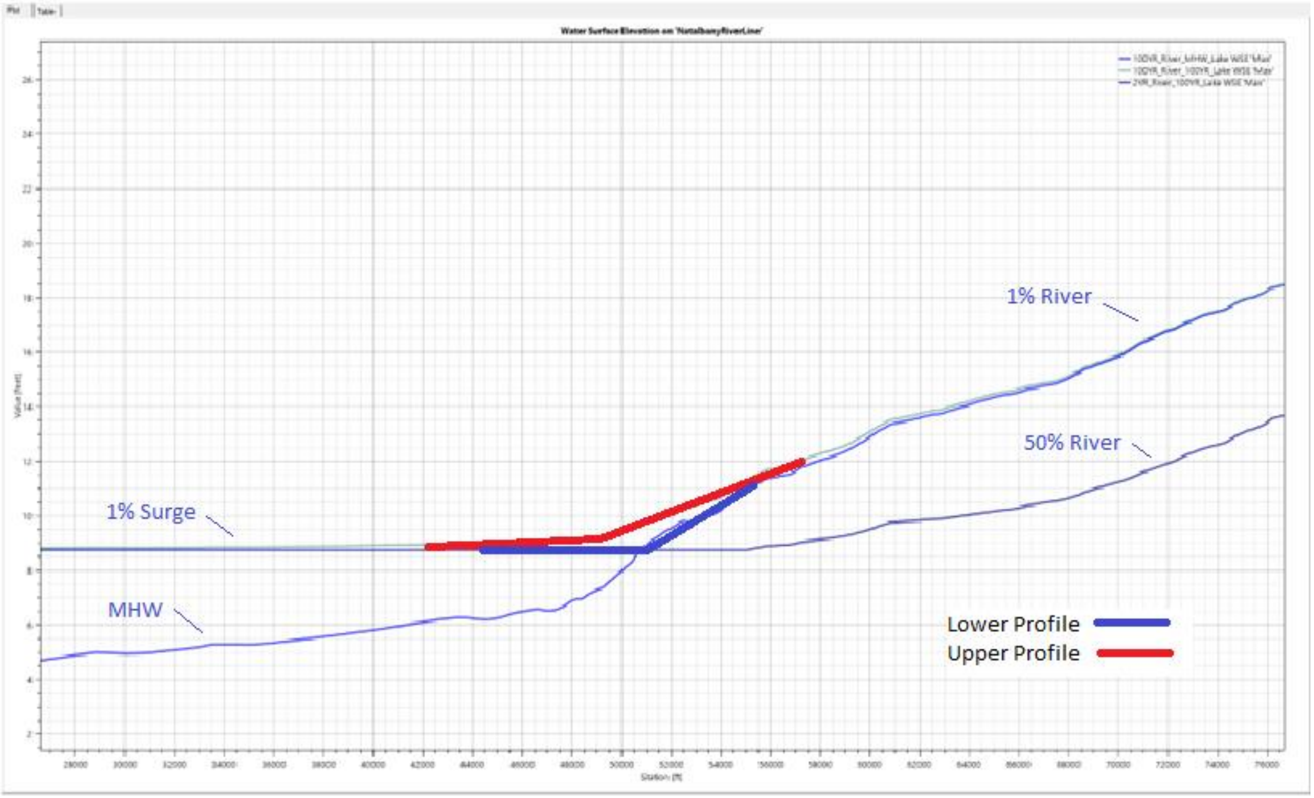


Figure B: 4-9. Water Surface Profiles of Coincident Surge and Riverine Flood Events - 1% AEP Event

4.7 FUTURE CONDITIONS

Future with and without project conditions are considered in USACE planning studies. The focus of project benefit at completion of the project and 50 years in the future is examined. Items such as future development, changes to land use, and climate change are several effects that have future consequence.

Future development, reported by the parish, will have a little impact to the overall hydrology and hydraulics of the study area. It is small in scale when compared to the entire parish watershed area. USACE also considered future hydraulics projects in the Parish. This includes the consideration of small-scale grant funded hydraulics projects in the Parish. Though beneficial, the hydraulic impacts will be localized and have little effect on the overall Parish hydraulics. It should also be noted that the effects of hydraulic improvements will locally reduce water levels. The exact benefit of these projects is unknown as they are in the initial phases of design at the time of this study. Discounting no hydraulic changes in future with and without project conditions is a conservative approach to future water levels in the riverine flooding extents of the parish.

Relative sea level change and regional subsidence are expected to be significant and are quantitively assessed in this study.

4.7.1 Relative Sea Level Change

Global, or eustatic, sea level rise 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 for the Tangipahoa River eventually drain to Lake Pontchartrain, and the river basins in the Natalbany River and Selser’s Creek drain to Lake Maurepas. 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 of sea level change to use for project evaluation. The curves were computed using the Sea-Level Calculator for Non-NOAA Long-Term Tide Gauges Version 2020.88 (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_nn_calc.html). The calculator has been updated to reflect calculated rates contained in the 2015 Updated Atlas of USACE Historic Daily Tide Data in Coastal Louisiana (https://erdc-library.erdc.dren.mil/xmlui/bitstream/handle/11681/25484/MRG%26P%20Report%20No%2014.pdf?sequence=1&isAllowed=y). This update adheres to the criteria discussed in EC 1165-2-212. Lake Pontchartrain at Mandeville (85575) has a record from Aug 1957 to Jul 2002, and Lake Pontchartrain at Frenier (85550) has a record from Jan 1950 to Dec 2002.

All three rates were examined in the future conditions phase. The end of the 50-year planning horizon is 2083. For the Tangipahoa River watershed, it was decided to calculate the 50-year sea level rise from the Lake Pontchartrain at Mandeville, LA gage. For the Natalbany River and Selser’s Creek watersheds, it was decided to calculate the 50-year sea level rise for both the Mandeville and Frenier Lake Pontchartrain gages and average the results. The 0.33 ft adjustment for converting from Lake Pontchartrain to Lake Maurepas was then applied. Calculated high, intermediate, and low-rate changes in relative sea level by the year 2083 are 4.14, 2.03, and 1.36 feet for Lake Pontchartrain Mandeville and 4.52, 2.40, and 1.74 feet for Lake Pontchartrain at Frenier. These values were added to the established downstream boundary condition levels for the frequency events.

Note that the 2017 CPRA Master Plan ADCIRC dataset reports the frequency water surface level effects of storm surge combining the aspects of surge, wind, and tidal effects. When including a sea level change component, it is common practice when assessing water levels in coastal studies to separately consider these components before combining them through linear superposition to determine the total water level. However, the use of linear superposition introduces error due to the complex nonlinear interaction of these components. In this study, the downstream boundary conditions were determined by linearly adding surge frequency levels, MHW, and sea level rise. There is an inherent uncertainty introduced with the inundation results due to these components non-linear interaction.

4.7.2 Sea Level Rise Projection

Sea level rise and its sensitivity on project alternatives has been considered in the Tangipahoa FRM study. Because sea level rise is accounted for in the base year (2033) and the future-with and without project conditions (2083), a single sea level curve must be selected when computing water levels for economic analysis. The sea level rise trends and projections for New Canal Station, LA are shown in Figure B: 4-10. New Canal Station is the closest gage to the downstream model boundaries with a suitable period of record that includes the most recent gage observations.

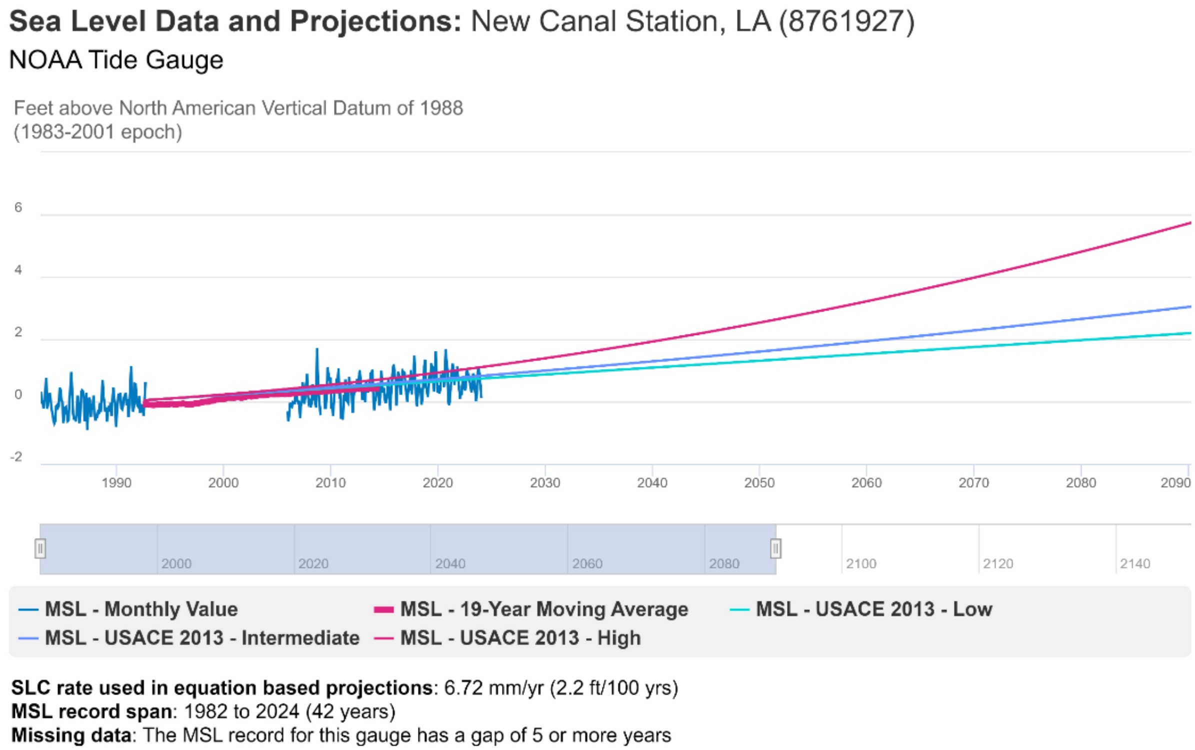


Figure B: 4-10. New Canal Station, LA Sea Level Change Projections

The decision to use the intermediate sea level rise curve is supported by comparing the gage at the New Canal Station (8761927) to the USACE sea level rise projections. The USACE Sea Level Analysis tool (https://climate.sec.usace.army.mil/slat/) shows that the 40-year record trend at this gage is lower than the low sea level rise projection, while the USACE Sea Level Tracker tool shows that the 19-year moving average for mean sea level has followed the low and intermediate sea level rise projection curves over the past decade. Given the variance in the comparison of the gage record to sea level rise projections, the intermediate curve was selected to calculate the floodplain water surfaces for the TSP. The intermediate projection will lead to the more conservative estimates over the low curve without the potential for over prediction of the high curve.

4.7.3 Future Without Project Boundary Condition

The HEC-RAS downstream boundary conditions for riverine flooding are stages that represent the mean high-high water level of Lake Pontchartrain and Lake Maurepaus. For coastal flooding, boundary condition stages use the frequency estimated storm surge levels taken from the 2017 CPRA Master Plan ADCIRC dataset. Stage boundaries are used along the entire extents of the southern boundary of the models where the 2D domain interacts with Lake Pontchartrain and Maurepaus.

There are two gages on the western and northeastern shore of Lake Pontchartrain to determine the boundary conditions for future conditions. They are Lake Pontchartrain at Frenier, LA and Mandeville, LA respectively. The Lake Pontchartrain MHW level was used as the existing conditions downstream stage for the Lower Tangipahoa River model. An average elevation shift of +0.33 ft was applied to Lake Pontchartrain stages for use at the downstream condition at Lake Maurepas in the year 2023 existing conditions model. Additional change was added for the shift in base year based on sea level rise projections.

For downstream boundary conditions for the Lower Tangipahoa River model, stages of 4.45, 2.34, and 1.67 feet (high to low curves) were used for the future conditions. For downstream boundary conditions for the Natalbany River and Selser's Creek model, the SLR values from the Mandeville gage and Frenier gage were averaged, and then added onto the base year existing conditions stage. Stages of 4.97, 2.86, and 2.19 feet were used for the year 2083 future conditions. These values are tabulated in Table B: 4-7.

Table B: 4-7. Downstream Boundary Condition Stages along the Extents where the Model Domain Interacts with Lake Pontchartrain and Lake Maurepaus

Condition Type	Tangipahoa River Downstream Boundary Stage	Natalbany River and Selser's Creek Downstream Boundary Stage
Existing Conditions - Base Year 2033	0.59 ft	0.96 ft
Future Conditions Low SLR Rate (year 2083)	1.67 ft	2.19 ft
Future Conditions Intermediate SLR Rate (year 2083)	2.34 ft	2.86 ft
Future Conditions High SLR Rate (year 2083)	4.45 ft	4.97 ft

4.7.4 Future Without Project Model Results

Relying on the intermediate sea level rise projections (Section 4.7.2), the models were run to predict water levels for the base year 2033 and year 2083 (base year + 50 years). The 2083 future without project condition river profiles are compared to 2023 existing conditions in Annex F. The effects of sea level change on the coastal surge boundary extents are illustrated in Figure B: 4-12. Blue is the riverine flood extents. Red is the year 2083 coastal surge extent and Yellow is the base year 2033 coastal surge extent.

As can be seen in the profile plots and Figure B: 4-11, the effects of sea level change 50 years out from the base year propagate the coastal surge boundary 0.6 miles and 1.7 miles upstream on the Tangipahoa and Natalbany River. Sea level change over the next 50 years will have a significant impact on the southern extents of the parish during coastal storm surge events.

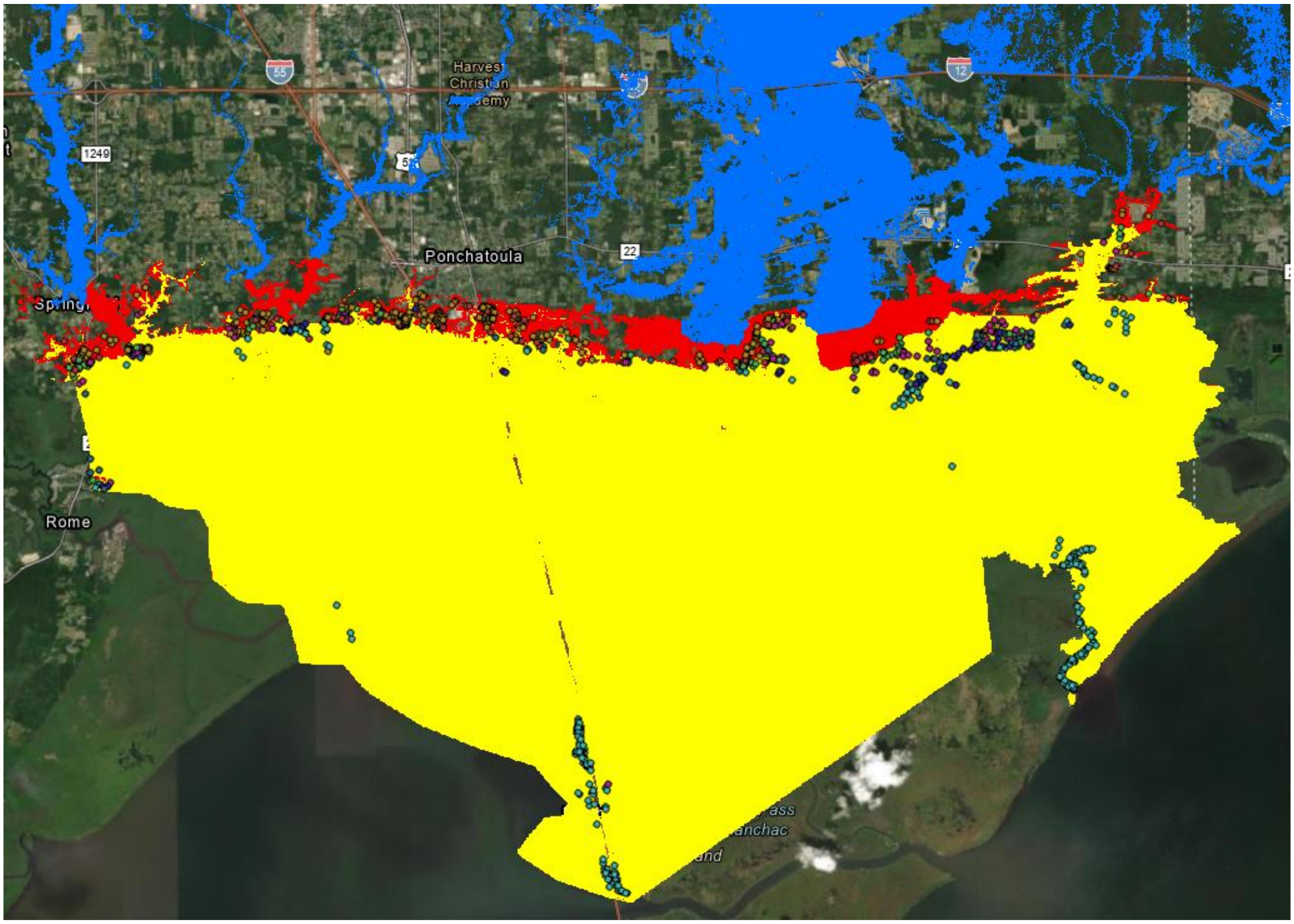


Figure B: 4-11. Effects of Sea Level Rise (50 years out - 2083) on Coastal Surge Impacts - 1% AEP Event (Blue is the riverine flood extents. Red is the year 2083 coastal surge extent and Yellow is the base year 2033 coastal surge extent).

SECTION 5
Coastal Surge Analysis

5.1 ADCIRC MODELING

The 2017 Coastal Protection and Restoration Authority (CPRA) dataset – existing conditions was used to develop storm surge and wave parameters at specific frequencies. Using a 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 JPM-OS synthetic storms. The storms cover a range of hypothetical tracks, forward speeds, intensities, and sizes. Figure B: 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 B: 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. ADCIRC, which computes storm surge water surface elevations, is coupled with SWAN (Simulating WAves Nearshore) to compute significant wave height and peak wave period. The couple of ADCIRC and SWAN yields frequency surge levels that are forced by both wind velocities and atmospheric pressure.

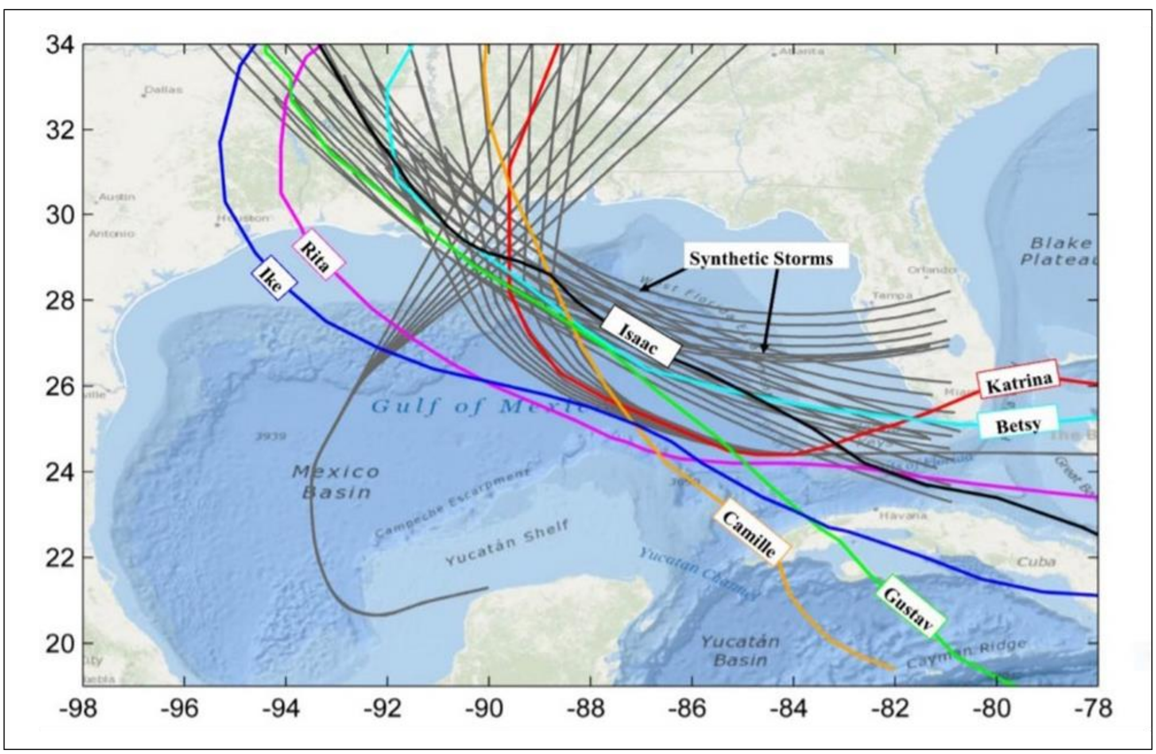


Figure B: 5-1. Tracks for all 152 Synthetic Storms Compared against Historically Significant Events

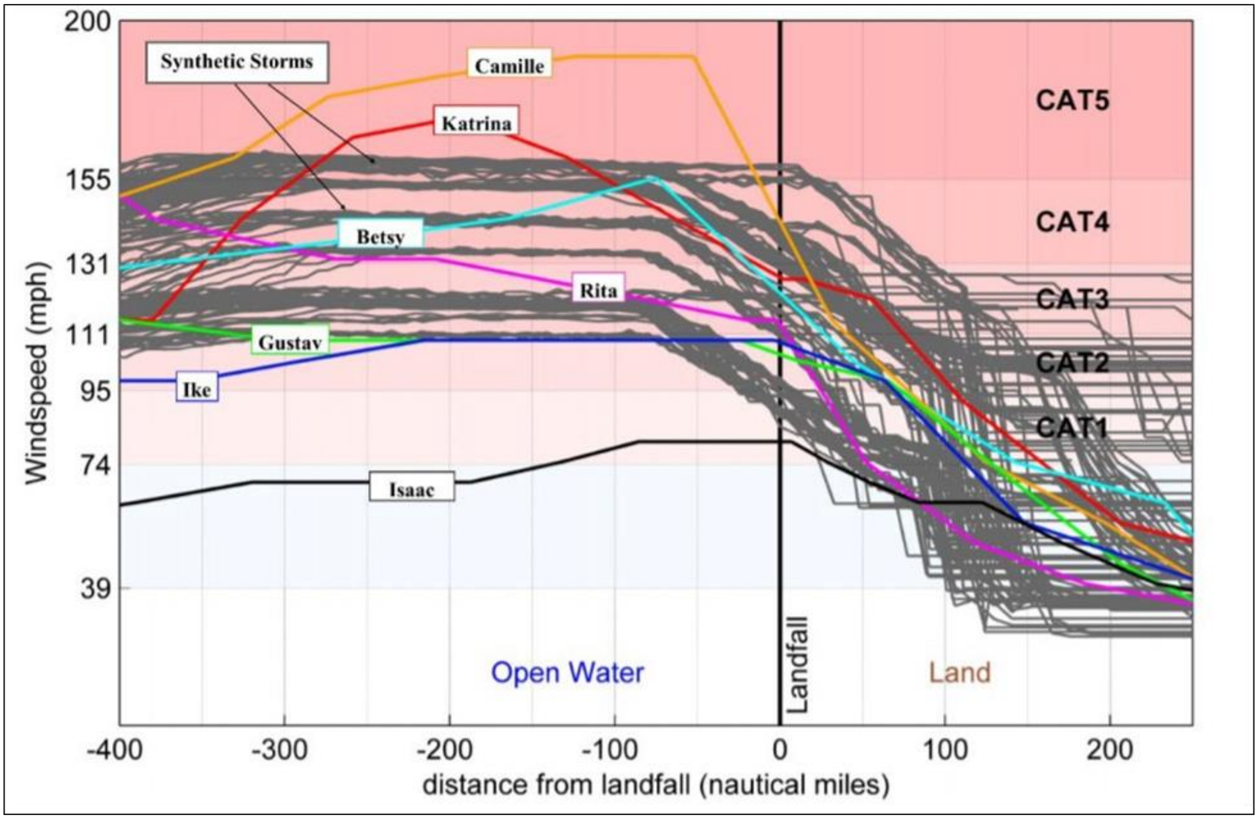


Figure B: 5-2. Wind-speeds for all 152 Synthetic Storms Compared against Historically Significant Events

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 sea level change 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 2033 ("base year"). Adding the 50-year window needed for economic analysis results in 2083 ("future year"). At 50+ years out, sea level rise 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 sea level rise specified in USACE guidance (ER 1100-2-8162). The future conditions results based on the intermediate rate of sea level rise 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, sea level rise, and surge. By inputting return period and sea level rise, 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 sea level rise 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 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% AEP events.

5.2 EFFECTS OF HURRICANE WIND FORCING

For the August 2021 event, wind force data from the Hurricane Ida ARCIRC simulation was applied. Reformatted to run in HEC-RAS, the goal was to see if wind force had a significant effect on raising flood levels.

MatLab was used to convert the ADCIRC data to a format that could be imported into HEC-RAS. From this, rasters of the wind magnitude and wind direction were created using HEC-RAS to use in the Hurricane Ida simulations.

For the August 2021 event, the wind direction was mostly Westward, and the maximum wind speed during the event in the project area was approximately 110 ft/sec. The water surface elevation profile for the Tangipahoa River was calculated for the 2021 run for the conditions with and without the wind force. The difference in water surface profiles of the lower Tangipahoa River can be seen in Figures B: 5-3 through 5-5. The area of impact is shown in Figure B: 5-6.

Overall, the maximum rise in water surface elevation due to wind force for the August 2021 event was 0.15 ft. The area affected by wind force was also very small, only covering about a 3 mile stretch of river at the downstream end just before it empties into Lake Pontchartrain. The results of this wind sensitivity analysis show that for Hurricane Ida wind did not have a significant effect on the level of the water surface elevation and extent of flooding.

Though not the case during Hurricane Ida, the possibility of high winds in a northern direction are possible. High northerly winds could possibly see a greater increase in water surface elevation in the region of impact (Figure B: 5-6). The results of the 2021 event along with the fact that there are a low number of structures affected by flooding south of Louisiana Highway 22, the extent and magnitude of increase in water surface elevation would show a small increase in economic damages.

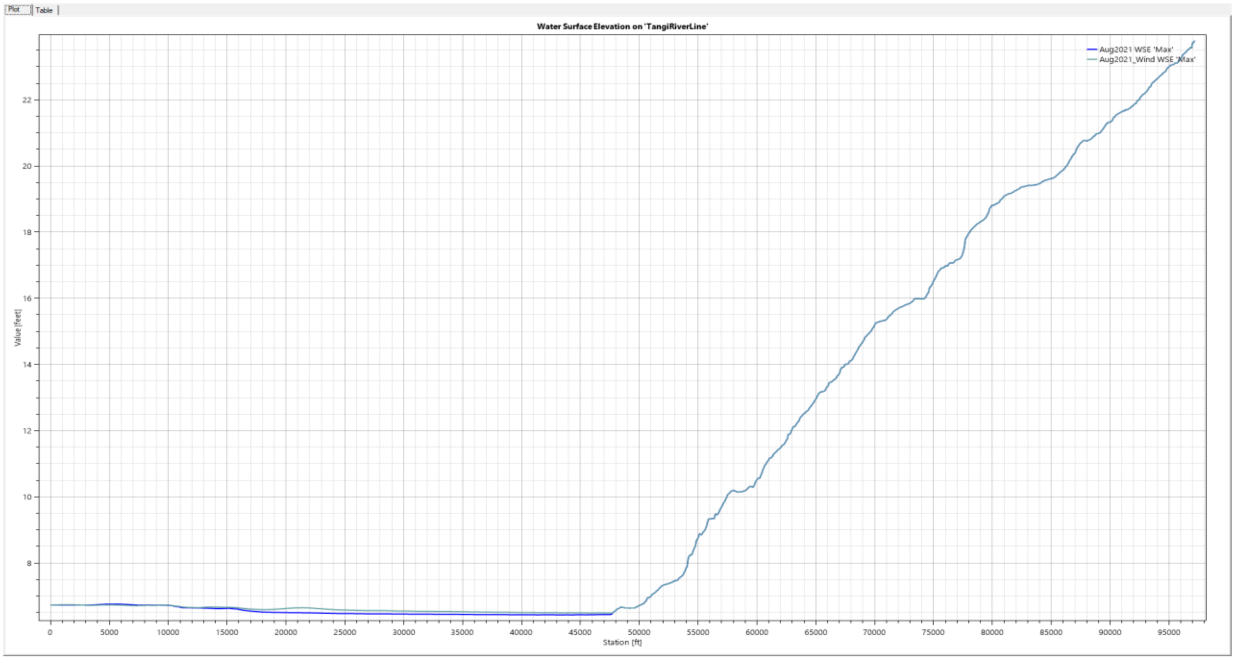


Figure B: 5-3. Profile of the Lower Tangipahoa River Showing Difference in Wind Force Conditions

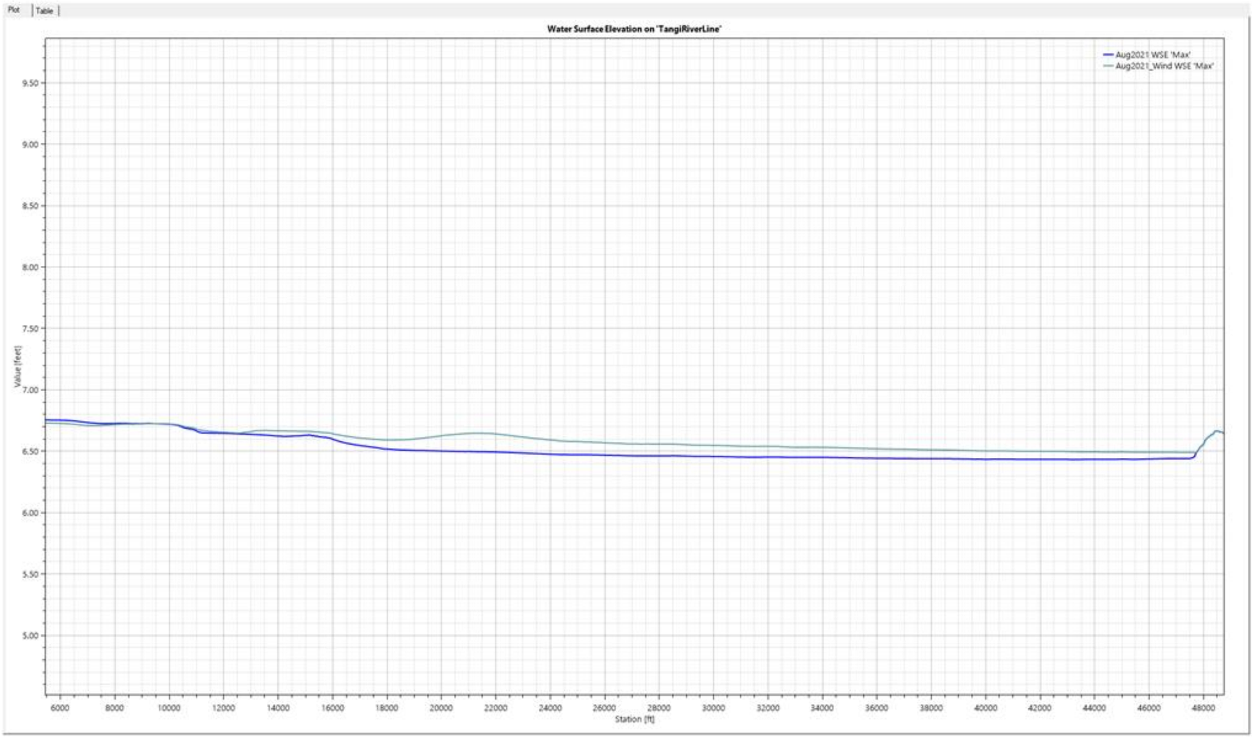


Figure B: 5-4. Wind Force Focused Profiles for the Lower Tangipahoa River (Station 6,000 to 48,000)

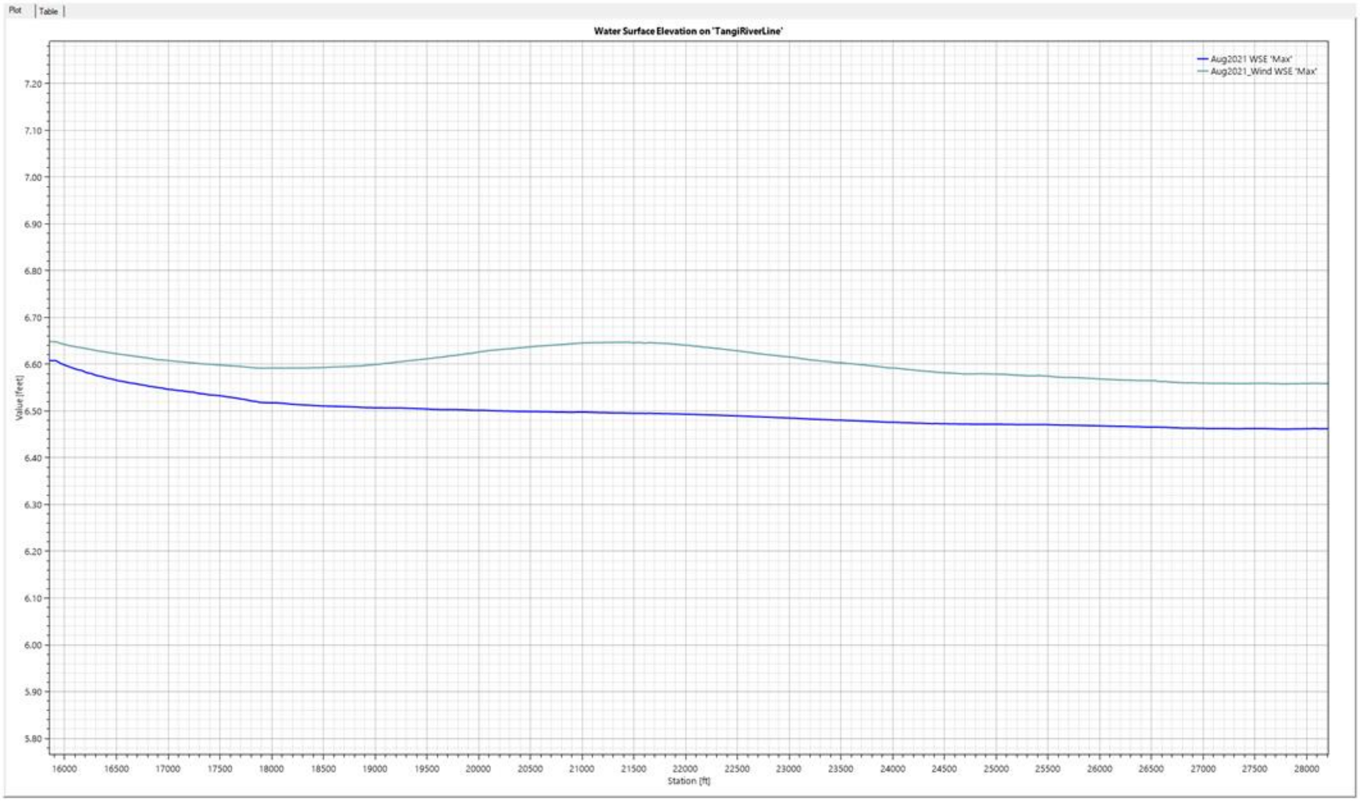


Figure B: 5-5. Wind Force Focused Profiles for the Lower Tangipahoa River (Station 16,000 to 28,000)

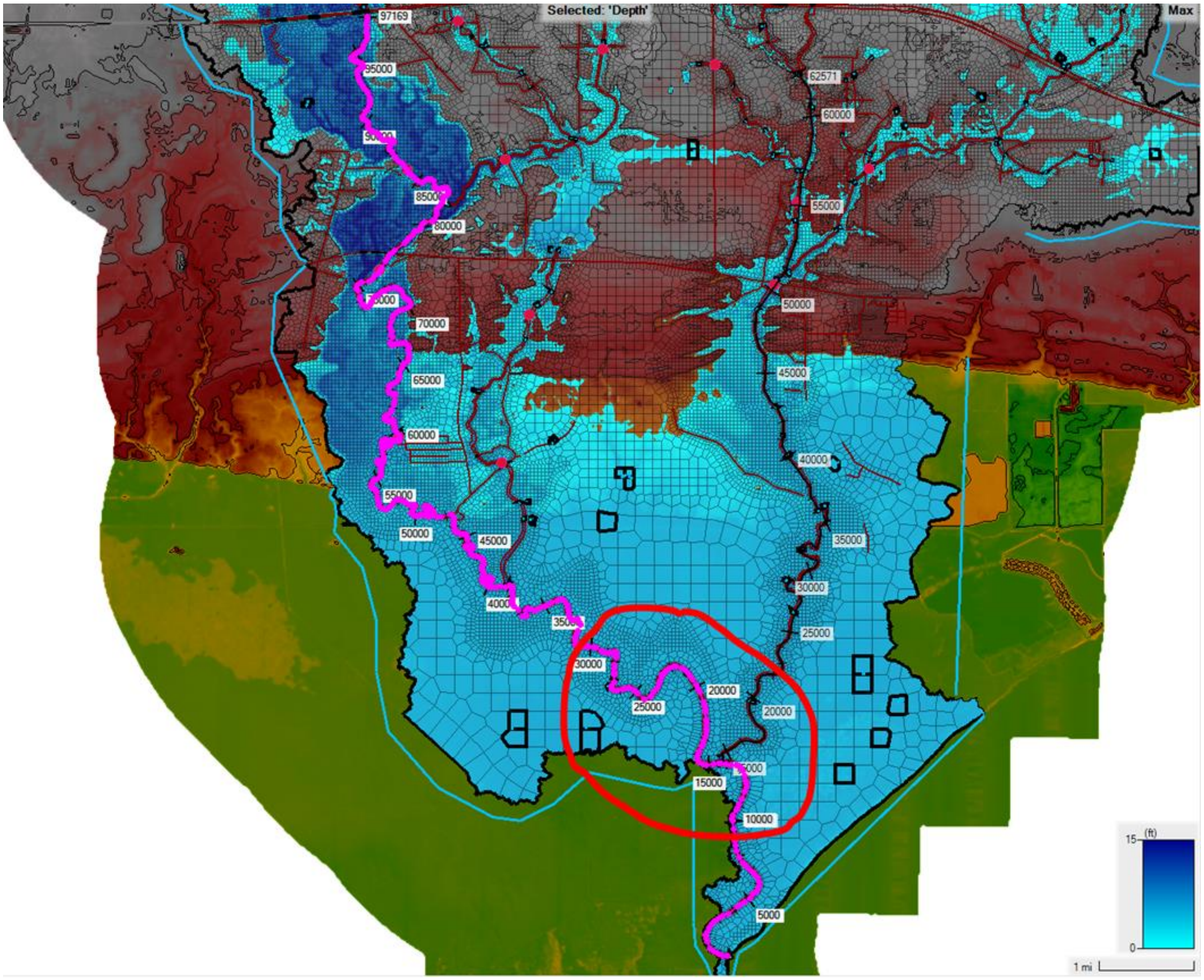


Figure B: 5-6. Hurricane Ida - Area Affected by Wind Force (circled in red)

SECTION 6
Proposed Measures

6.1 PROPOSED MEASURES

This FRM study will evaluate alternatives that can manage damages to structures and manage rainfall and storm-related flood risks in the study area, therefore reducing life safety concerns. This study developed an array of structural and non-structural measures to meet the flood risk management objectives. Some of the structural measures examined are:

- Detention Ponds
- Diversion Channels
- Channel Improvements/Dredging
- Elevation of Roadways
- Levees and Floodwalls
- Reservoirs
- Revetment
- Snagging and Clearing
- Water Control Structures

The non-structural measures examined are:

- Elevation of Homes
- Flood Proofing Critical Infrastructure (Dry and Wet)
- Residential Flood Proofing (Dry and Wet)
- Acquisition and Relocation

As a component to the structural and non-structural measures, natural and nature-based solutions were incorporated where possible. Some of these solutions were:

- Reclamation of Abandoned Quarries for Flood Storage
- Detention Ponds with Wetland Restoration Benefit
- Beneficial Use of Dredge/Snag Material

- Application of the Louisiana Watershed Initiative

6.2 STRUCTURAL ALTERNATIVES

There were 51 structural alternatives in the initial array of alternatives. A large portion were screened due to effectiveness or project cost versus benefit.

Coastal affects control the flooding in the Parish south of Highway 22. The hydraulic analysis does capture this in the base year and future year models. The case of riverine flooding only is also captured as well. However, riverine flooding dominates the flooding in the areas of the proposed structural measures.

The focused array of structural alternatives included measures where hydraulic analysis was performed to capture their flood risk reduction effectiveness. The focused array of structural measures examined are:

- Alternative 3: Washley Creek
    - 3a: Robert Levee (WASH-1)
    - 3a: Robert Levee Short (WASH-2)
    - 3b: Robert Levee with Combined Detention Basin (WASH-3)
- Alternative 4: Beaver Creek/Tangipahoa River
    - 4a: Tangipahoa Levee (SPTR-1a and 1b)
- Alternative 5: Bedico Creek
    - 5a: Roadway elevation of Firetower Road near LA-22 (BED-1)
    - 5b: Roadway elevation of Highway 22 near Firetower Road intersection (BED-4)
    - 5C: Combination of BED-1 and BED-4 (BED-5)
- Alternative 6: Little Chappepeela/Cooper Creek
    - 6a: Roadway elevation and Bridge Replacement along Briar Patch Cemetery Road (LCC-1)
- Alternative 7: Tangipahoa River and Chappepeela Creek
    - 7a: Tangipahoa Snagging and Clearing from Hwy 190 to Independence (SNG-1)

- 7b: Tangipahoa River and Chappepeela Creek from Tangipahoa River to Little Chappepeela Creek (SNG-3).

The focused array of alternatives were shown to be hydraulically effective in flood risk reduction. Construction quantities and associated costs of construction were determined for the economic analysis of the benefit costs.

6.2.1 Alternative 3: Washley Creek and the Robert, LA Levee Alternatives

Robert, LA receives a lot of regular and reoccurring flood damage. Because of its proximity to the Tangipahoa River at the confluence of Washley Creek, the flooding is extensive and deep. Levees protecting the town of Robert, LA were examined with two levee alignments proposed.

In the proposed conditions HEC-RAS model, levees were modeled as 2D storage area connections. To get the extents of the alignment the storage area connection weir embankment was high enough above the ground surface to ensure water would not pass over top. Once water was ensured to not pass around the levee alignment, the levee height was set to 0.25 feet above the 1% AEP water surface profile against the levee. Adjustments were made to the levee profile to correct abrupt changes in water surface and to level out the levee profile transition.

The HEC-RAS models were run with the proposed levees where it was ensured that the water did not overtop the levee until exceedance of the 1% AEP storm event. In the model, residual flood risk from interior drainage was seen for the events equal to or less than the 1% AEP event and increased river stages on the riverside of the levee were observed.

6.2.1.1 Levee Alignment WASH-1

The WASH-1 levee alignment around Robert, LA has two sections. The first starts at the road to Robertson Cemetery extending south adjacent to Chemekette Road and the Tangipahoa River. The alignment continues south crossing US Highway 190 eventually turning northeast south of the Bennett Lane neighborhood. Adjacent to Washley Creek the levee crosses Pole Bridge Branch and Holden Branch. The levee alignment continues across Doc Hyde Road and US Highway 190 where it terminates 2,200 feet north of US Highway 190. The second alignment, used to restrict flow crossover from Washley Creek into Holden Branch, is adjacent to Washley Creek 3,700 feet east of Riverdale Heights Road. The levee alignment is shown in Figure B: 6-1.

This levee alignment requires gate closure structures at LA 445, Doc Hyde Road, and US Highway 190 (two separate closures sections). Two pump stations are also required pass Holden Branch and Pole Bridge Branch drainage during high Washley Creek stages. Gravity drainage will be allowed during normal Washley Creek conditions. The modeled capacity of the Pole Bridge Branch pump station was 450 cubic feet per second and the capacity of the Holden Branch pump station was 350 cubic feet per second.

The levee and 1% AEP event water surface profile for the two alignments are shown in Figures B: 6-2 and 6-3. The levee was designed to protect up to the 1% AEP event with the 0.5% AEP event overtopping the levee. The 1% AEP event inundation extents showing the residual flood risk is shown in Figure B: 6-5. For comparison purposes, the existing conditions inundation extents are shown in Figure B: 6-4.

Stage reduction in Robert, LA from implementation of WASH-1 is substantial. At the Highway 190 crossing of Pole Bridge Branch the water level reduces 8.4 feet during the 1% AEP event. At the Highway 190 crossing of Holden Branch the water level reduces 7.5 feet.

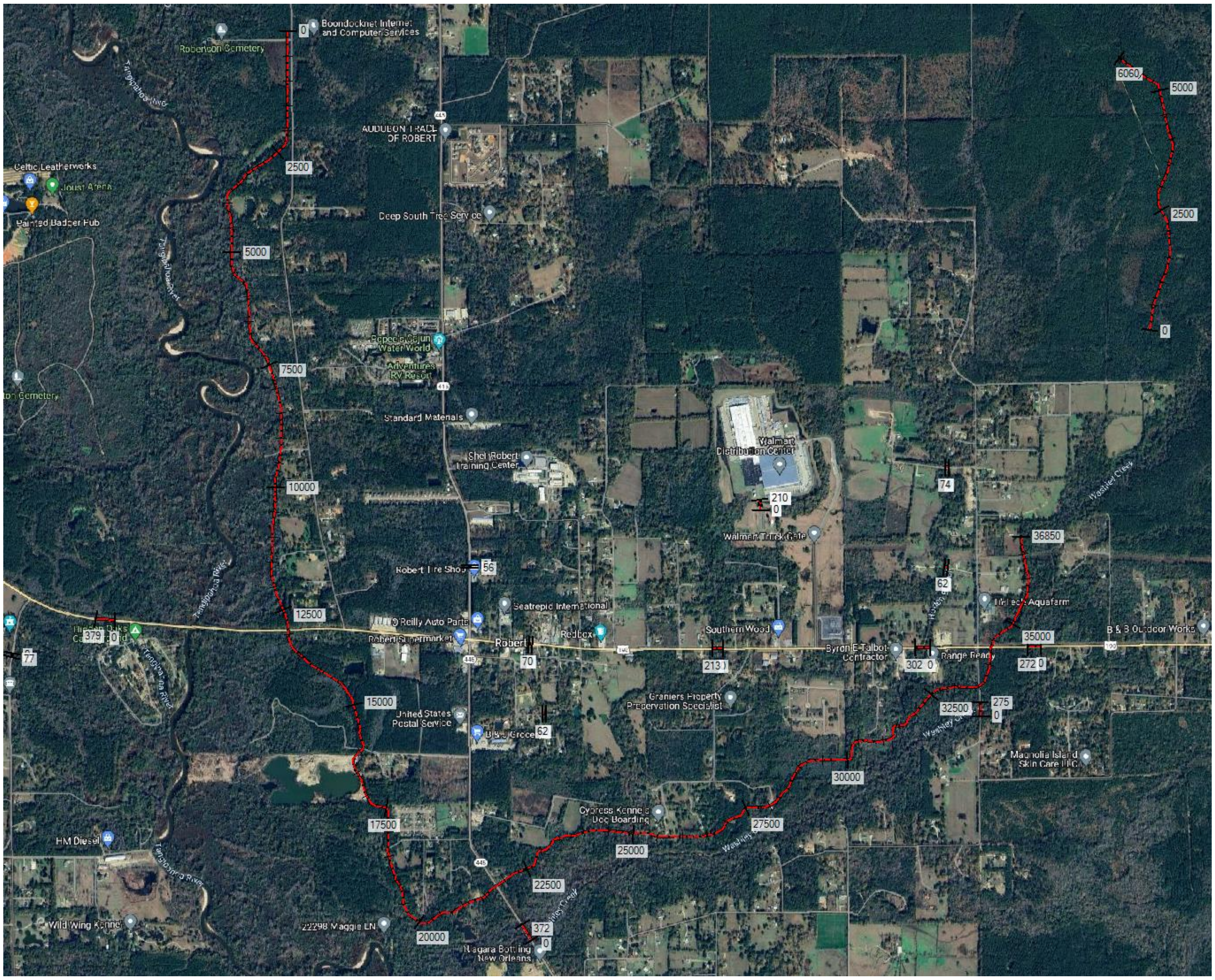


Figure B: 6-1. WASH-1 Levee Alignment

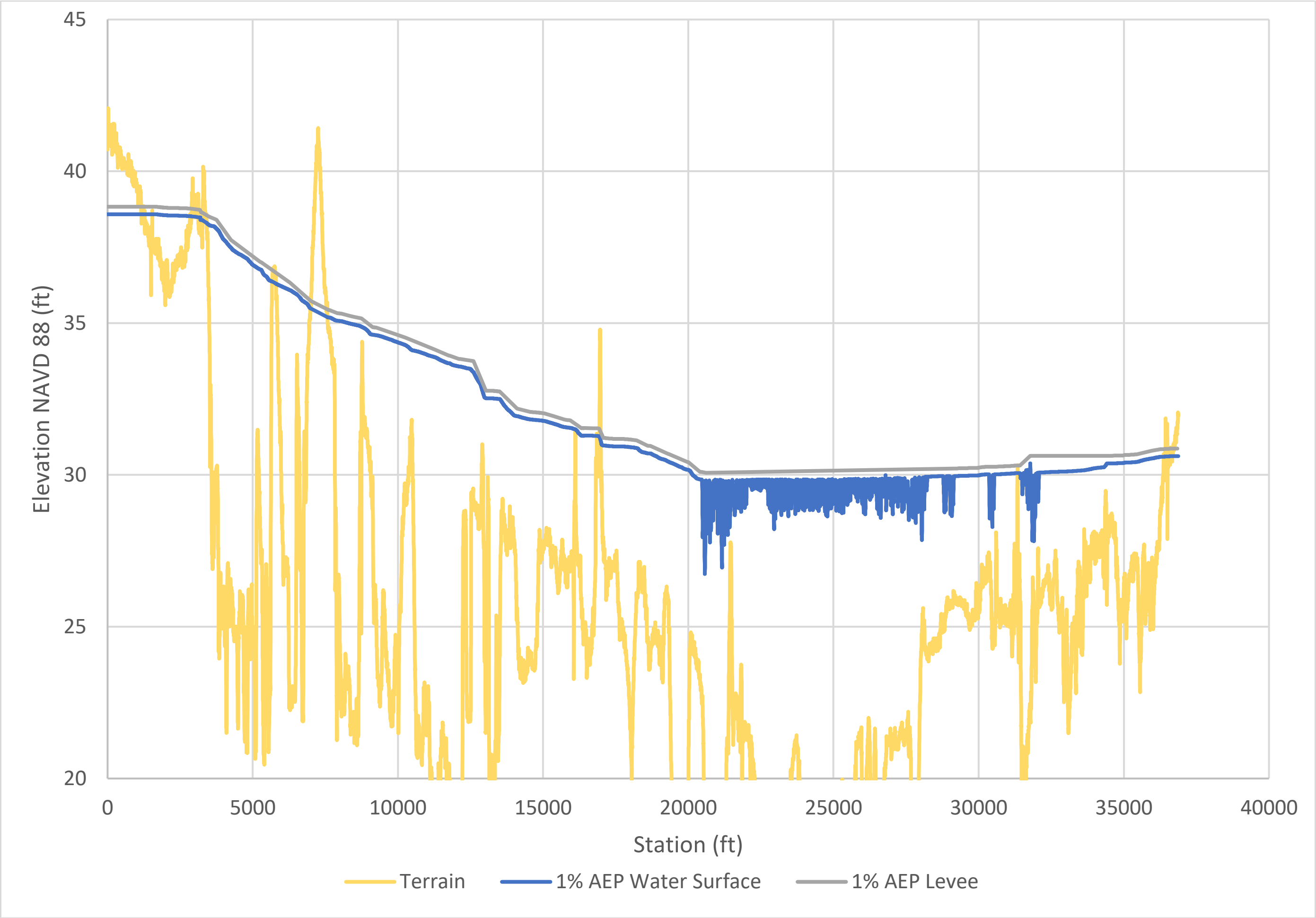


Figure B: 6-2. WASH-1 Main Section Profile

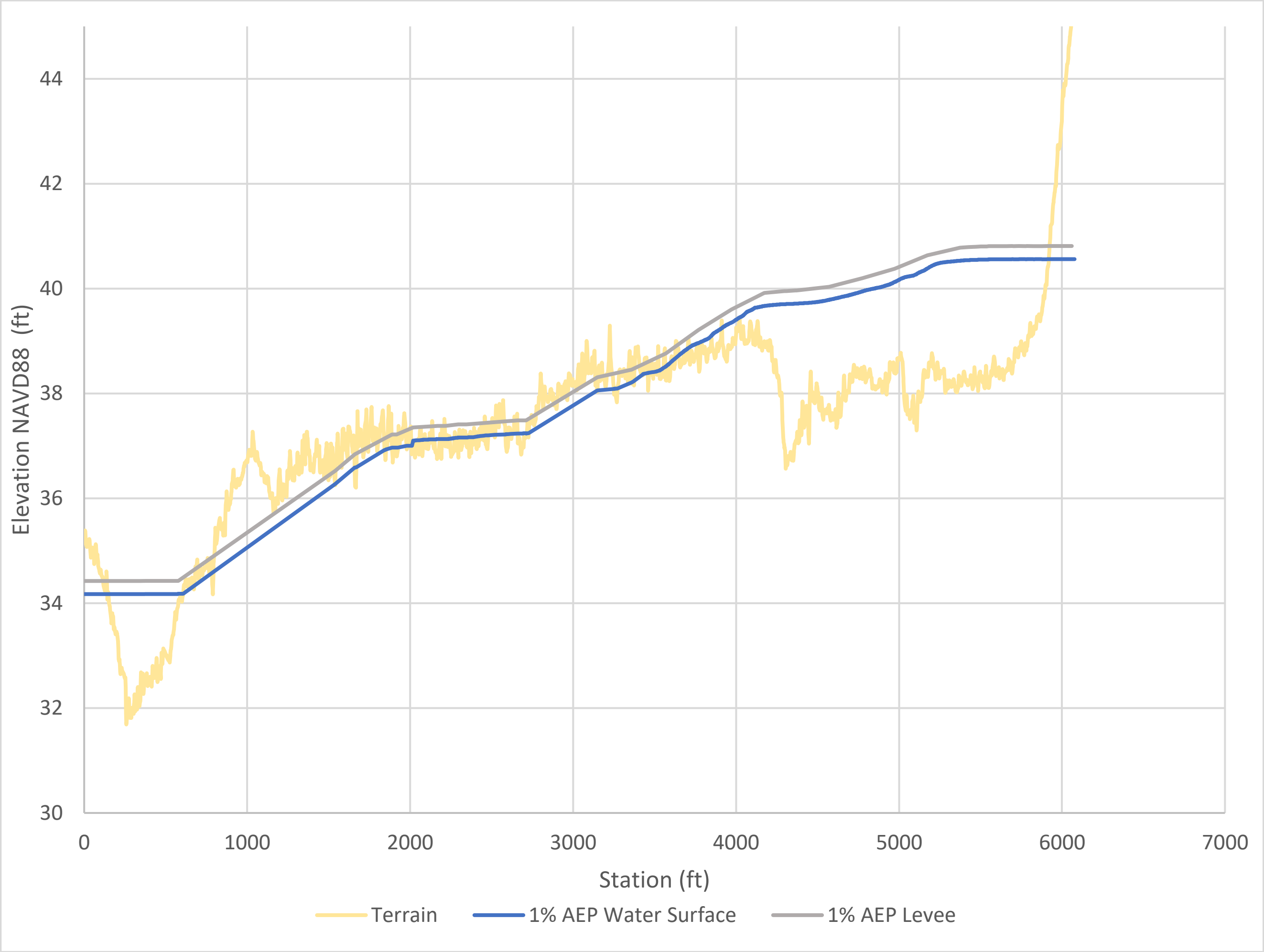


Figure B: 6-3. WASH-1 Crossover Section Profile

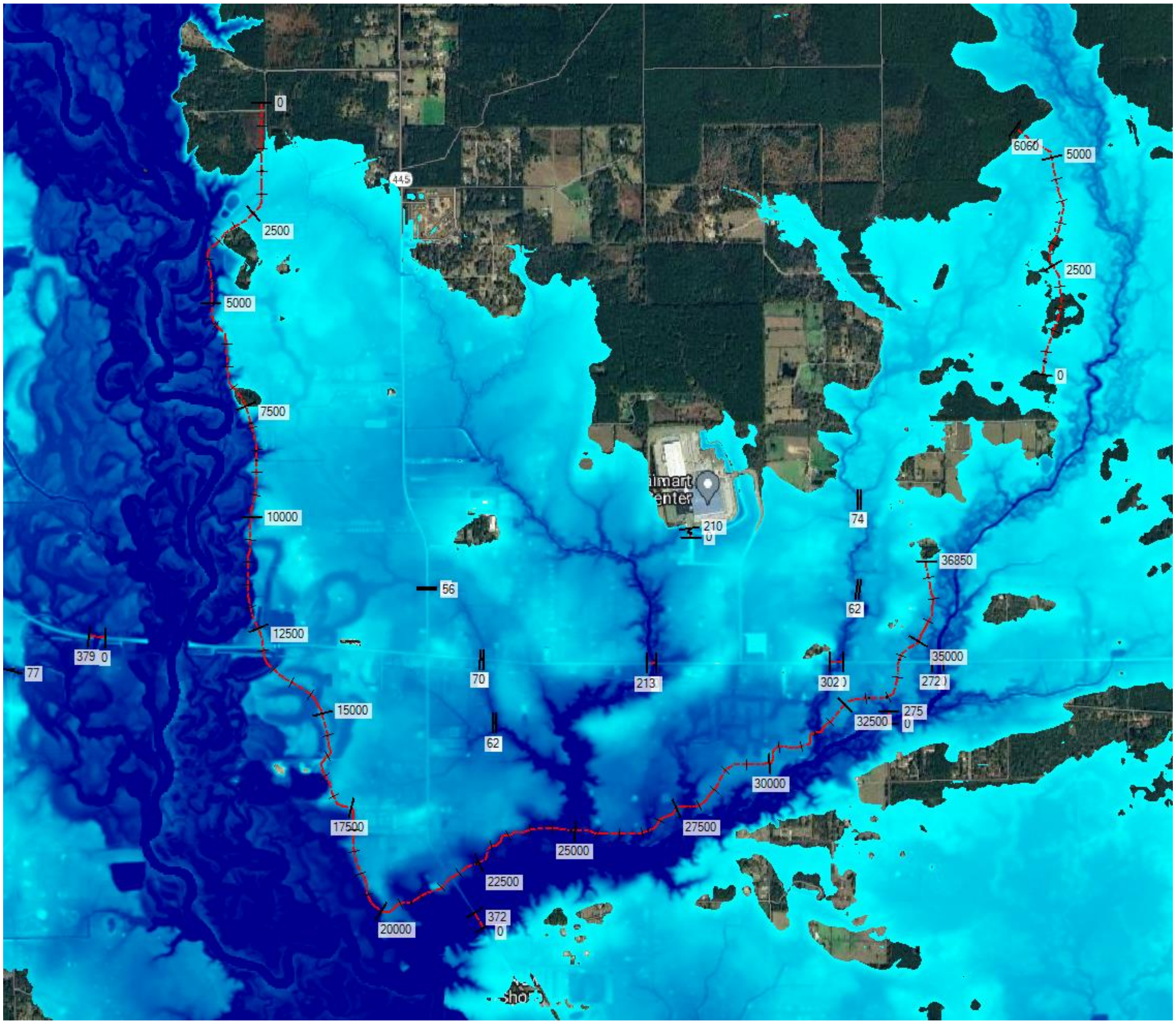


Figure B: 6-4. Existing Conditions Robert, LA Inundation - 1% AEP Event WASH-1

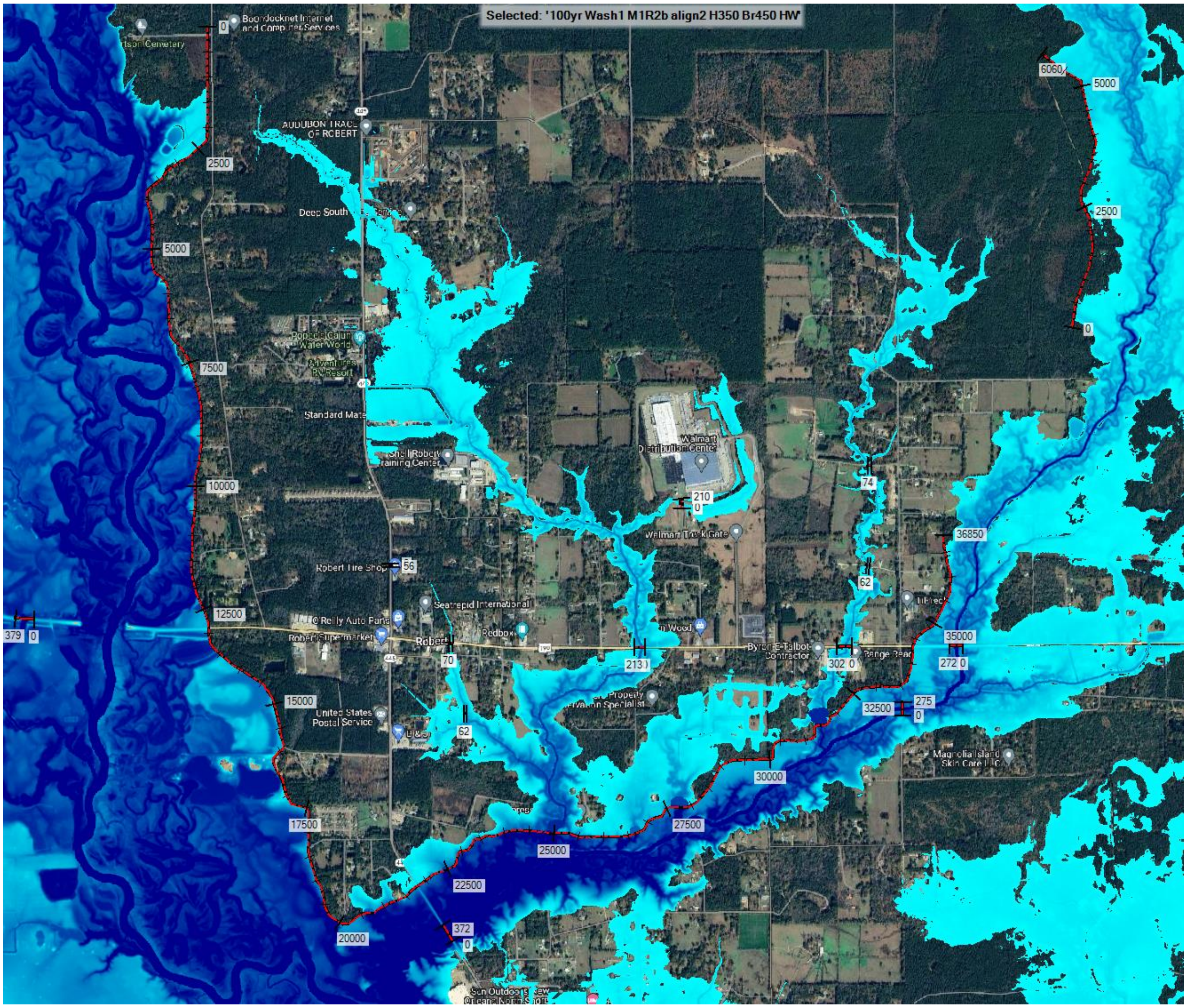


Figure B: 6-5. WASH-1 Levee Inundation - 1% AEP Event

6.2.1.2 Levee Alignment WASH-2

The WASH-2 levee alignment around Robert, LA is a single segment. It starts at the road to Robertson Cemetery extending south adjacent to Chemekette Road and the Tangipahoa River. The alignment continues south crossing US Highway 190 eventually turning northeast south of the Bennett Lane neighborhood. Adjacent to Washley Creek the levee crosses Pole Bridge Branch. The levee alignment continues till it turns north between Holden Branch and Dixie Farm Road. Adjacent to Holden Branch, it crosses US Highway 190 and continues north until it reaches Needham Road where it terminates. The levee alignment is shown in Figure B: 6-6.

This levee alignment requires gate closure structures at LA 445 and US Highway 190 (two separate closures sections). One pump station is also required to pass Pole Bridge Branch drainage during high Washley Creek stages. Gravity drainage will be allowed during normal Washley Creek conditions. The modeled capacity of the Pole Bridge Branch pump station was 350 cubic feet per second.

The levee and 1% AEP event water surface profile for the alignment is shown in Figures B: 6-7. The levee was designed to protect up to the 1% AEP event with the 0.5% AEP event overtopping the levee. The 1% AEP event inundation extents showing the residual flood risk is shown in Figure B: 6-9. For comparison purposes, the existing conditions inundation extents are shown in Figure B: 6-8.

Stage reduction in Robert, LA from implementation of WASH-2 is substantial. At the Highway 190 crossing of Pole Bridge Branch the water level reduces 5.7 feet during the 1% AEP event.

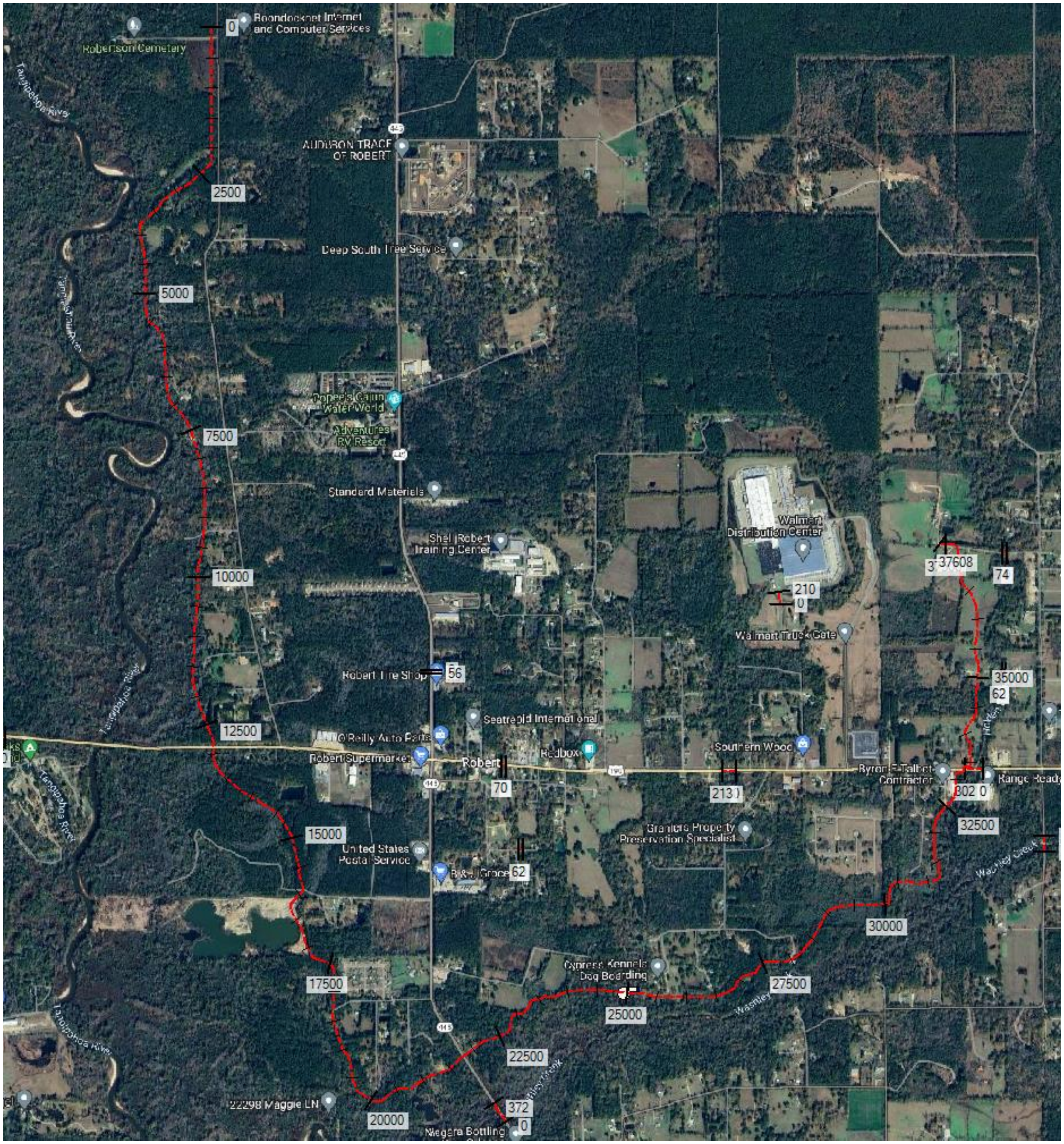


Figure B: 6-6. WASH-2 Levee Alignment

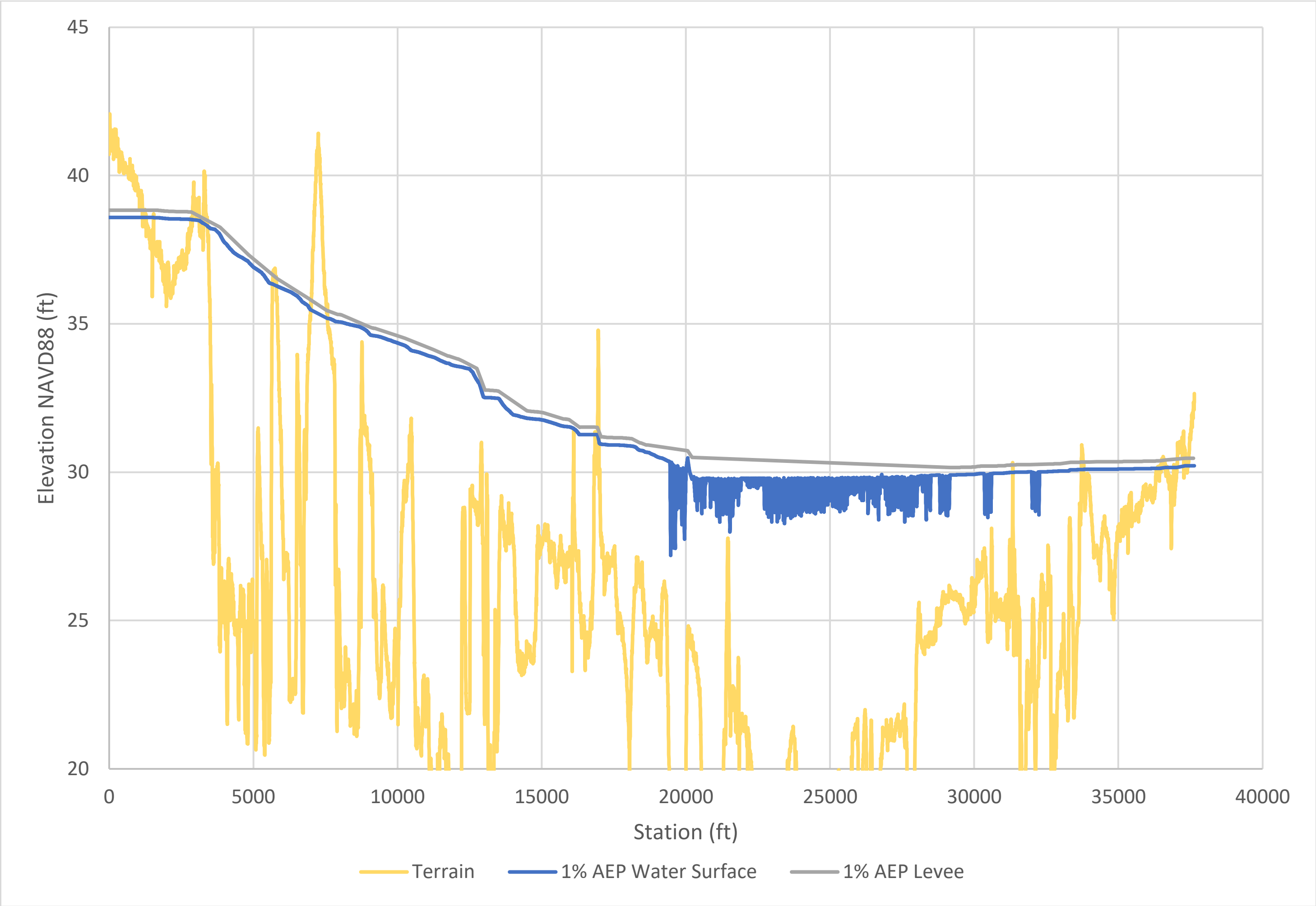


Figure B: 6-7. WASH-2 Main Section Profile

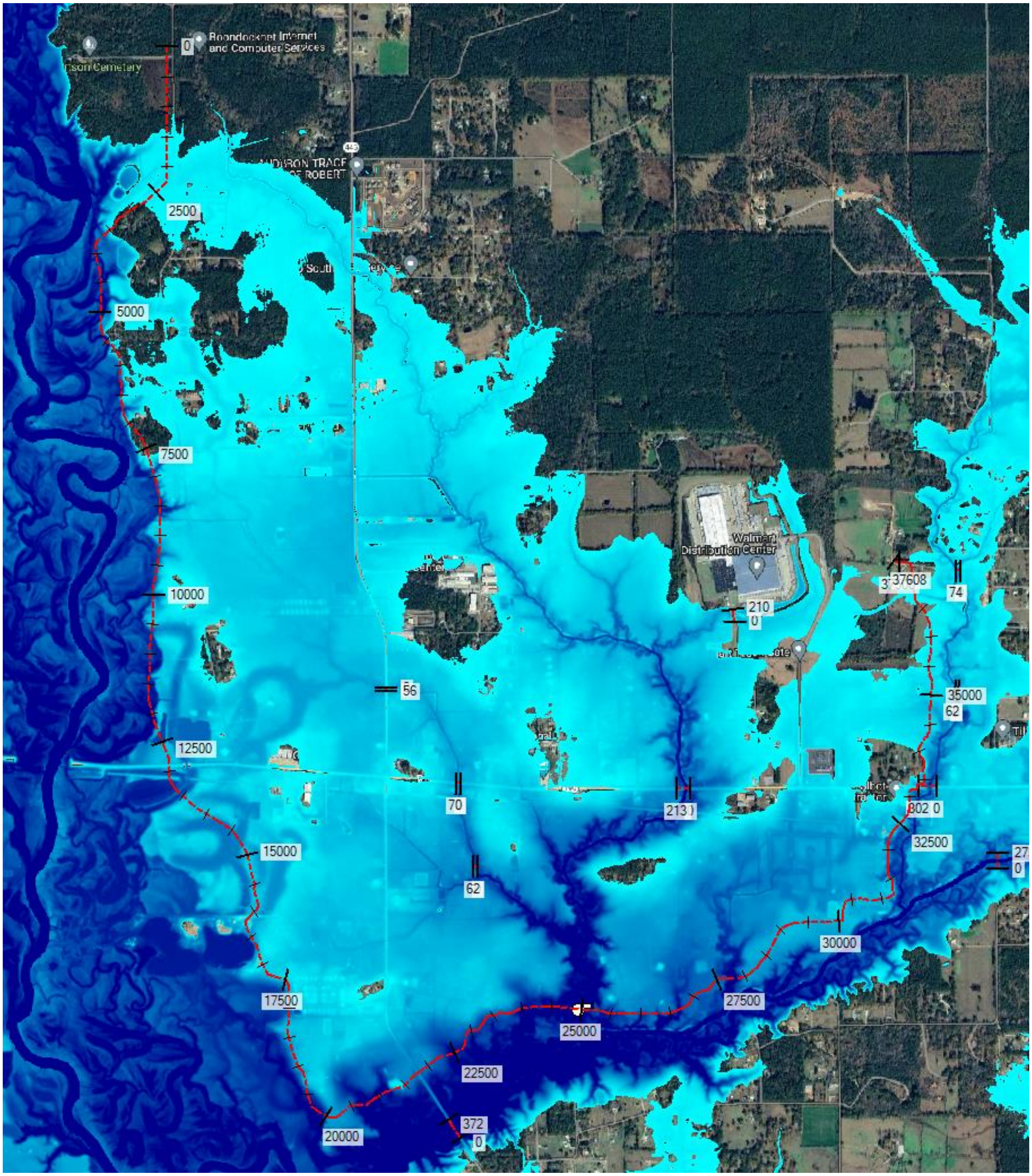


Figure B: 6-8. Existing Conditions Robert, LA Inundation - 1% AEP Event WASH-2

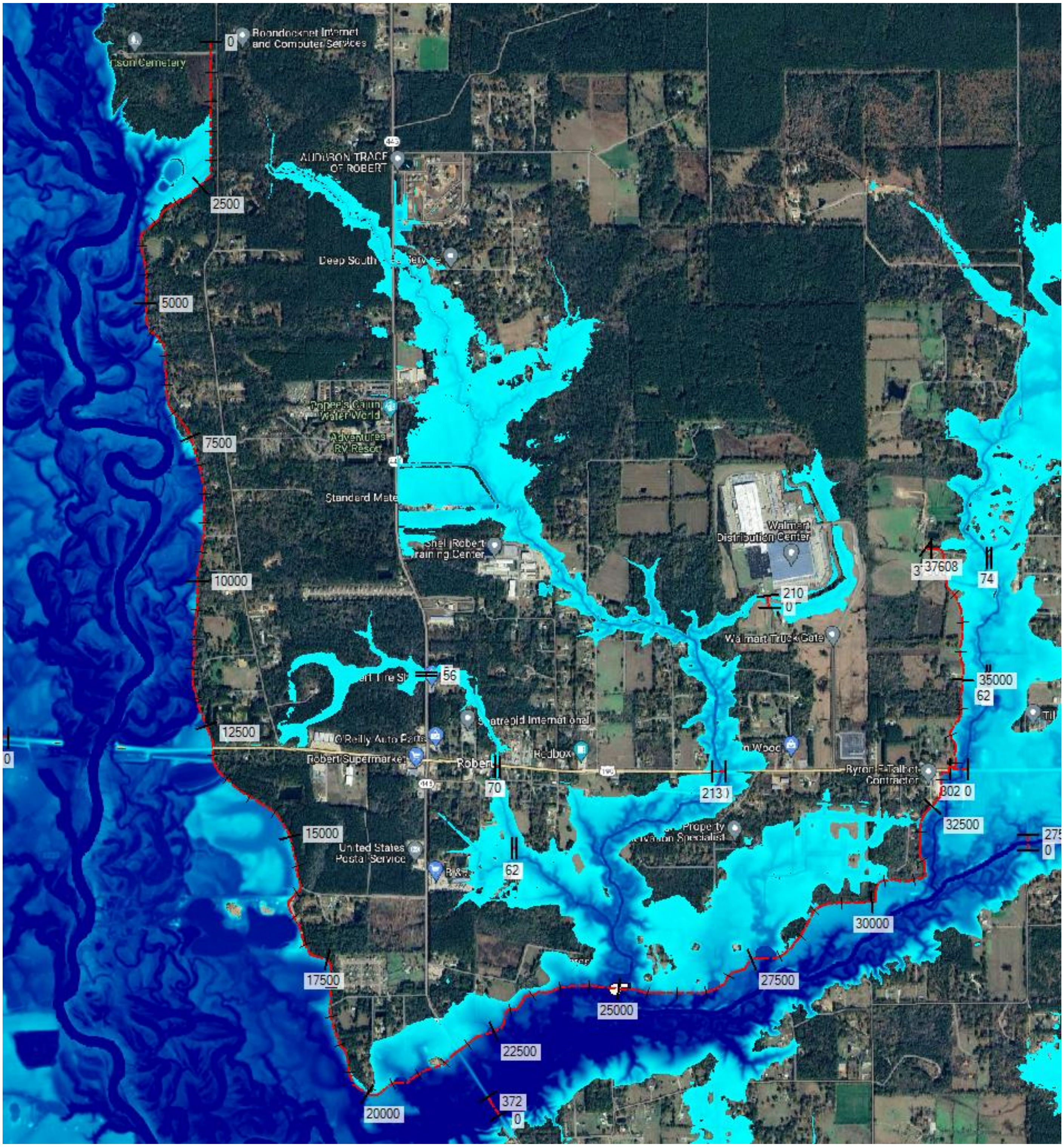


Figure B: 6-9. WASH-2 Levee Inundation - 1% AEP Event

6.2.1.3 Detention Basin WASH-3

As is discussed in Appendix D – Economics, WASH-1 and WASH-2 are not NED justifiable projects. The alternative benefit cost ratios are less than one and the net annual benefits are negative. Since WASH-3 is only effective if the Robert, LA levee alternatives are implemented, the detention basin would not be feasible. A hydraulic analysis was not performed on the WASH-3 alternative.

6.2.2 Alternative 4: Beaver Creek/Tangipahoa River and the Tangipahoa Levee Alternative

Tangipahoa, LA receives a lot of regular and reoccurring flooding from both Beaver Creek and the Tangipahoa River. Because of its proximity to the Tangipahoa River at the confluence of Beaver Creek, the flooding is extensive. A levee protecting the town of Tangipahoa, LA was examined with two separate levee sections.

In the proposed conditions HEC-RAS model, the levee segments were modeled as 2D storage area connections. To get the extents of the alignment the storage area connection weir embankment was high enough above the ground surface to ensure water would not pass over top. Once water was ensured to not pass around the levee alignment, the levee height was set to 0.25 feet above the 1% AEP water surface profile against the levee. Adjustments were made to the levee profile to correct abrupt changes in water surface and to level out the levee profile transition.

The HEC-RAS models were run with the proposed levees where it was ensured that the water did not overtop the levee until exceedance of the 1% AEP storm event. In the model increased river stages on the riverside of the levee were observed.

6.2.2.1 Levee Alignment SPTR-1A and 1B

The SPTR-1A and 1B levee alignment around Tangipahoa, LA has two segments. The 1A segment starts just west of the west end of the unnamed road just north of the Browns Chapel Missionary Baptist Church. It goes north to than east adjacent to Beaver Creek. It passes over Highway 1050 north of Cook Lane. It continues east between Cook Lane and Beaver Creek. It passes north of Morris Lane transversing to the southeast eventually tying into Highway 51. Part of this segment also includes a close-off of the area between Highway 51 and the railroad. Segment 1B starts 570 feet south of the termination of the 1A section branching off to the west from the railroad. The segment primarily runs southeast adjacent to Beaver Creek north of Franklin Street, Jackson Street, and an unnamed neighborhood. Segment 1B terminates at Center Street. The levee alignment is shown in Figure B: 6-10.

Because there are no large tributaries into Beaver Creek and since drainage is primarily to the south through the village of Tangipahoa, a pump station is not necessary. Sluice gates can be used to allow for storage of the interior drainage during high Beaver Creek stages.

The levee and 1% AEP event water surface profile for the two segments are shown in Figures B: 6-11 and 6-12. The levee was designed to protect up to the 1% AEP event with the 0.5% AEP event overtopping the levee. The 1% AEP event inundation extents showing the residual flood risk is shown in Figure B: 6-14. For comparison purposes, the existing conditions inundation extents are shown in Figure B: 6-13.

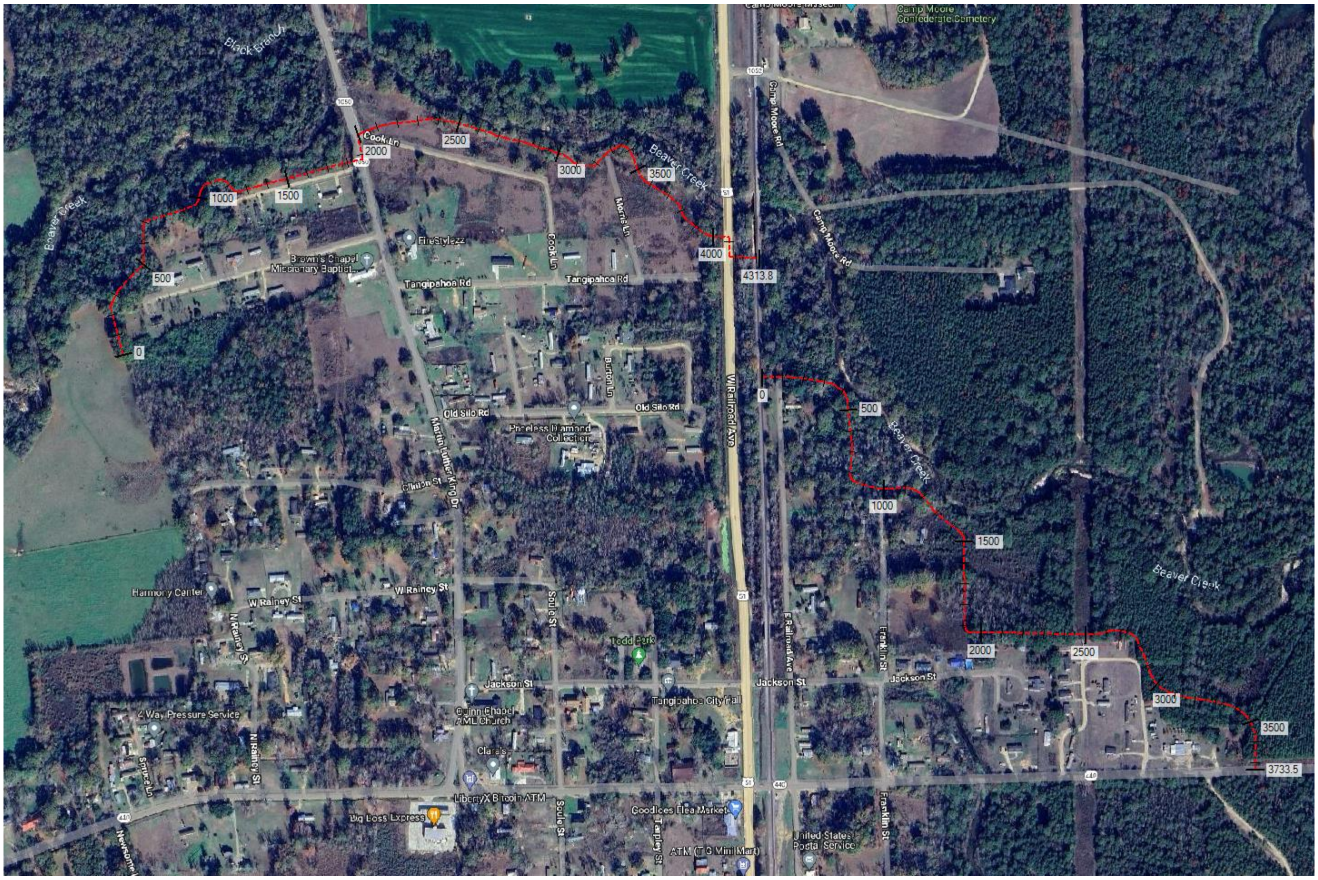


Figure B: 6-10. SPTR-1A and 1B Levee Alignment

Figure B: 6-11. SPTR-1A Levee Profile

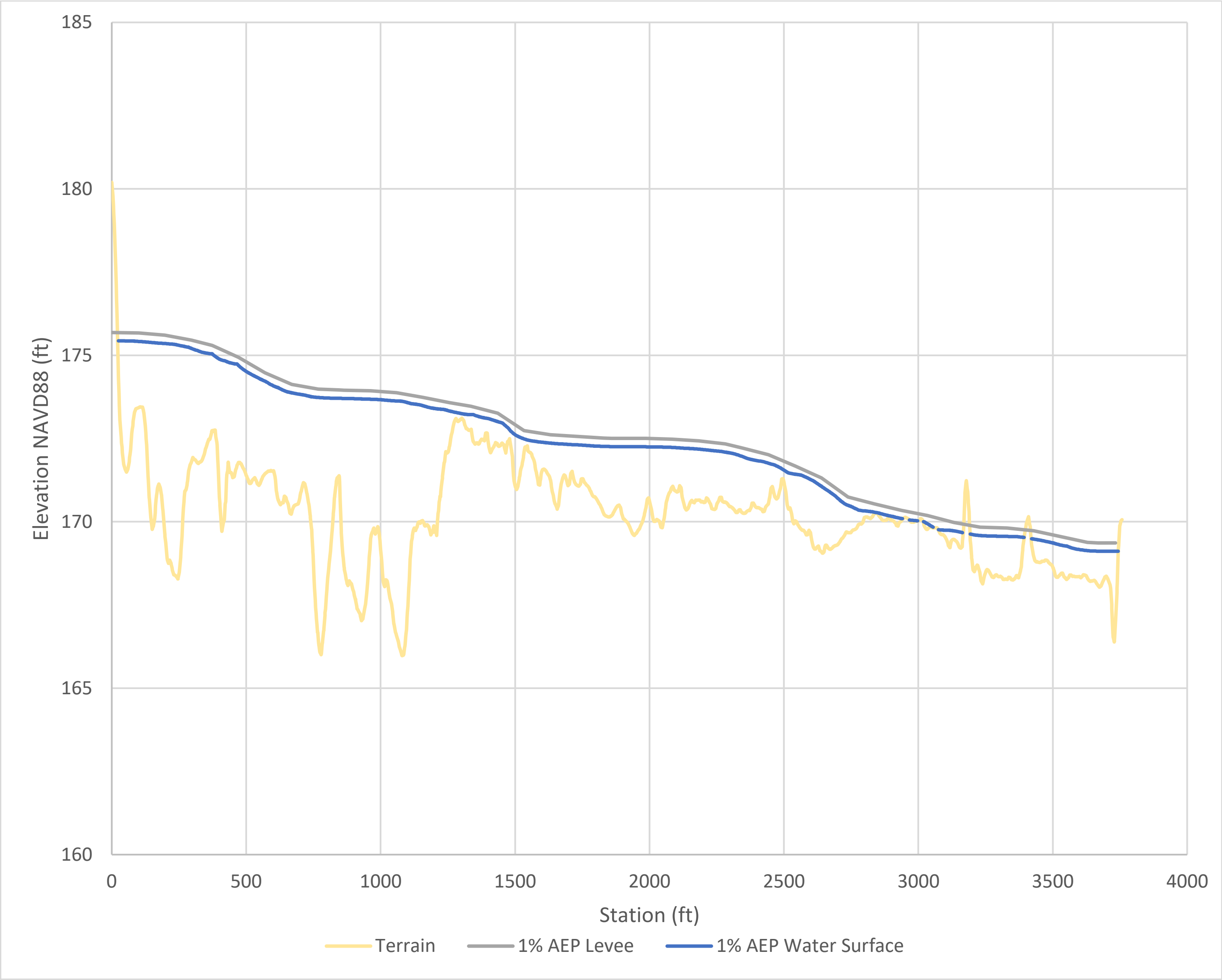


Figure B: 6-12. SPTR-1B Levee Profile

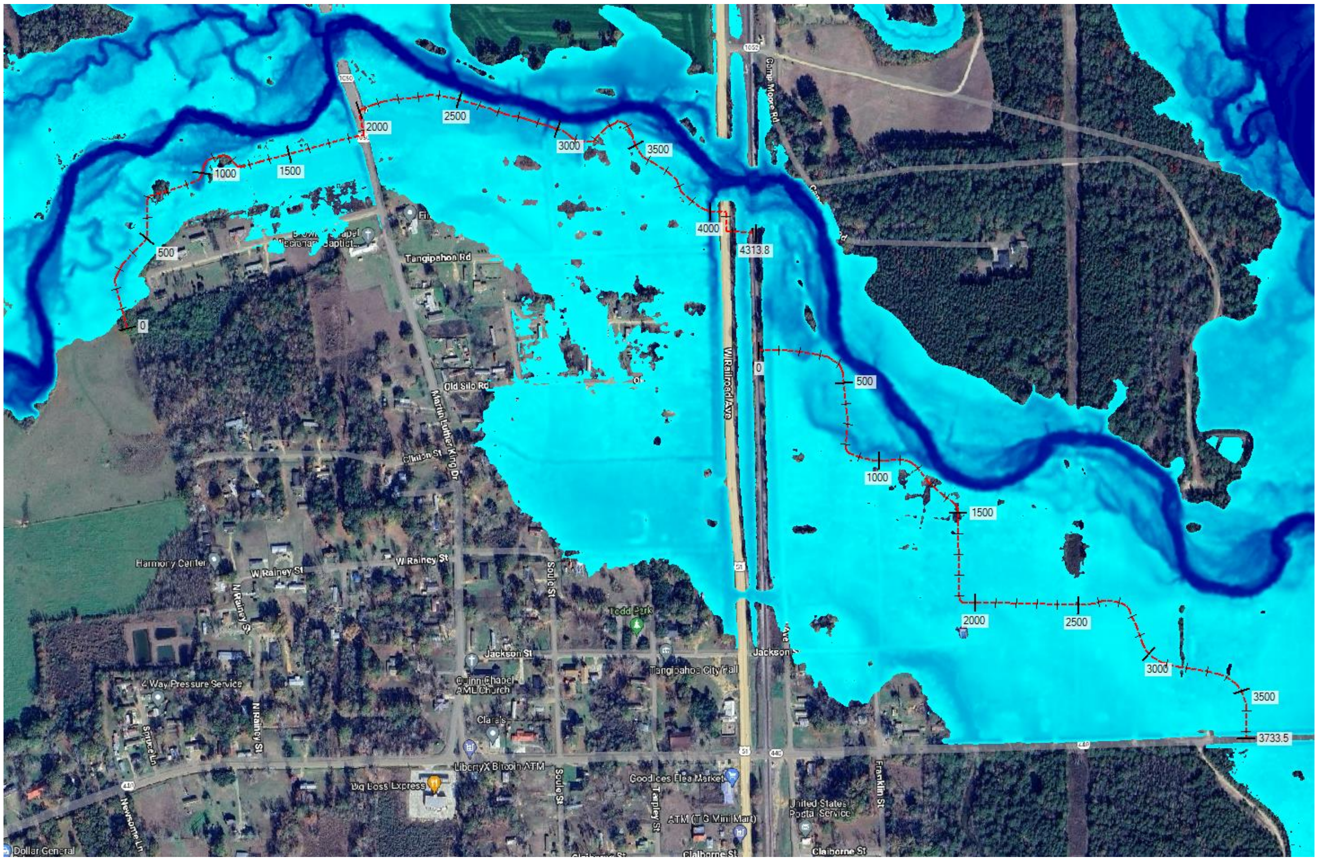


Figure B: 6-13. Existing Conditions Tangipahoa, LA Inundation - 1% AEP Event SPTR-1A and 1B

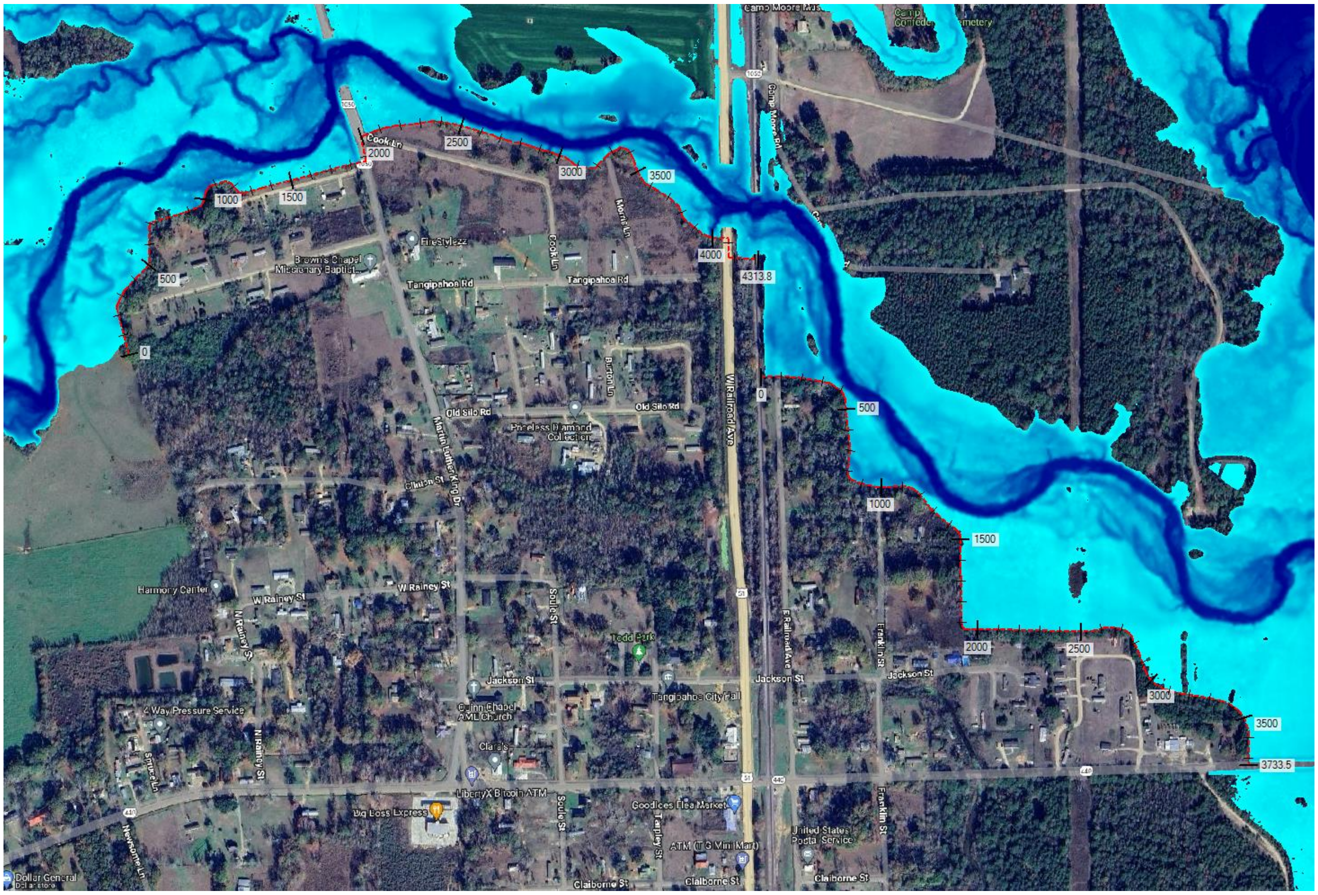


Figure B: 6-14. SPTR-1A and 1B Levee Inundation - 1% AEP Event

6.2.3 Alternative 5: Bedico Creek Roadway Elevation

These roadway elevation alternatives focus on roadways effected by flooding from Bedico Creek from both riverine and lake surge event flooding. The roadways examined are Fire Tower Road at the Cedar Branch crossing, Highway 22 near the crossing of Bedico Creek, and Fire Tower Road near Highway 22.

For the Bedico Creek roadway elevations, 2D storage area connections are used to define the roadway in the proposed condition HEC-RAS models. The new road elevations were specified with a constant level tying into the existing road grade.

6.2.3.1 Fire Tower Road near Cedar Branch (BED-1)

The segment of Fire Tower Road proposed to be raised is the road and bridge section that crosses Cedar Branch. This section is between April Lane and Crown Drive on Fire Tower Road. Figure B: 6-15 shows the road raise section delineated by a red line along with the 1% AEP event inundation.

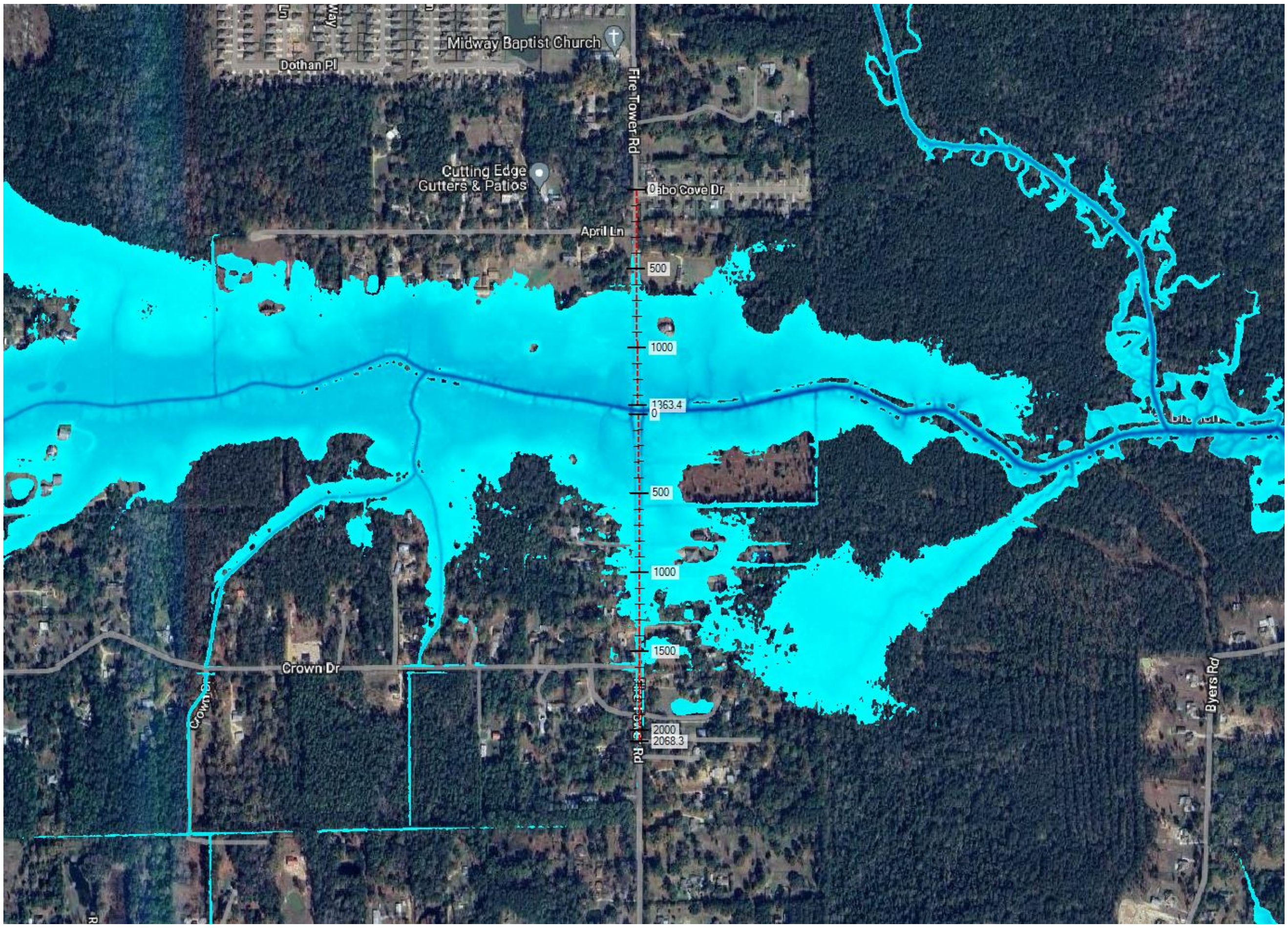


Figure B: 6-15. Fire Tower Road Raise and 1% AEP Event Inundation

Raising this segment of road to the 0.5% AEP event water surface level plus 0.5 feet was examined. Though effective in maintaining access during events at or below the 0.5% AEP event water surface level, impacts upstream of the bridge are measurable. The computed increase in water surface level on the upstream side of the bridge during a 1% AEP event is 0.3 feet. Because of the negative impacts, this measure though feasible, is not recommended because the extents of the impacted area are large.

6.2.3.2 Highway 22 and Lower Fire Tower Road (BED-4)

The segment of Highway 22 proposed to be raised is the west road approaching the bridge that crosses the Tangipahoa River. The raise on Highway 22 would start at the intersection of Fire Tower Road. The lower Fire Tower Road section is near the intersection with Highway 22. It would start 640 feet north on Fire Tower Road. The reason for the raise on the lower portion of Fire Tower Road is because of the impacts induced from the raise of Highway 22. Figure B: 6-16 shows the road raise section delineated by a red line along with the 1% AEP event inundation. The 2D storage area connection over the Tangipahoa River is the bridge which does not need to be raised.

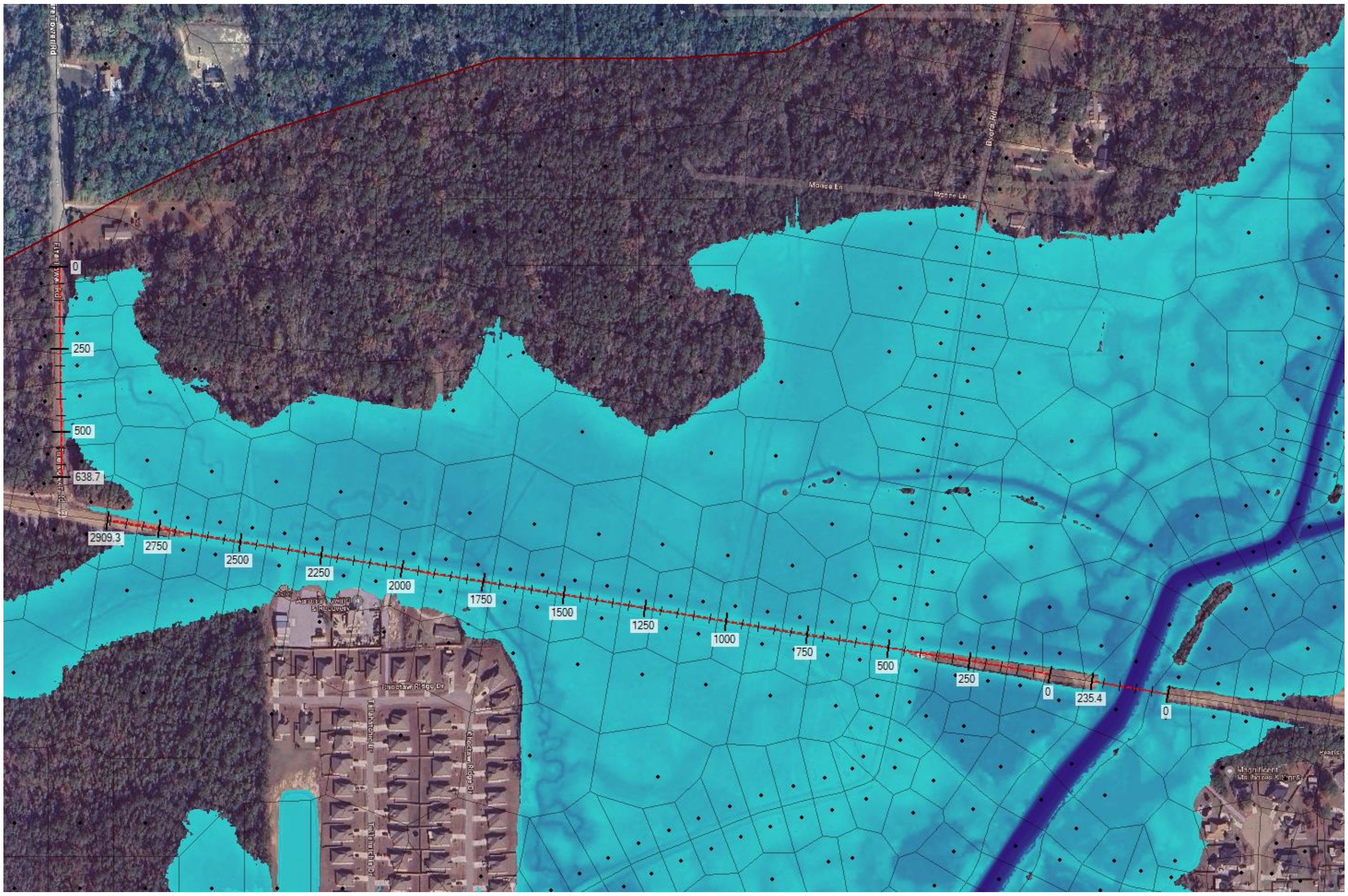


Figure B: 6-16. Highway 22 and Lower Fire Tower Road Raise and 1% AEP Event Inundation

Raising this segment of road to the 0.5% AEP event water surface level plus 0.5 feet was examined. Though effective in maintaining access during events at or below the 0.5% AEP event water surface level, impacts upstream of the bridge are small. The computed increase in water surface level on the upstream side of the bridge during a 1% AEP event is less than 0.1 feet. Because of the minor stage impacts and lack of habitable structures in this area, this measure is feasible and therefore recommended for implementation.

6.2.3.3 Combination of Fire Tower Road (BED-1) and Highway 22 Road (BED-4) Raise (BED-5)

BED-5 is the implementation of raising both Fire Tower Road and Highway 22. Since the Fire Tower Road raise over Cedar Branch is not recommended, this combination of alternatives is not recommended. The impact analysis for the combination of alternatives yields the same results as the individual alternatives.

6.2.4 Alternative 6: Little Chappepeela/Cooper Creek Road Raise

The Alternative 6 road raise stems from flooding from Cooper Creek on Briar Patch Cemetery Road. Cooper Creek is a tributary to Little Chappepeela Creek.

Cooper and Little Chappepella Creek fall in the 1D domain of the Lower Middle Tangipahoa River HEC-RAS model. Because bridge information was unknown at the time of the existing conditions model creation, ineffective flow areas were used to define the elevated roadway on the upstream and downstream bridge cross sections in the proposed conditions model. The new road elevations were specified with a constant level tying into the existing road grade.

6.2.4.1 Briar Patch Cemetery Road and Bridge Raise (LCC-1)

The segment of Briar Patch Cemetery Road proposed to be raised is the approaching road and bridge that crosses the Cooper Creek. The raise on Briar Patch Cemetery Road would start near the intersection of Loranger Road and end near the next intersection east (unnamed road). Figure B: 6-17 shows the road raise section delineated by a purple line along with the 1% AEP event inundation.

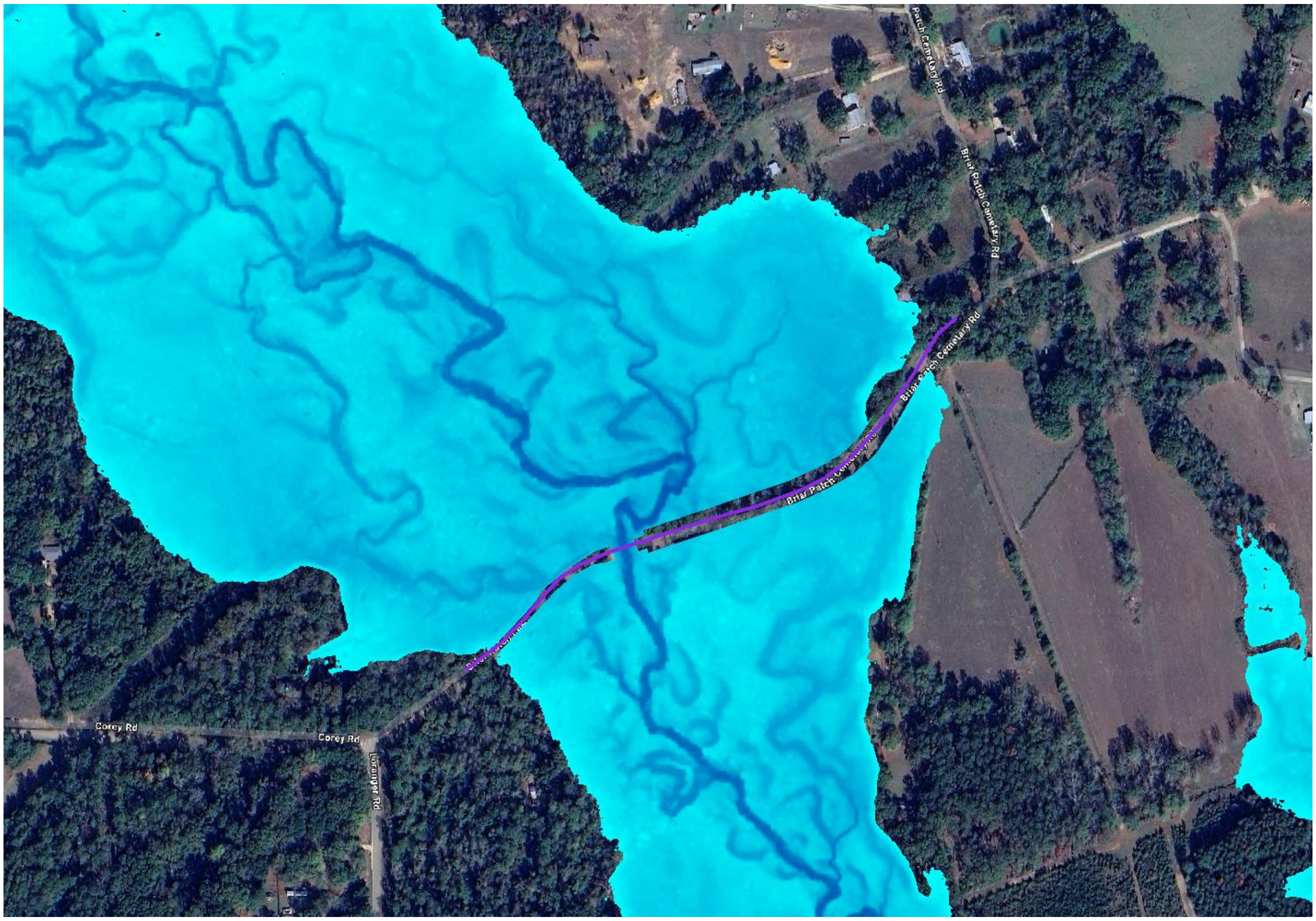


Figure B: 6-17. Briar Patch Cemetery Road Raise and the 1% AEP Inundation

Raising this segment of road to the 0.5% AEP event water surface level plus 0.5 feet was examined. Though effective in maintaining access during events at or below the 0.5% AEP event water surface level, impacts upstream of the bridge are small. The computed increase in water surface level on the upstream side of the bridge during a 1% AEP event is less than 0.2 feet. Because of the minor stage impacts and lack of habitable structures in this area, this measure is feasible and therefore recommended for implementation.

6.2.5 Alternative 7: Tangipahoa River and Chappepeela Creek Clearing and Snagging

Clearing and snagging of the Tangipahoa River and tributaries were considered in Alternative 7. Clearing and snagging was considered on portions of the Tangipahoa River and Chappepeela Creek. Since the Tangipahoa River scenic waterway in Louisiana, state law restricts that only 50% of material can be removed during the clearing and snagging efforts.

The Natalbany River basin was also considered and analyzed, but because of the local drainage district proactive efforts in channel maintenance, clearing and snagging is not recommended as it was recently completed.

In order to capture the effects of clearing and snagging, channel roughness coefficients were reduced. In the existing conditions model, the 2D area channels were configured with Manning’s n-value calibration regions. A channel Manning’s n-value of 0.06 was assumed. For the reaches to be cleared and snagged, the Manning’s n-value was reduced to 0.038. That value was chosen as it represents a dredged channel, irregular side slopes and bottom, with moderate brush.

6.2.5.1 Tangipahoa River Clearing and Snagging (SNG-1)

Clearing and snagging the Tangipahoa River upstream of the coastal surge influence was analyzed. The extent of clearing and snagging starts upstream at the Highway 40 overpass near Independence, LA and continues downstream until reaching the Highway 190 overpass. Downstream of Highway 190, was previously cleared within the last few years. Figure B: 6-18 shows the extents of clearing and snagging proposed on the Tangipahoa River.

The water surface level changes resulting from clearing and snagging are illustrated in Figure B: 6-19. Most of the stage deviation is in the zone that was clear and snagged. For over 80% of the inundation area in this zone, the stage reduction resulting from clearing and snagging ranges from 0.2 to 0.6 feet during the 1% AEP event. Therefore, Tangipahoa River clearing and snagging is effective in reducing water surface levels and is recommended for implementation.

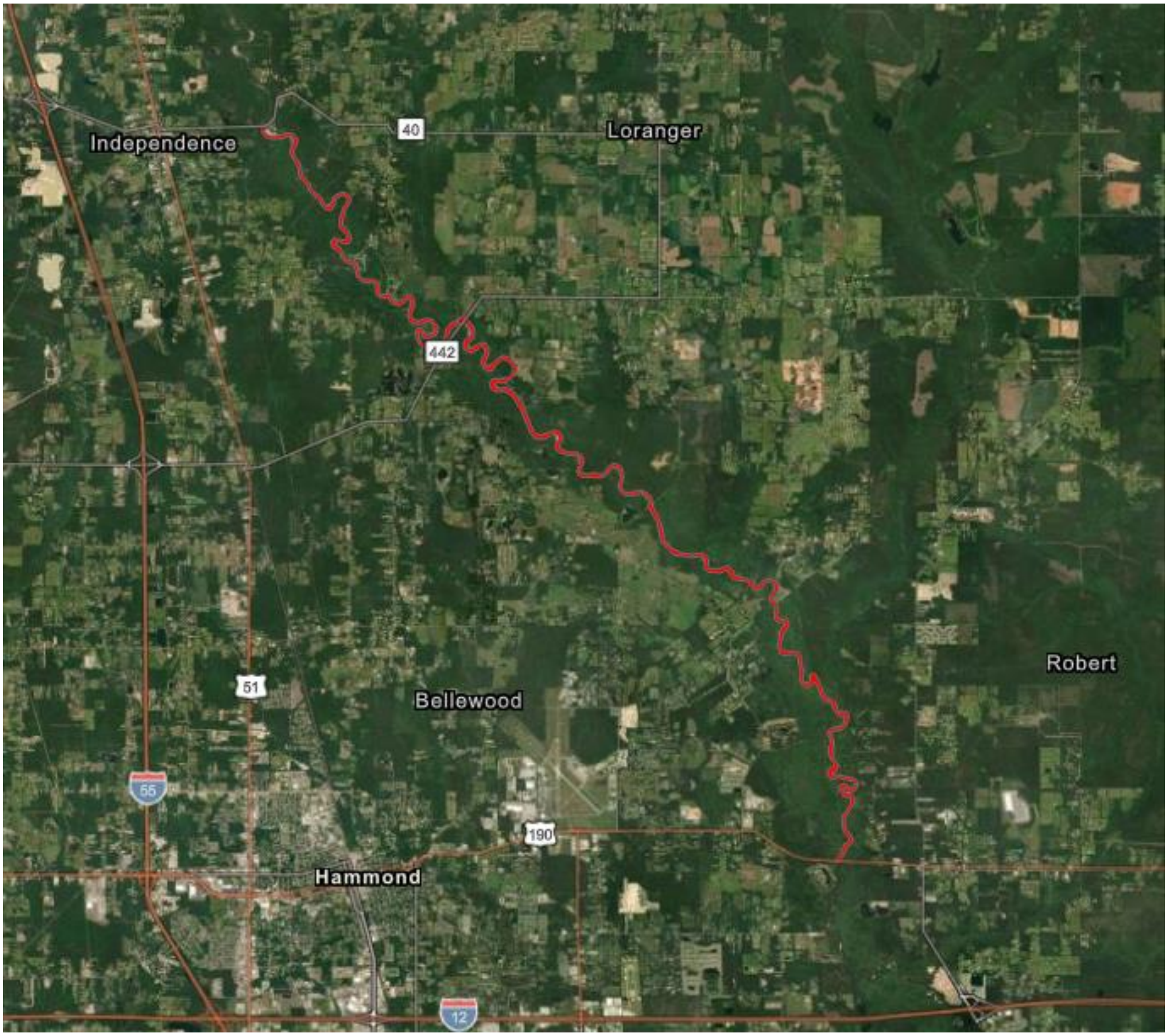


Figure B: 6-18. Extents of Tangipahoa River Clearing and Snagging Alternative

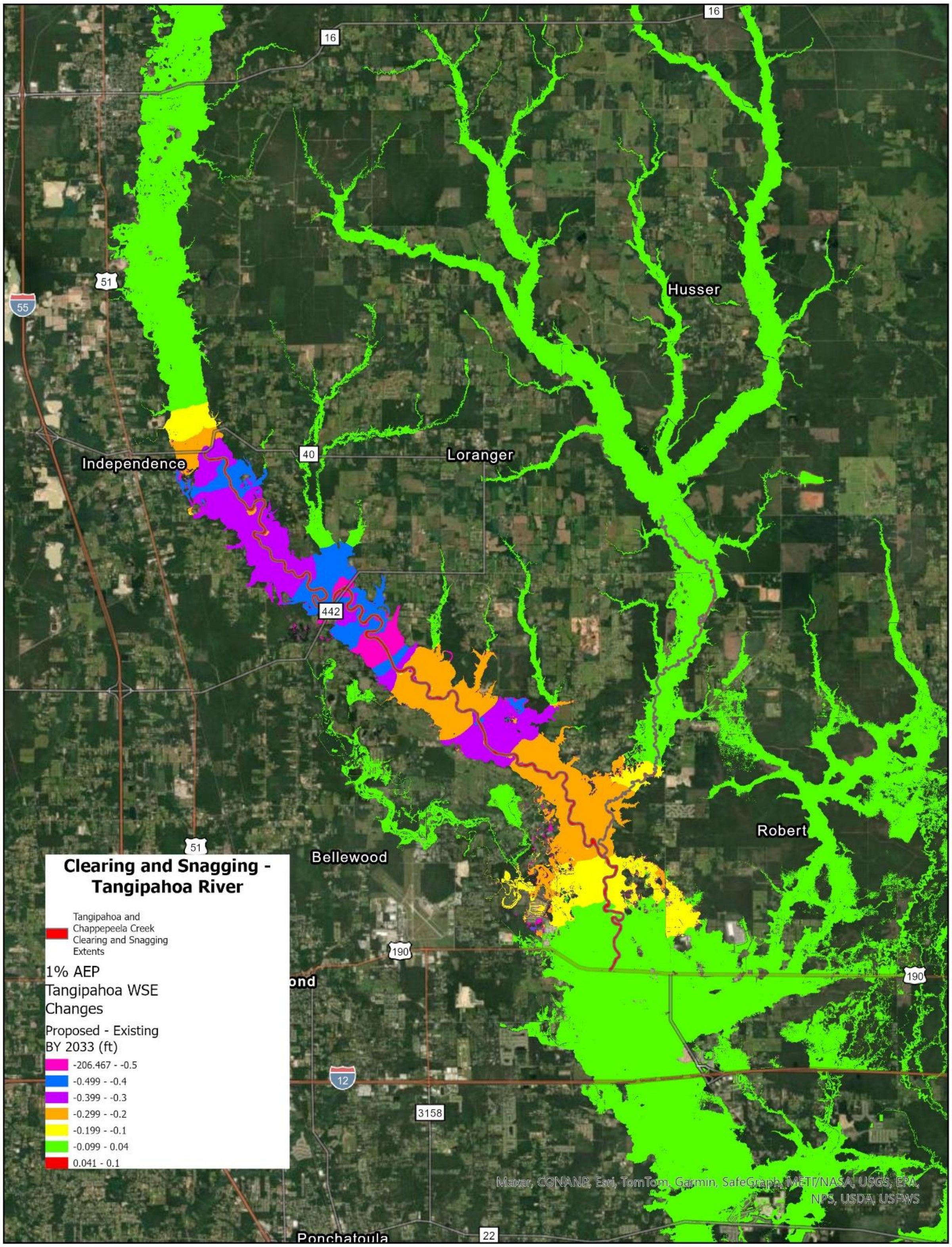


Figure B: 6-19. Tangipahoa C&S Water Surface Level Reduction - 1% AEP Event

6.2.5.2 Tangipahoa River and Chappepeela Creek Clearing and Snagging

Clearing and snagging the Tangipahoa River and Chappepeela Creek upstream of the coastal surge influence was analyzed. The Tangipahoa River extent of clearing and snagging starts upstream at the Highway 40 overpass near Independence, LA and continues downstream until reaching the Highway 190 overpass. The Chappepeela Creek extent of clearing and snagging starts upstream at the confluence with Little Chappepeela Creek and continues downstream until reaching the Tangipahoa River confluence. Figure B: 6-20 shows the extents of clearing and snagging proposed on the Tangipahoa River.

The water surface level changes resulting from clearing and snagging are illustrated in Figure B: 6-21. Most of the stage deviation is in the zone that was clear and snagged. For over 80% of the inundation area in this zone, the stage reduction resulting from clearing and snagging ranges from 0.2 to 0.6 feet during the 1% AEP event. Therefore, Tangipahoa River and Chappepeela Creek clearing and snagging is effective in reducing water surface levels and is recommended for implementation.

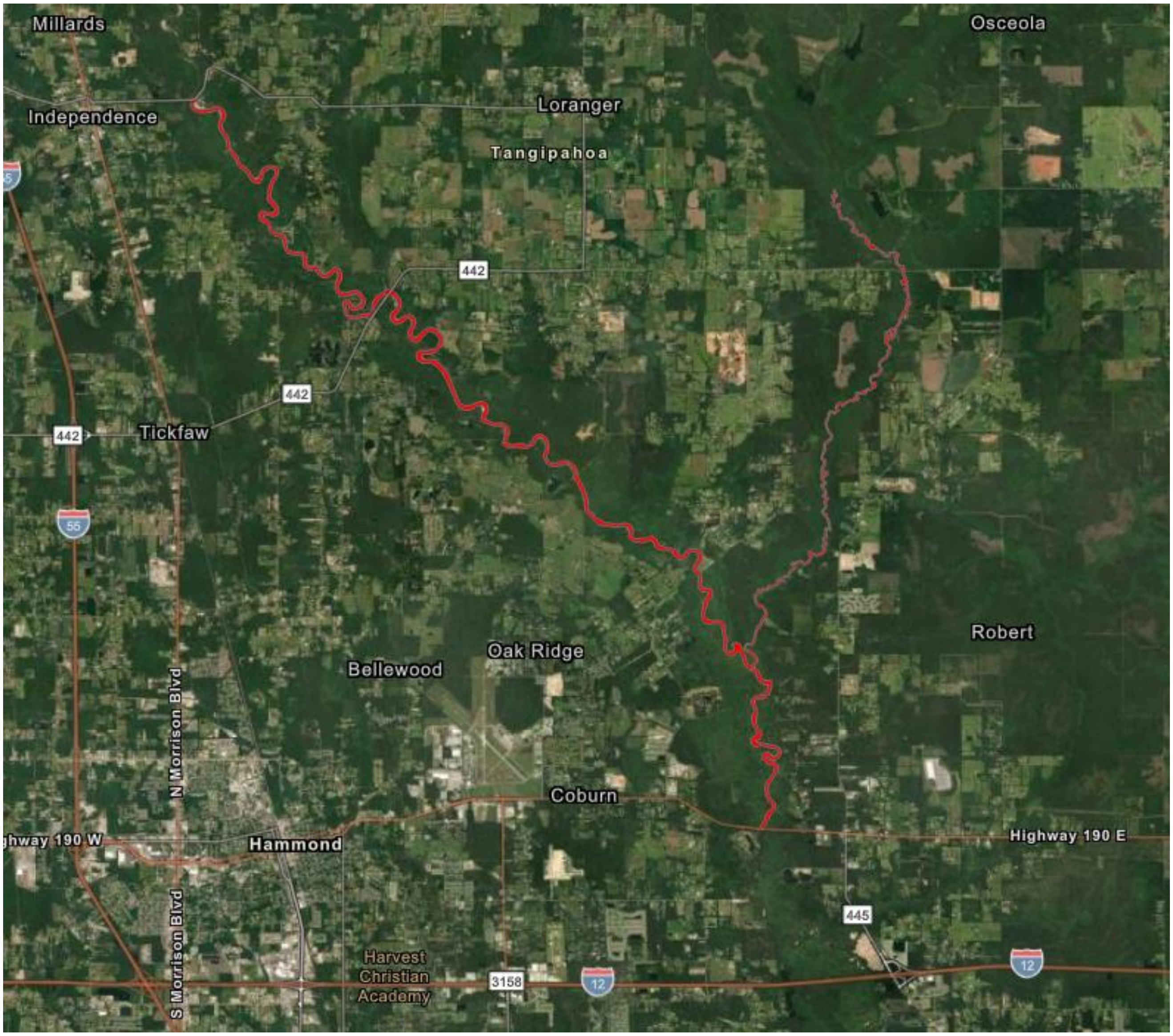


Figure B: 6-20. Extents of Tangipahoa River and Chappapeela Creek Clearing and Snagging

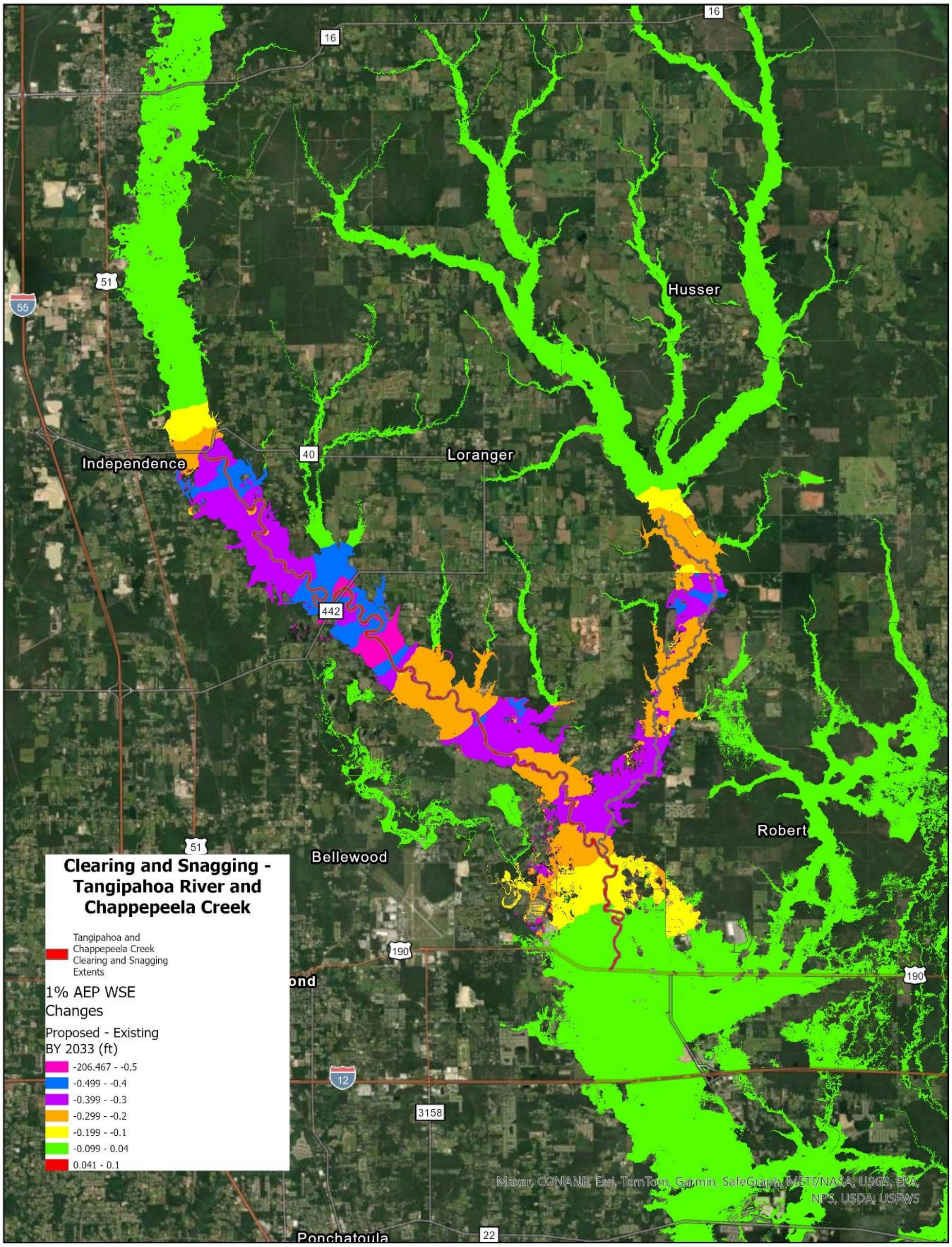


Figure B: 6-21. Tangipahoa River and Chappepeela Creek C&S Water Surface Level Reduction - 1% AEP Event

6.3 NON-STRUCTURAL ALTERNATIVES

Non-structural measures deal with flood proofing and acquisition of structures. Acquisition is the less desirable solution of outright purchase of flooded structures. Project sponsors are much more amenable to flood proofing. For residential structures flood proofing is elevation of the residence. For commercial properties the solution is dry flood proofing. For structures exceeding flood proofing elevation thresholds acquisition is the solution.

Non-structural alternatives rely on the existing and future without project condition water surface elevation grids. Specific to flood proofing the base year (2033) coastal surge/riverine frequency grids merged were used in the selection of structures. For flood proofing protection or elevation levels, the future year (2083) coastal surge/riverine frequency grids merged with an addition of two feet were used. For each measure riverine flooding dominance was also captured in the hydraulic analysis in accordance with the project authority. The generation of these grids is discussed in Sections 3 and 4 of this Appendix.

The non-structural alternative analysis is discussed in greater detail in Appendix G – Economics.

SECTION 7

References and Resources

Project References:

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

Methods for Estimating Annual Exceedance Discharges for Streams in Arkansas, Based on Data Through Water Year 2013; USGS (2013). https://pubs.usgs.gov/sir/2016/5081/sir20165081.pdf

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

Sea Level Analysis Tool; USACE (2022). https://climate.sec.usace.army.mil/slat/

2015 Updated Atlas of USACE Historic Daily Tide Data in Coastal Louisiana; USACE (2015) https://erdc-library.erdc.dren.mil/xmlui/bitstream/handle/11681/25484/MRG%26P%20Report%20No%2014.pdf?sequence=1&isAllowed=y

Websites:

USGS data source: https://waterdata.usgs.gov

Software:

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

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

Advanced Circulation (ADCIRC) Model

ArcGIS Pro 3.1.1

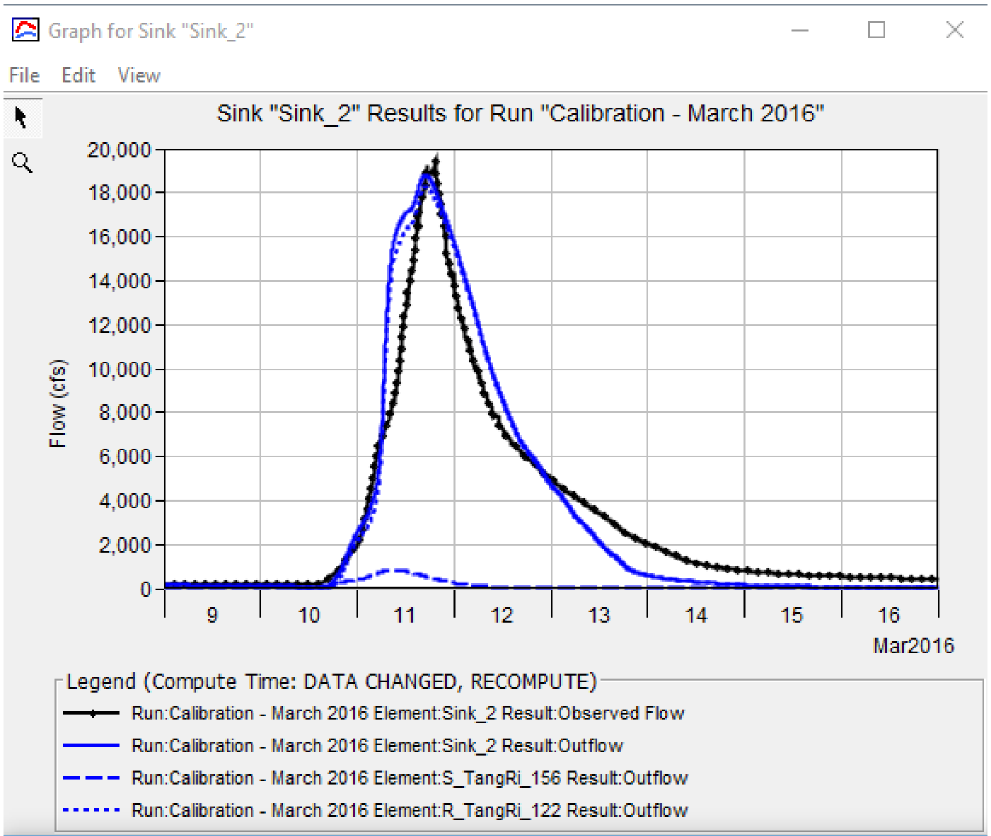
SECTION 8
List of Acronyms and Abbreviations

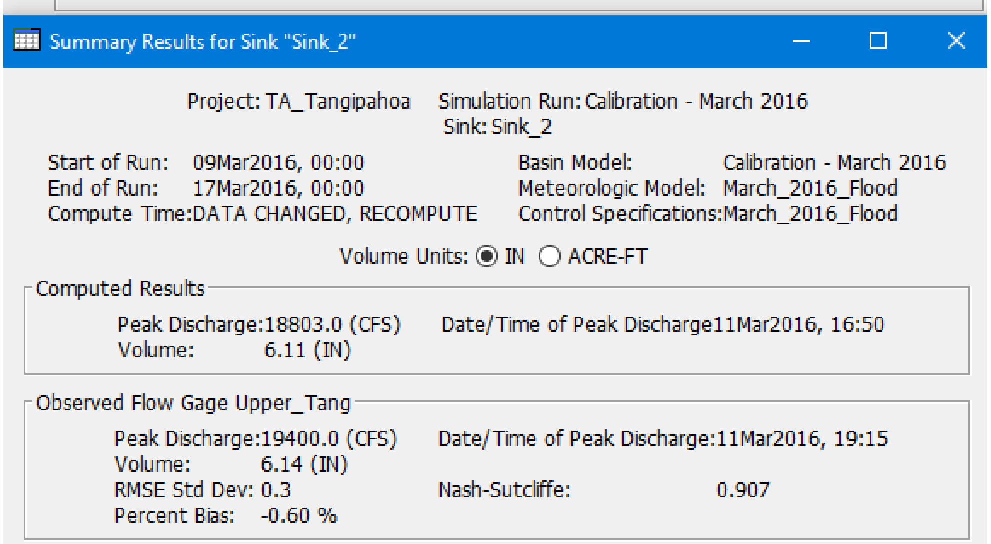
cfs	Cubic Feet per Second
ft	Feet
in	Inches
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling Software
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HEC-SSP	Hydrologic Engineering Center – Statistical Software Package
ADCIRC	Advanced Circulation Model
SWAN	Simulating Waves Nearshore Model
MATLAB	Matrix Laboratory Programming Language (MathWorks)
USACE	U.S. Army Corps of Engineers
CEMVS	St. Louis District (USACE)
CEMVN	New Orleans District (USACE)
MVD	Mississippi Valley Division (USACE)
USGS	U.S. Geological Survey
NOAA	National Oceanic and Atmospheric Administration
CPRA	Coastal Protection and Restoration Authority (State of Louisiana)
AEP	Annual Exceedance Probability
PDT	Product Delivery Team
FRM	Flood Risk Management
HUC	Hydrologic Unit Codes
SSURGO	Soil Survey Geographic Database
NLCD	National Land Coverage Database
NAVD 88	North American Vertical Datum 1988
NAD	North American Datum
DEM	Digital Elevation Model
NSI	National Structure Inventory Database (2022)
NRCS	Natural Resources Conservation Service
Tc	Time of Concentration

R	Storage Coefficient
2D	Two-Dimensional
1D	One-Dimensional
EMA	Expected Moments Algorithm
Manning's N	Manning's Roughness Coefficient
MHW	Mean High-High Water
EM	Engineer Manual
SLR	Sea Level Rise
JPM-OS	Joint Probability Method - Optimal Sampling
NED	National Economic Development

Annex A: Hydrologic Calibration Plots

Upper Tangipahoa HMS Flow Calibration (Osyka, LA)





Summary Results for Sink "Sink_2"

Project: TA_Tangipahoa Simulation Run: Calibration - March 2016
Sink: Sink_2

Start of Run:	09Mar2016, 00:00	Basin Model:	Calibration - March 2016
End of Run:	17Mar2016, 00:00	Meteorologic Model:	March_2016_Flood
Compute Time:	DATA CHANGED, RECOMPUTE	Control Specifications:	March_2016_Flood

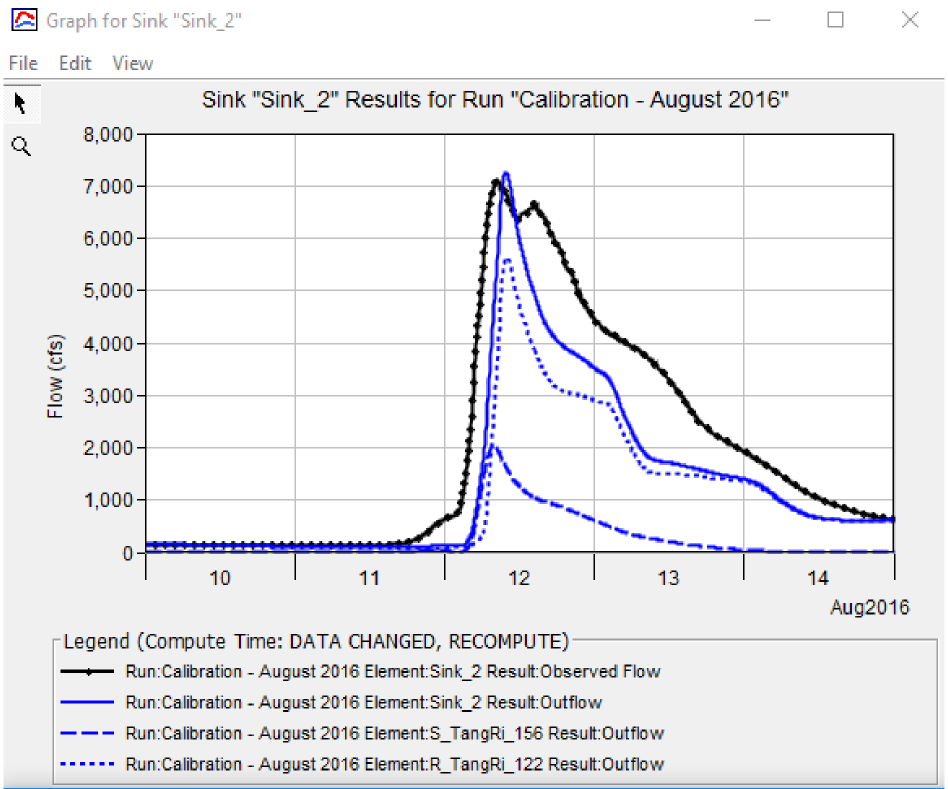
Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	18803.0 (CFS)	Date/Time of Peak Discharge	11Mar2016, 16:50
Volume:	6.11 (IN)		

Observed Flow Gage Upper_Tang

Peak Discharge:	19400.0 (CFS)	Date/Time of Peak Discharge:	11Mar2016, 19:15
Volume:	6.14 (IN)		
RMSE Std Dev:	0.3	Nash-Sutcliffe:	0.907
Percent Bias:	-0.60 %		



Summary Results for Sink "Sink_2"

Project: TA_Tangipahoa Simulation Run: Calibration - August 2016
Sink: Sink_2

Start of Run: 10Aug2016, 00:00
End of Run: 15Aug2016, 00:00
Compute Time: DATA CHANGED, RECOMPUTE

Basin Model: Calibration - August 2016
Meteorologic Model: August_2016_Flood
Control Specifications: August_2016_Flood

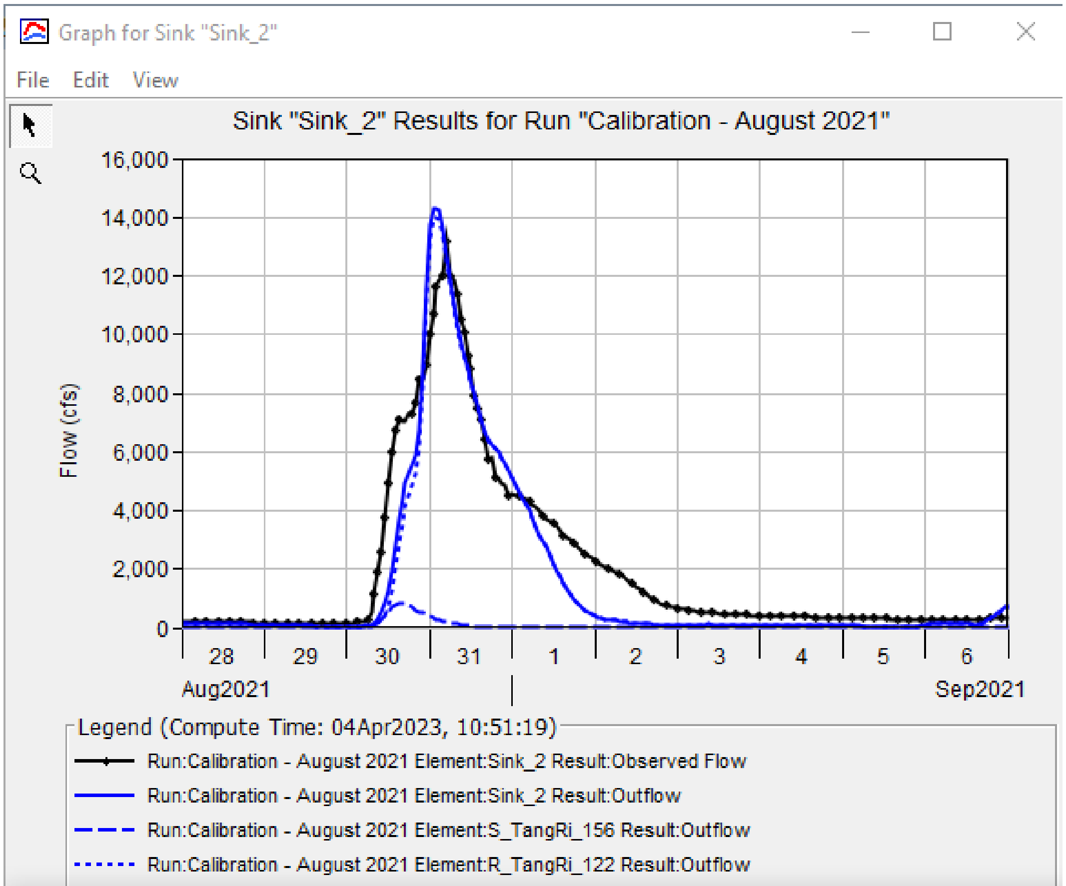
Volume Units: (•) IN ( ) ACRE-FT

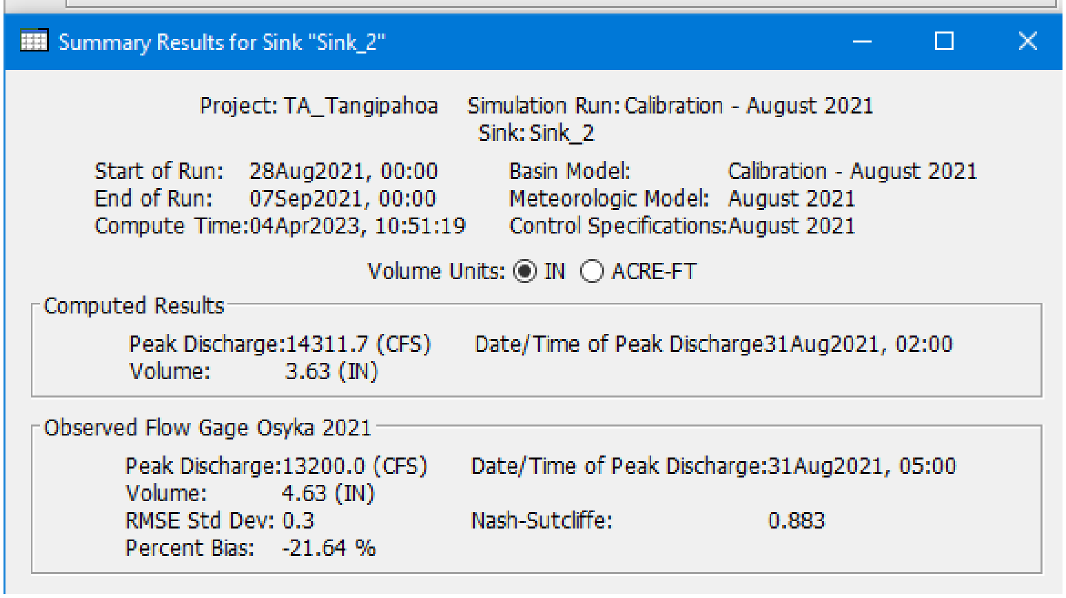
Computed Results

Peak Discharge: 7253.8 (CFS) Date/Time of Peak Discharge 12Aug2016, 09:50
Volume: 1.57 (IN)

Observed Flow Gage Upper_Tang

Peak Discharge: 7120.0 (CFS) Date/Time of Peak Discharge: 12Aug2016, 08:15
Volume: 2.27 (IN)
RMSE Std Dev: 0.5 Nash-Sutcliffe: 0.792
Percent Bias: -31.12 %




Summary Results for Sink "Sink_2"

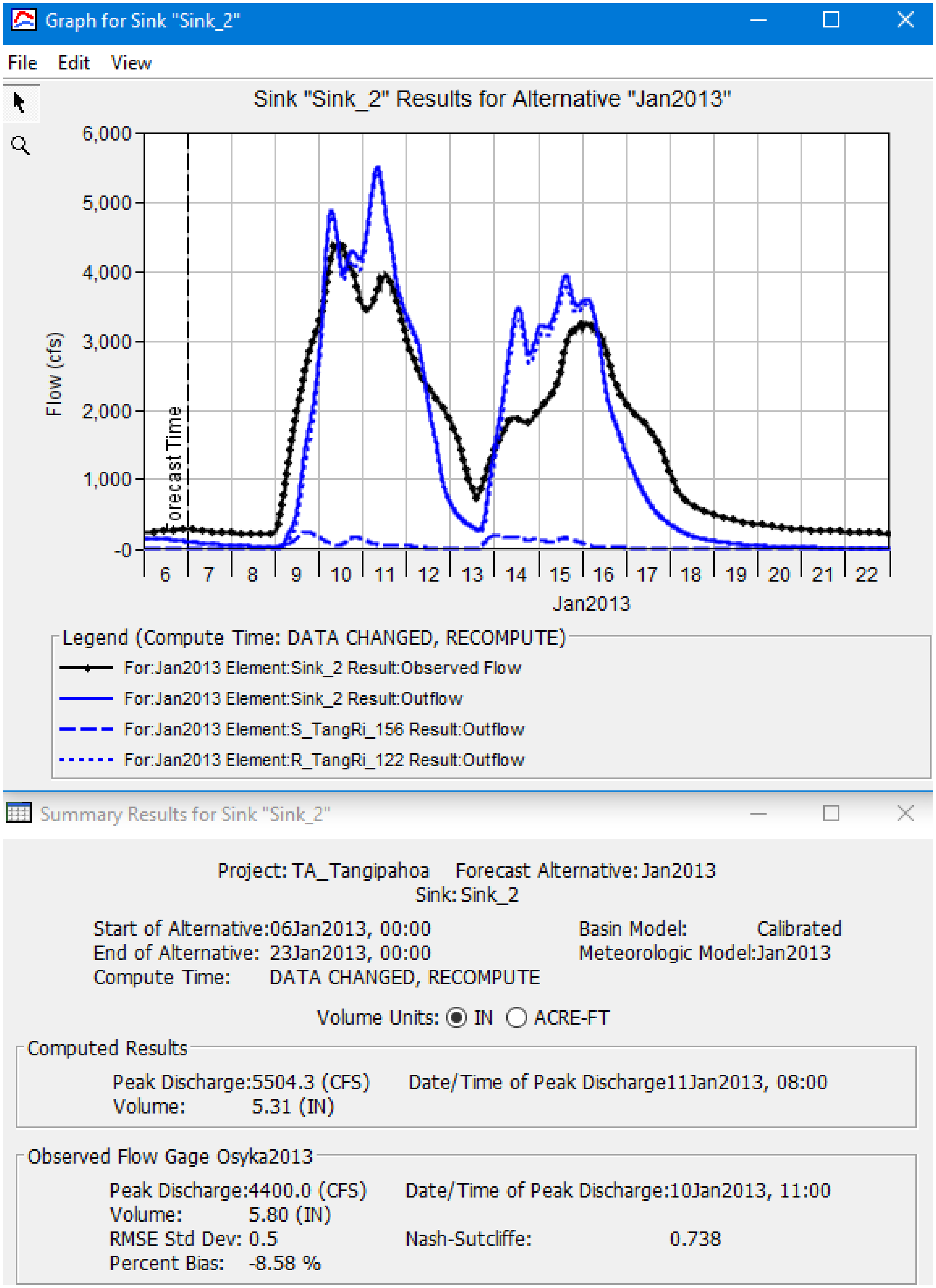
Project: TA_Tangipahoa Simulation Run: Calibration - August 2021
Sink: Sink_2

Start of Run: 28Aug2021, 00:00 Basin Model: Calibration - August 2021
End of Run: 07Sep2021, 00:00 Meteorologic Model: August 2021
Compute Time: 04Apr2023, 10:51:19 Control Specifications: August 2021

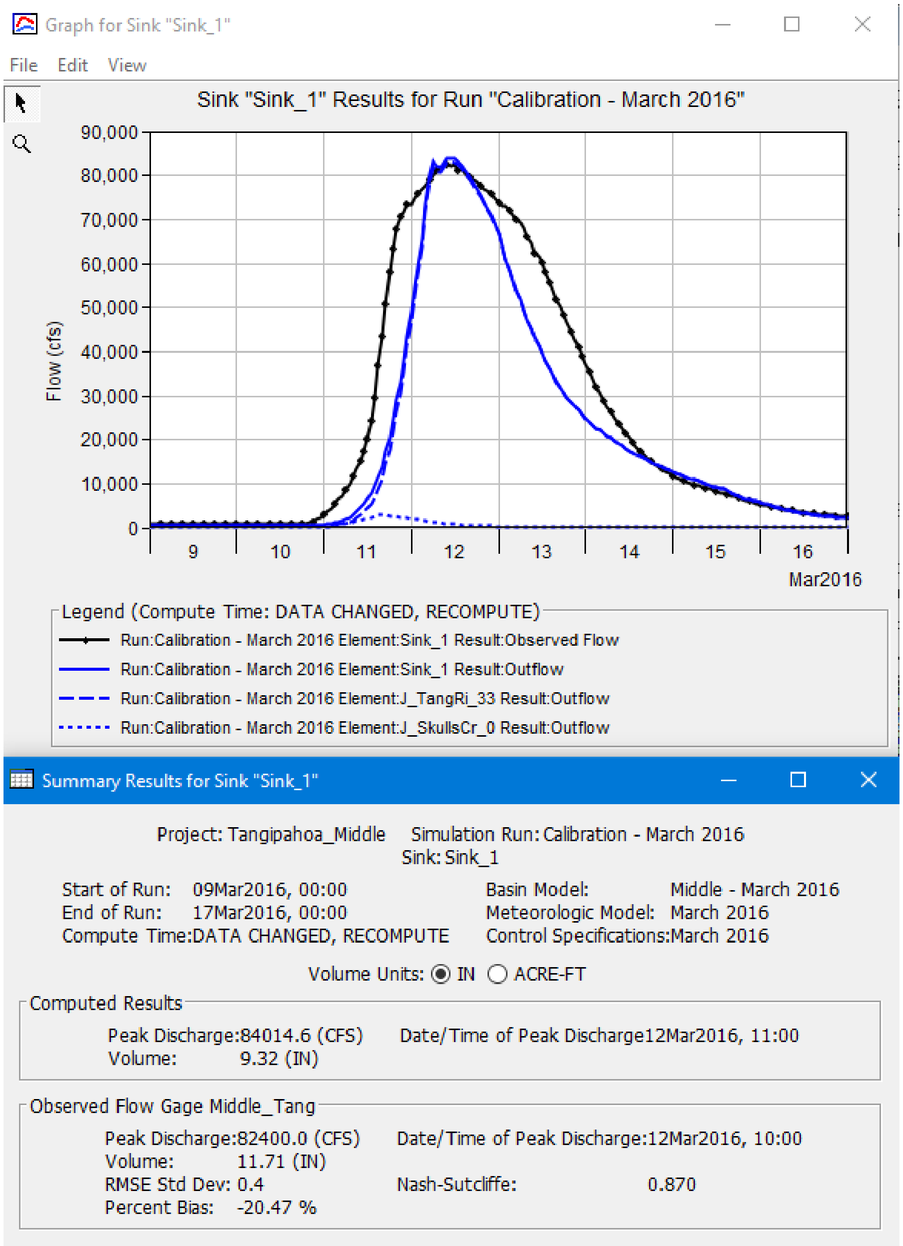
Volume Units: IN ACRE-FT

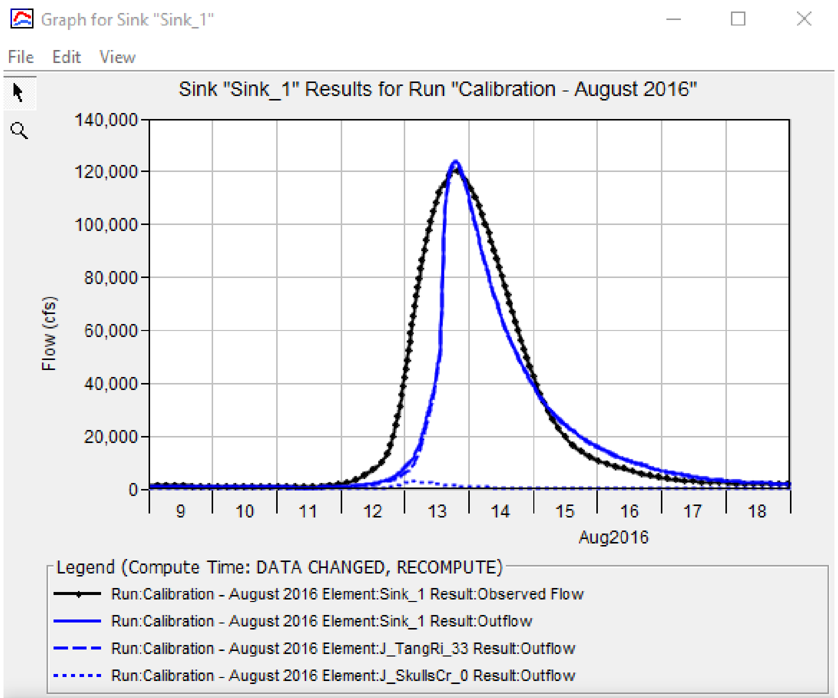
Computed Results
Peak Discharge: 14311.7 (CFS) Date/Time of Peak Discharge 31Aug2021, 02:00
Volume: 3.63 (IN)

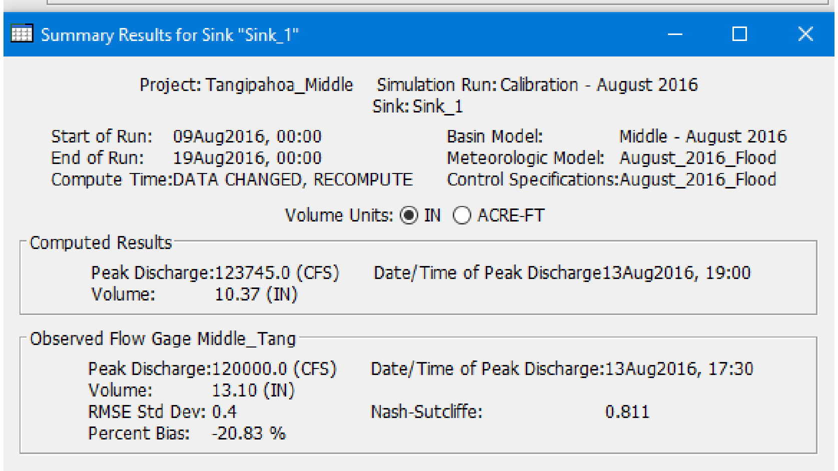
Observed Flow Gage Osyka 2021
Peak Discharge: 13200.0 (CFS) Date/Time of Peak Discharge: 31Aug2021, 05:00
Volume: 4.63 (IN)
RMSE Std Dev: 0.3 Nash-Sutcliffe: 0.883
Percent Bias: -21.64 %


Graph for Sink "Sink_2"
File Edit View
Sink "Sink_2" Results for Alternative "Jan2013"
Flow (cfs)
6,000
5,000
4,000
3,000
2,000
1,000
-0
orecast Time
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Jan2013
Legend (Compute Time: DATA CHANGED, RECOMPUTE)
For:Jan2013 Element:Sink_2 Result:Observed Flow
For:Jan2013 Element:Sink_2 Result:Outflow
For:Jan2013 Element:S_TangRi_156 Result:Outflow
For:Jan2013 Element:R_TangRi_122 Result:Outflow
Summary Results for Sink "Sink_2"
Project: TA_Tangipahoa Forecast Alternative: Jan2013
Sink: Sink_2
Start of Alternative: 06Jan2013, 00:00
End of Alternative: 23Jan2013, 00:00
Compute Time: DATA CHANGED, RECOMPUTE
Basin Model: Calibrated
Meteorologic Model: Jan2013
Volume Units: IN ACRE-FT
Computed Results
Peak Discharge: 5504.3 (CFS)
Date/Time of Peak Discharge 11Jan2013, 08:00
Volume: 5.31 (IN)
Observed Flow Gage Osyka2013
Peak Discharge: 4400.0 (CFS)
Date/Time of Peak Discharge: 10Jan2013, 11:00
Volume: 5.80 (IN)
RMSE Std Dev: 0.5
Nash-Sutcliffe: 0.738
Percent Bias: -8.58 %

Middle Tangipahoa HMS Flow Calibration (Robert, LA)






Summary Results for Sink "Sink_1"

Project: Tangipahoa_Middle Simulation Run: Calibration - August 2016
Sink: Sink_1

Start of Run: 09Aug2016, 00:00 Basin Model: Middle - August 2016
End of Run: 19Aug2016, 00:00 Meteorologic Model: August_2016_Flood
Compute Time:DATA CHANGED, RECOMPUTE Control Specifications:August_2016_Flood

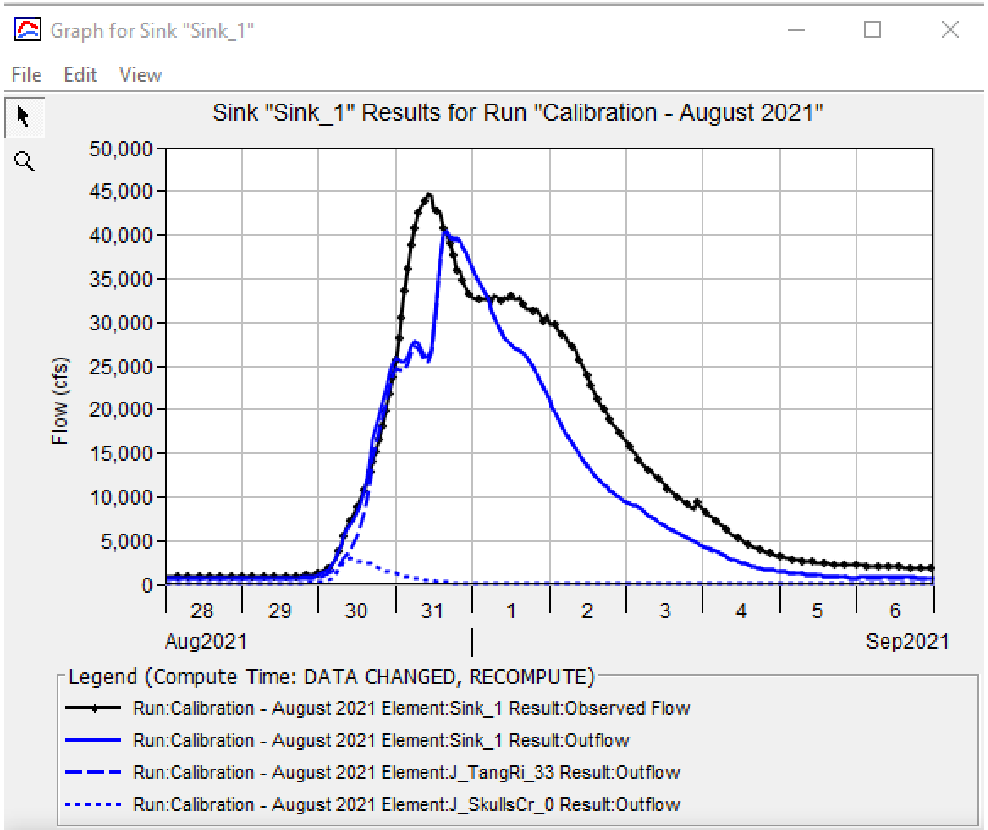
Volume Units: (•) IN ( ) ACRE-FT

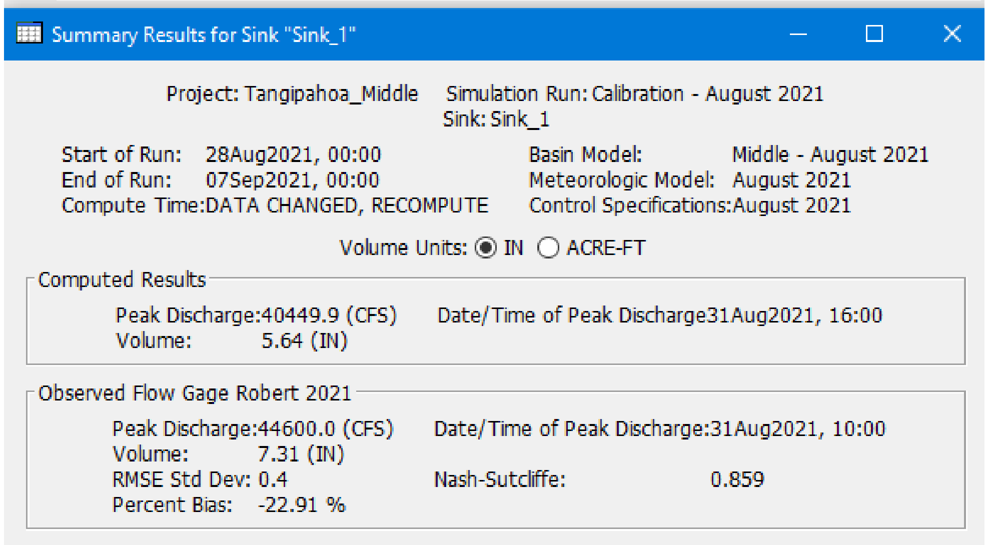
Computed Results

Peak Discharge:123745.0 (CFS) Date/Time of Peak Discharge13Aug2016, 19:00
Volume: 10.37 (IN)

Observed Flow Gage Middle_Tang

Peak Discharge:120000.0 (CFS) Date/Time of Peak Discharge:13Aug2016, 17:30
Volume: 13.10 (IN)
RMSE Std Dev: 0.4 Nash-Sutcliffe: 0.811
Percent Bias: -20.83 %





Summary Results for Sink "Sink_1"

Project: Tangipahoa_Middle Simulation Run: Calibration - August 2021
Sink: Sink_1

Start of Run:	28Aug2021, 00:00	Basin Model:	Middle - August 2021
End of Run:	07Sep2021, 00:00	Meteorologic Model:	August 2021
Compute Time:	DATA CHANGED, RECOMPUTE	Control Specifications:	August 2021

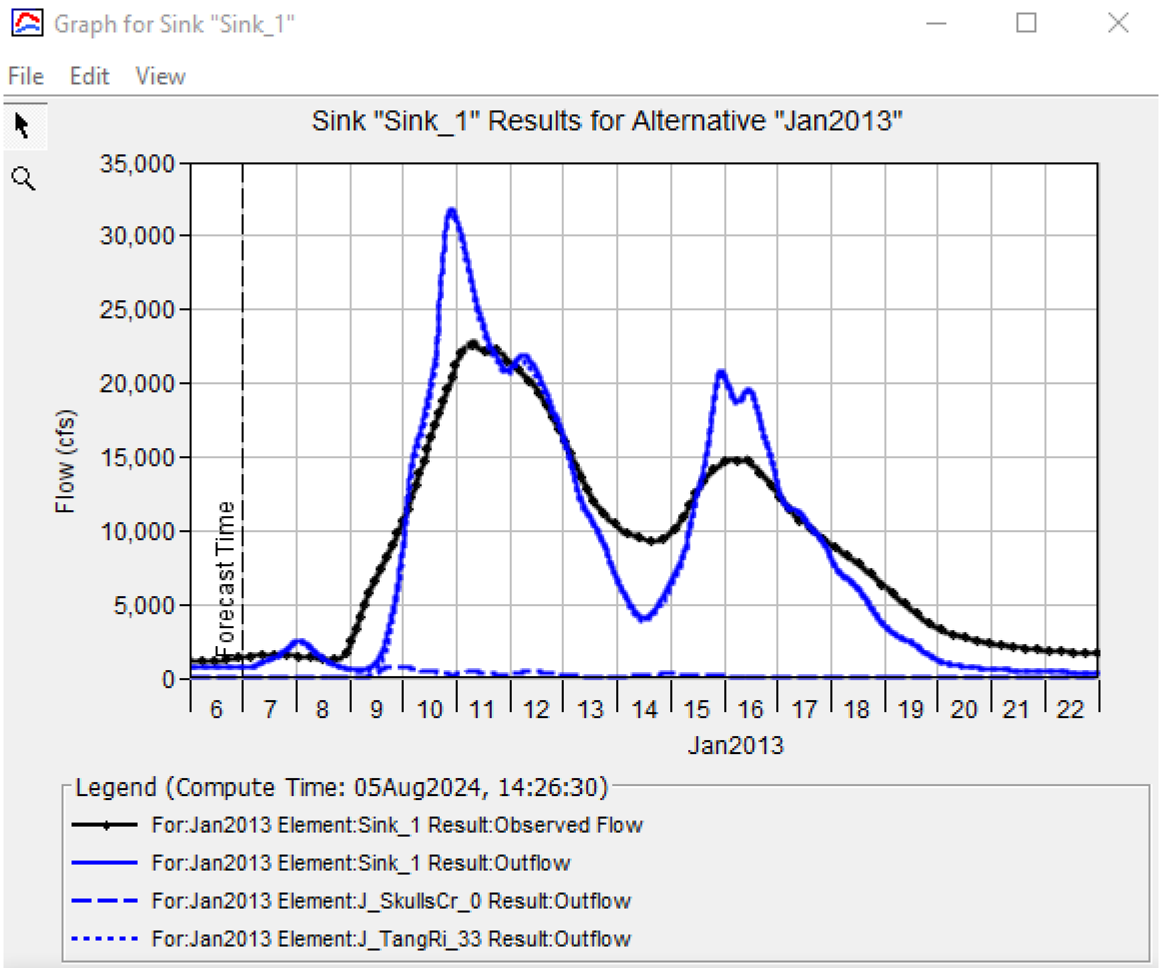
Volume Units: (•) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	40449.9 (CFS)	Date/Time of Peak Discharge	31Aug2021, 16:00
Volume:	5.64 (IN)		

Observed Flow Gage Robert 2021

Peak Discharge:	44600.0 (CFS)	Date/Time of Peak Discharge:	31Aug2021, 10:00
Volume:	7.31 (IN)		
RMSE Std Dev:	0.4	Nash-Sutcliffe:	0.859
Percent Bias:	-22.91 %		



Summary Results for Sink "Sink_1"

Project: TA_Tangipahoa Forecast Alternative: Jan2013
Sink: Sink_1

Start of Alternative: 06Jan2013, 00:00 Basin Model: TA_Middle
End of Alternative: 23Jan2013, 00:00 Meteorologic Model: Jan2013
Compute Time: 05Aug2024, 14:26:30

Volume Units: IN ACRE-FT

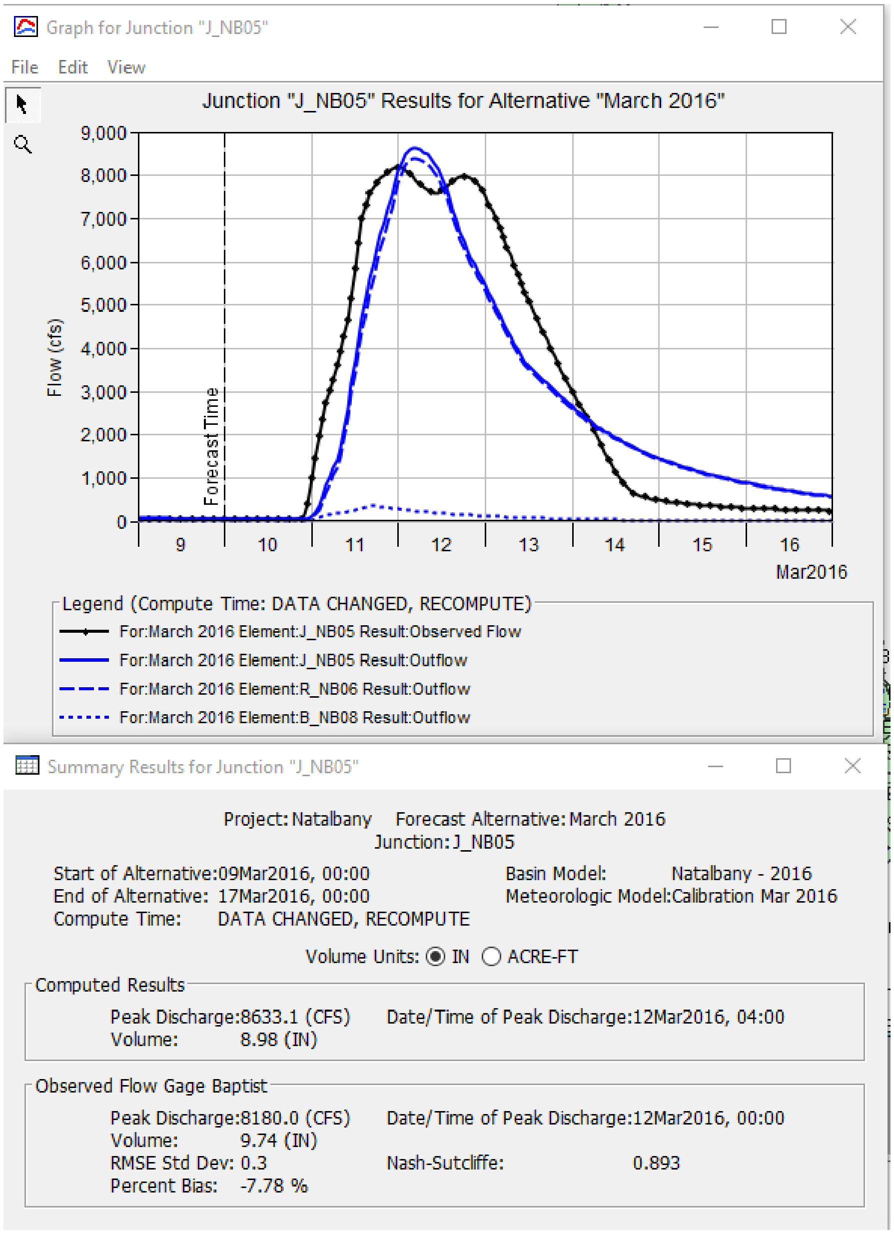
Computed Results

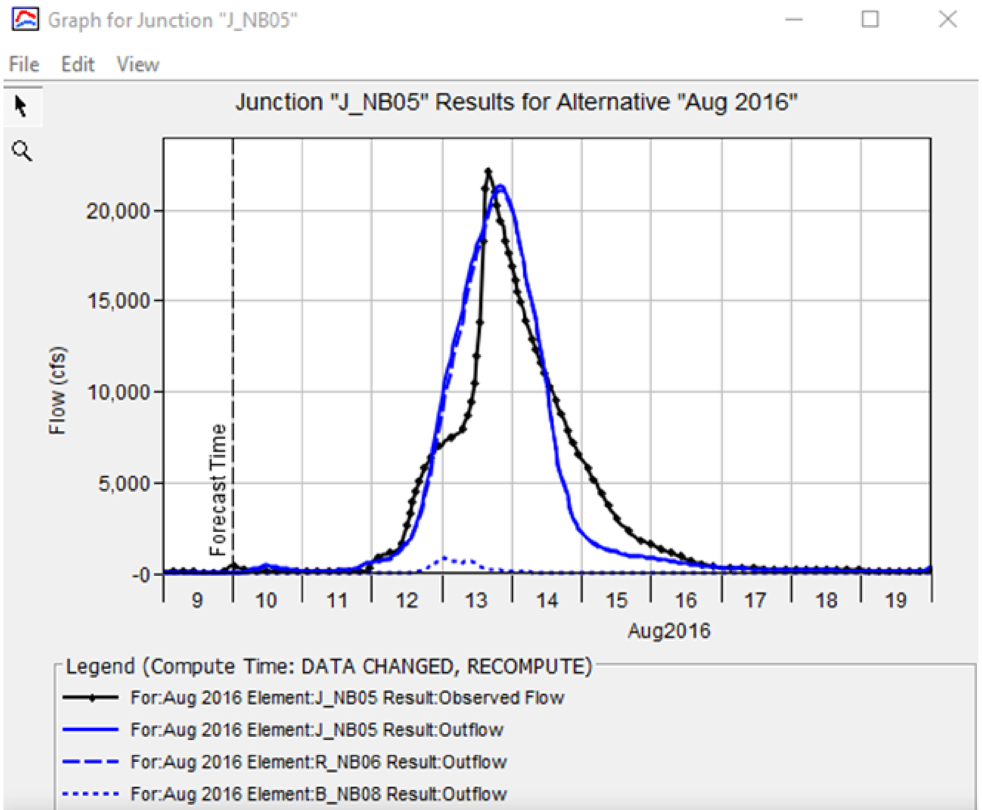
Peak Discharge: 31778.1 (CFS) Date/Time of Peak Discharge 10Jan2013, 21:40
Volume: 8.04 (IN)

Observed Flow Gage Robert2013

Peak Discharge: 22800.0 (CFS) Date/Time of Peak Discharge: 11Jan2013, 07:30
Volume: 8.45 (IN)
RMSE Std Dev: 0.4 Nash-Sutcliffe: 0.798
Percent Bias: -4.82 %

Natalbany HMS Flow Calibration (Baptist, LA)





Summary Results for Junction "J_NB05"

Project: Natalbany   Forecast Alternative: Aug 2016
Junction: J_NB05

Start of Alternative: 09Aug2016, 00:00   Basin Model: Natalbany - 2016
End of Alternative: 20Aug2016, 00:00   Meteorologic Model: Calibration Aug 2016
Compute Time: DATA CHANGED, RECOMPUTE

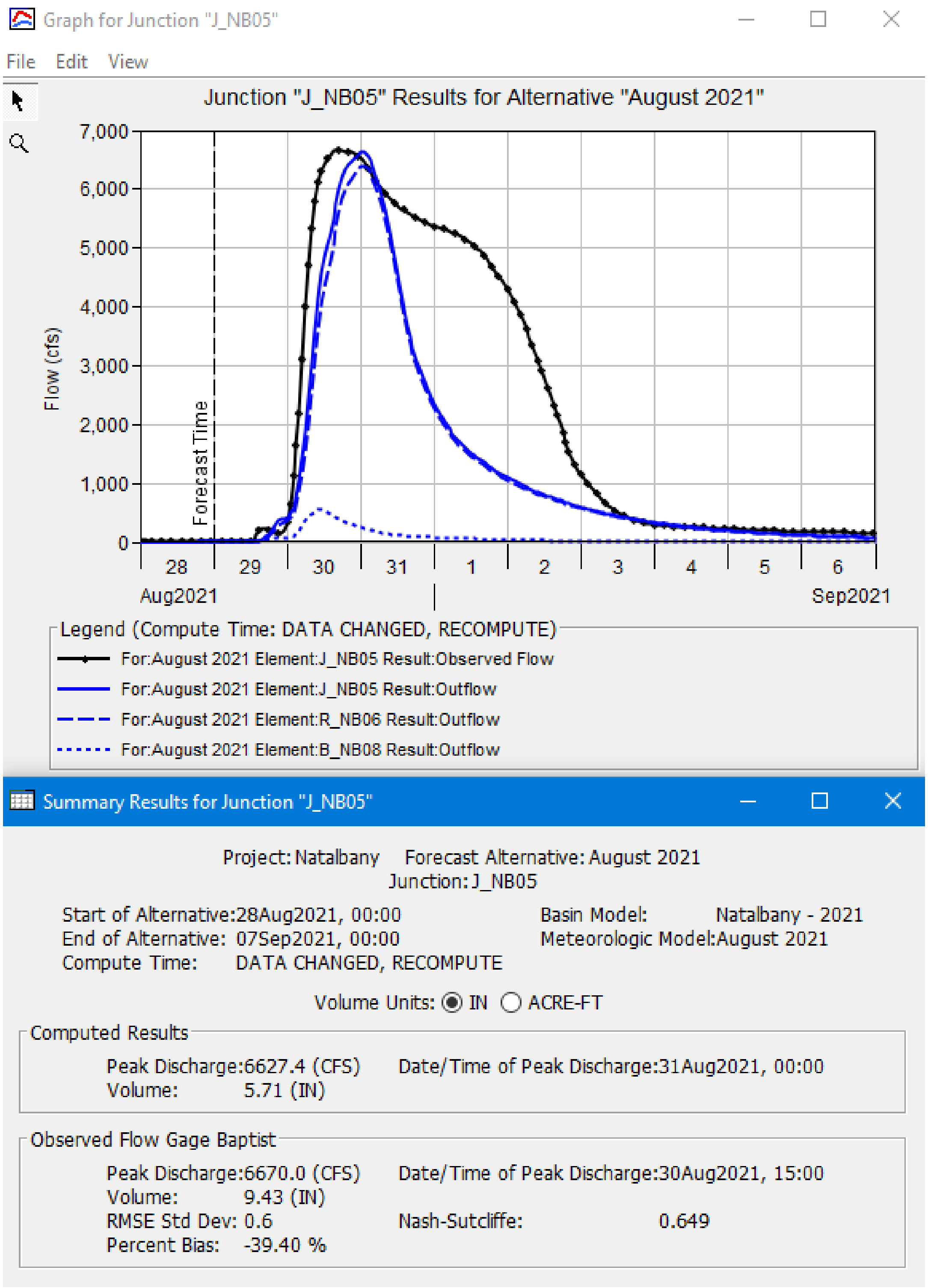
Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge: 21310.5 (CFS)   Date/Time of Peak Discharge: 13Aug2016, 20:00
Volume: 15.82 (IN)

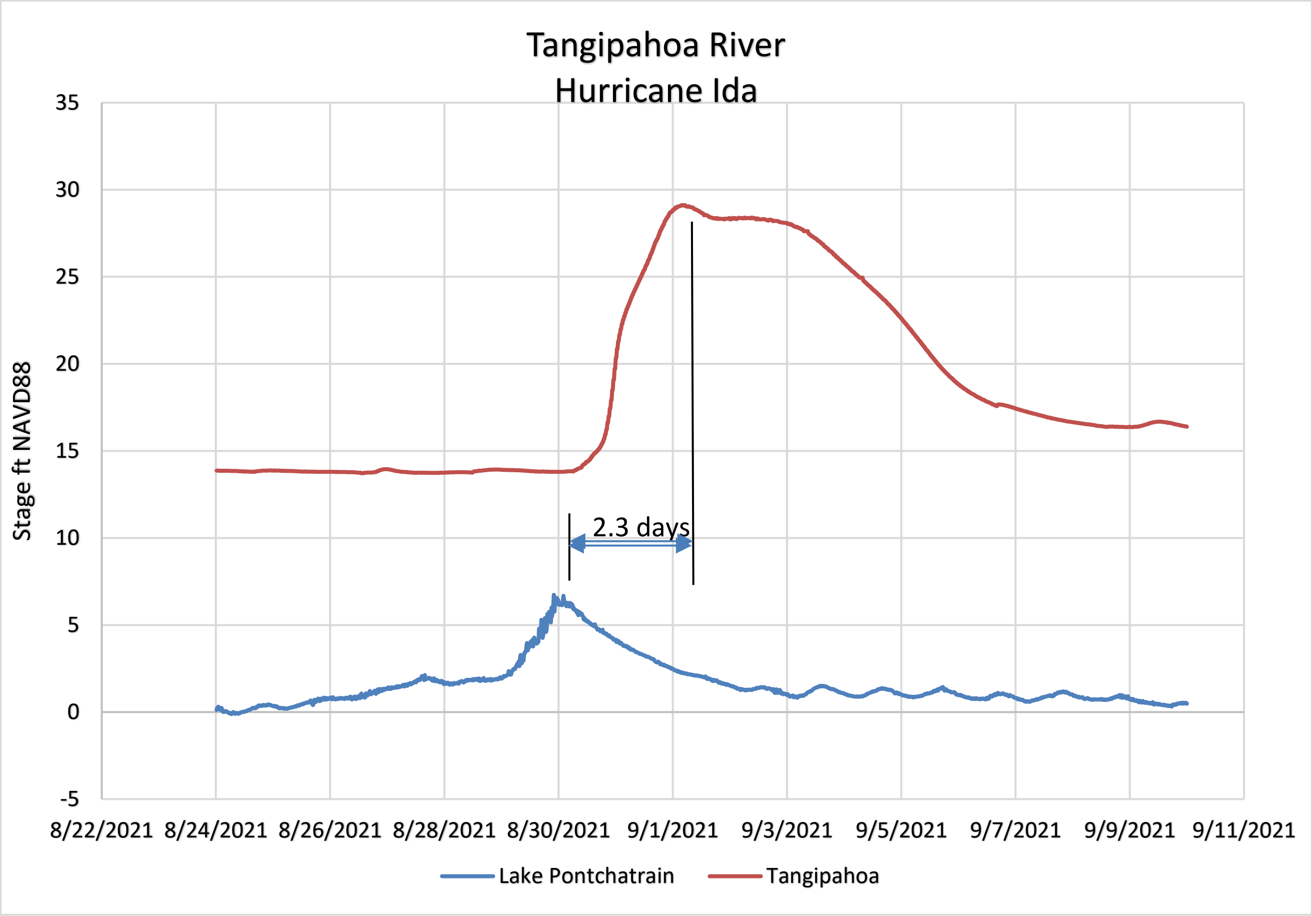
Observed Flow Gage Baptist

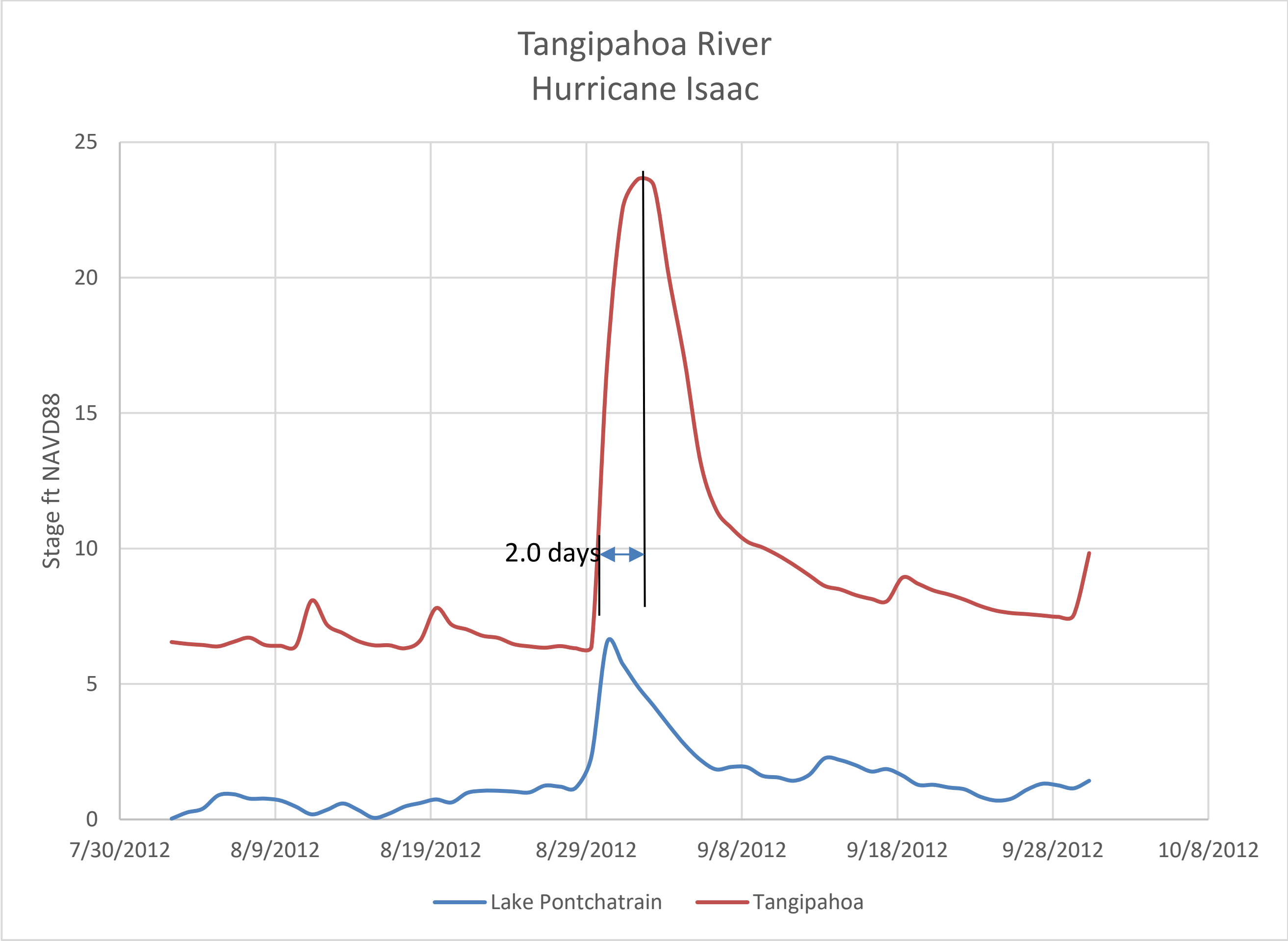
Peak Discharge: 22100.0 (CFS)   Date/Time of Peak Discharge: 13Aug2016, 16:00
Volume: 15.72 (IN)
RMSE Std Dev: 0.4   Nash-Sutcliffe: 0.870
Percent Bias: 0.61 %

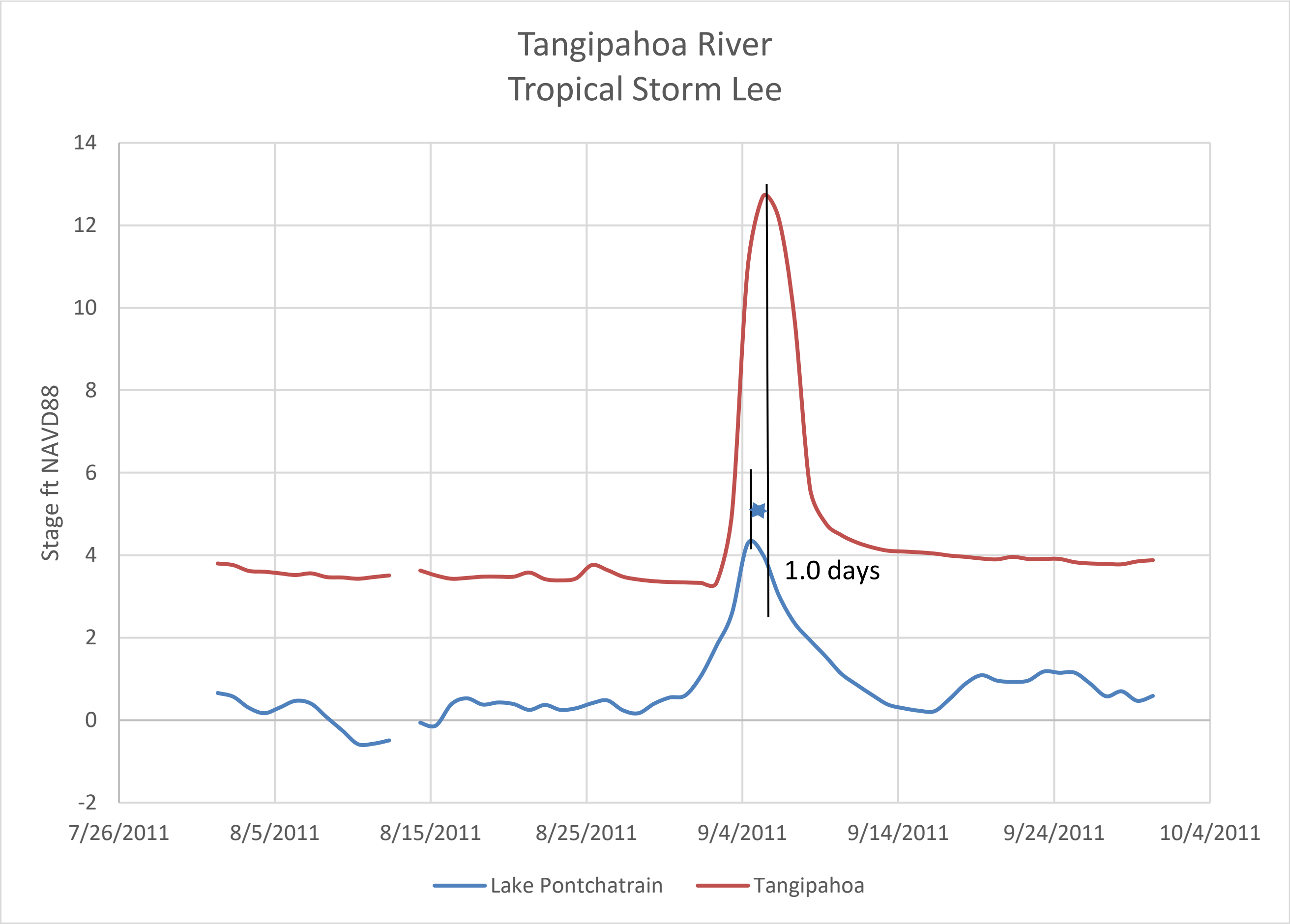

Graph for Junction "J_NB05"
File Edit View
Junction "J_NB05" Results for Alternative "August 2021"
Flow (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Forecast Time
28
29
30
31
1
2
3
4
5
6
Aug2021
Sep2021
Legend (Compute Time: DATA CHANGED, RECOMPUTE)
For:August 2021 Element:J_NB05 Result:Observed Flow
For:August 2021 Element:J_NB05 Result:Outflow
For:August 2021 Element:R_NB06 Result:Outflow
For:August 2021 Element:B_NB08 Result:Outflow
Summary Results for Junction "J_NB05"
Project: Natalbany Forecast Alternative: August 2021
Junction: J_NB05
Start of Alternative: 28Aug2021, 00:00
End of Alternative: 07Sep2021, 00:00
Compute Time: DATA CHANGED, RECOMPUTE
Basin Model: Natalbany - 2021
Meteorologic Model: August 2021
Volume Units: IN ACRE-FT
Computed Results
Peak Discharge: 6627.4 (CFS)
Date/Time of Peak Discharge: 31Aug2021, 00:00
Volume: 5.71 (IN)
Observed Flow Gage Baptist
Peak Discharge: 6670.0 (CFS)
Date/Time of Peak Discharge: 30Aug2021, 15:00
Volume: 9.43 (IN)
RMSE Std Dev: 0.6
Nash-Sutcliffe: 0.649
Percent Bias: -39.40 %

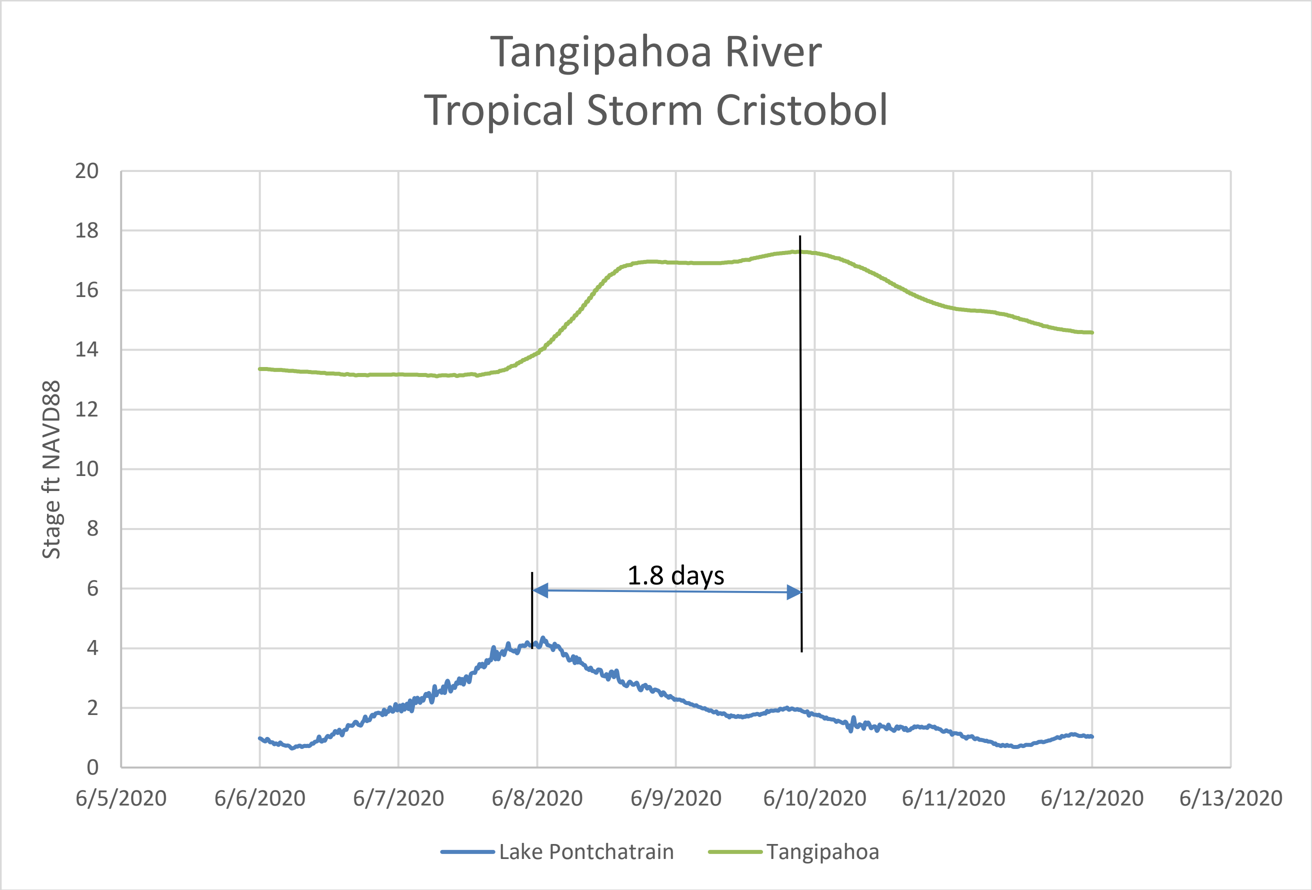
Annex B: Compound Flooding Gage Correlation, Elevation Profiles, and Compound Flooding Zones

Tangipahoa Gage Correlation

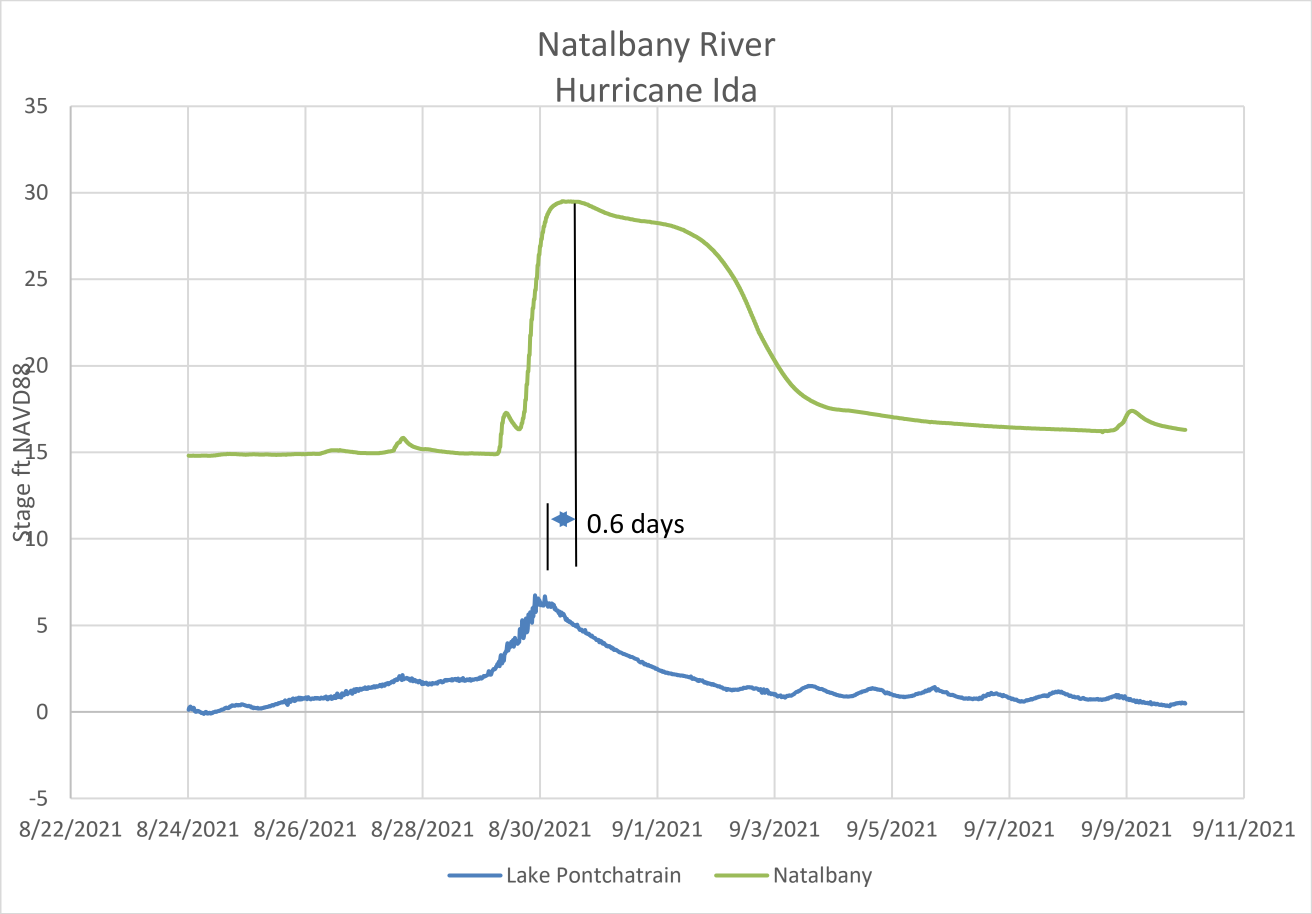


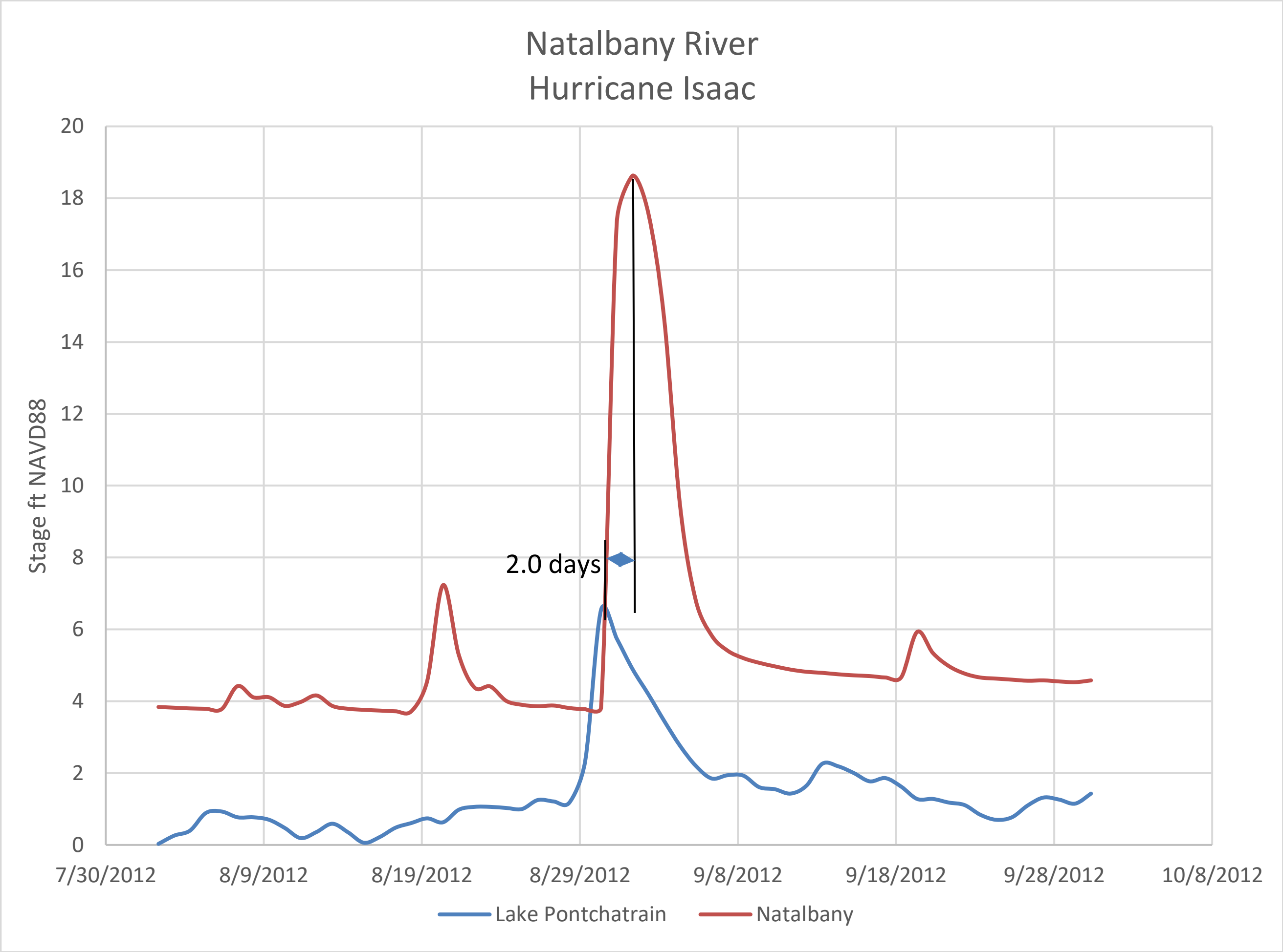

Tangipahoa River
Hurricane Isaac
Stage ft NAVD88
25
20
15
10
5
0
7/30/2012
8/9/2012
8/19/2012
8/29/2012
9/8/2012
9/18/2012
9/28/2012
10/8/2012
2.0 days
Lake Pontchatrain
Tangipahoa

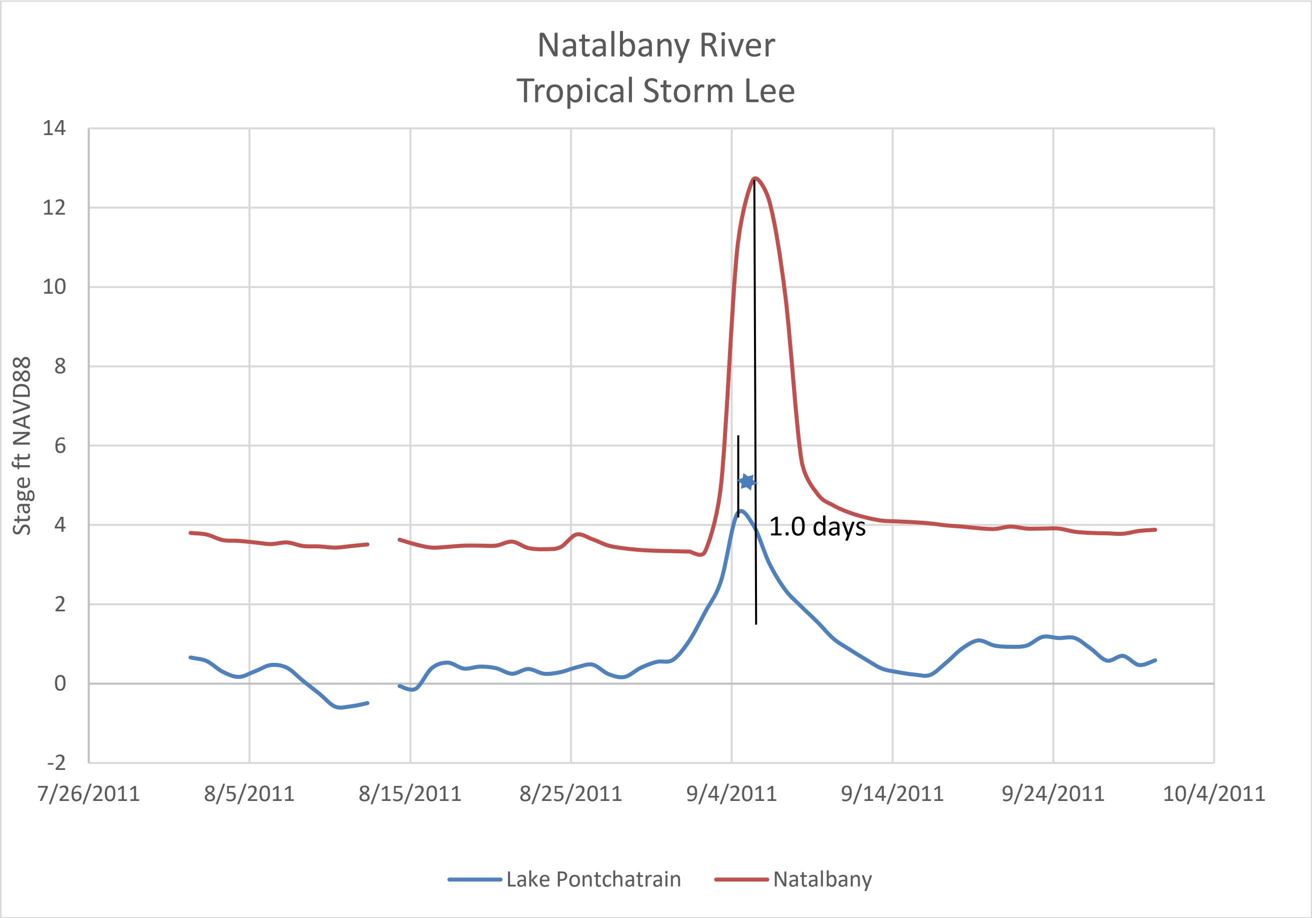

Tangipahoa River
Tropical Storm Lee
Stage ft NAVD88
14
12
10
8
6
4
2
0
-2
7/26/2011
8/5/2011
8/15/2011
8/25/2011
9/4/2011
9/14/2011
9/24/2011
10/4/2011
1.0 days
Lake Pontchatrain
Tangipahoa

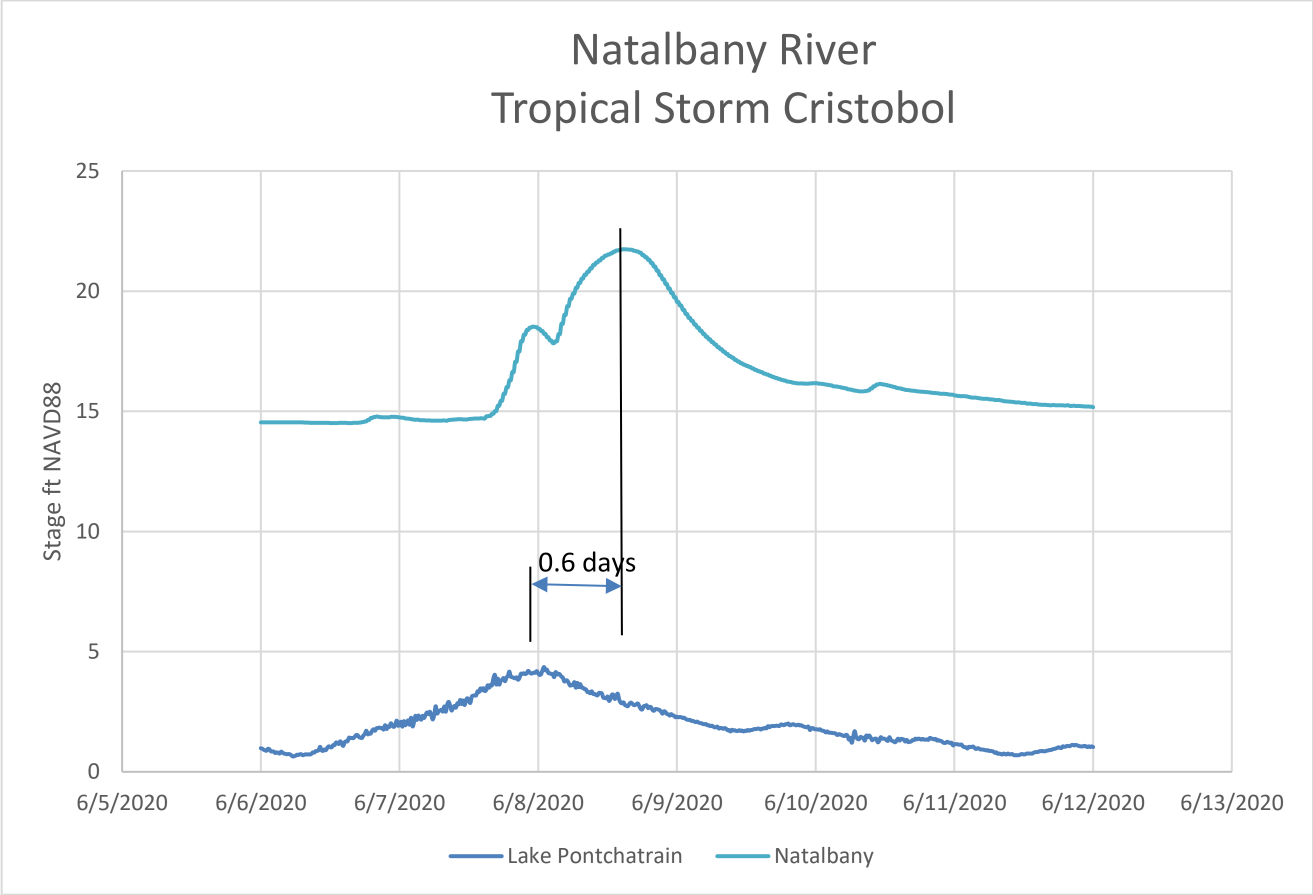

Tangipahoa River
Tropical Storm Cristobol
Stage ft NAVD88
20
18
16
14
12
10
8
6
4
2
0
1.8 days
6/5/2020
6/6/2020
6/7/2020
6/8/2020
6/9/2020
6/10/2020
6/11/2020
6/12/2020
6/13/2020
Lake Pontchatrain
Tangipahoa

Natalbany Gage Correlation

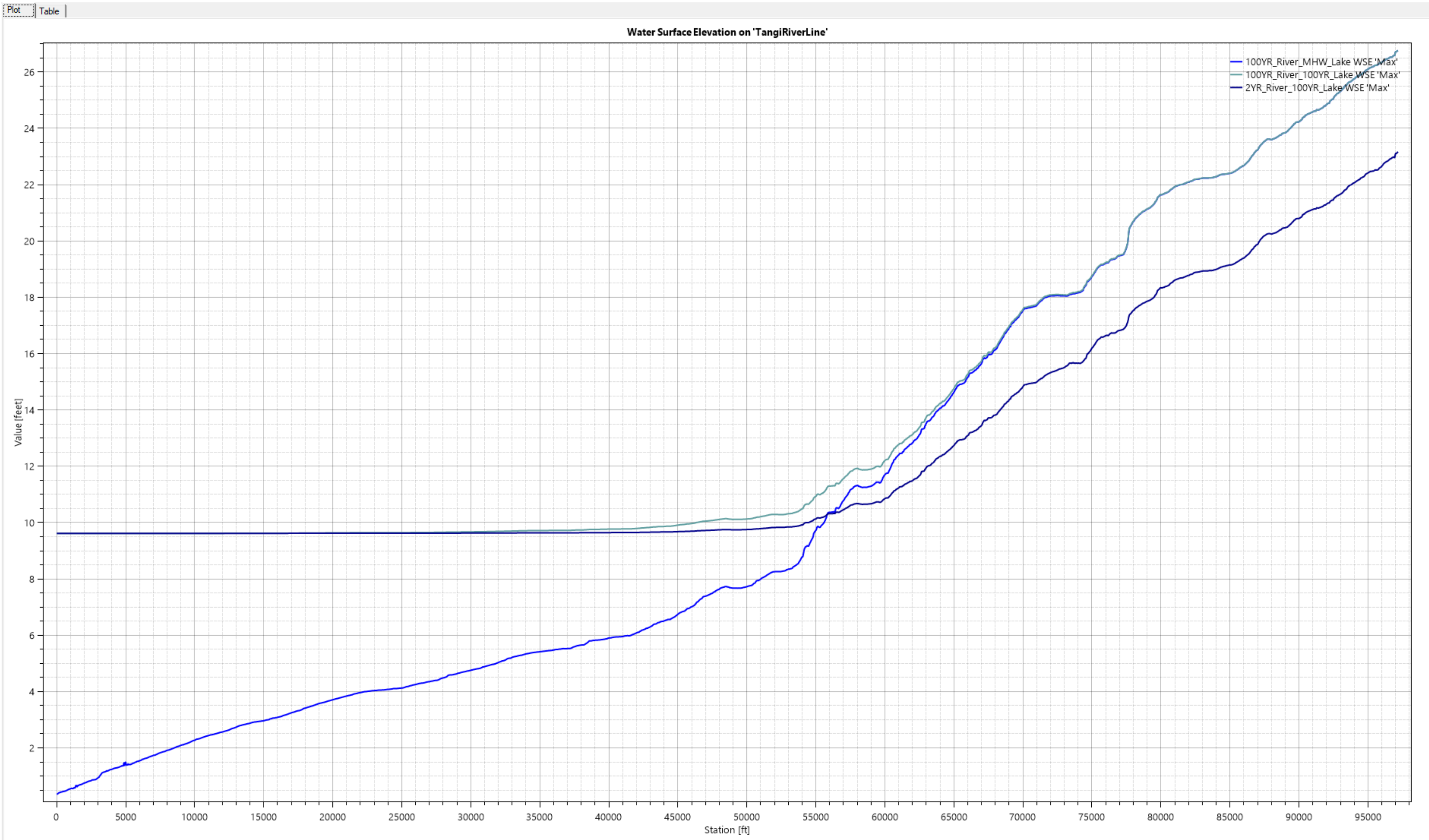



Natalbany River
Hurricane Isaac
Stage ft NAVD88
20
18
16
14
12
10
8
6
4
2
0
2.0 days
7/30/2012
8/9/2012
8/19/2012
8/29/2012
9/8/2012
9/18/2012
9/28/2012
10/8/2012
Lake Pontchatrain
Natalbany

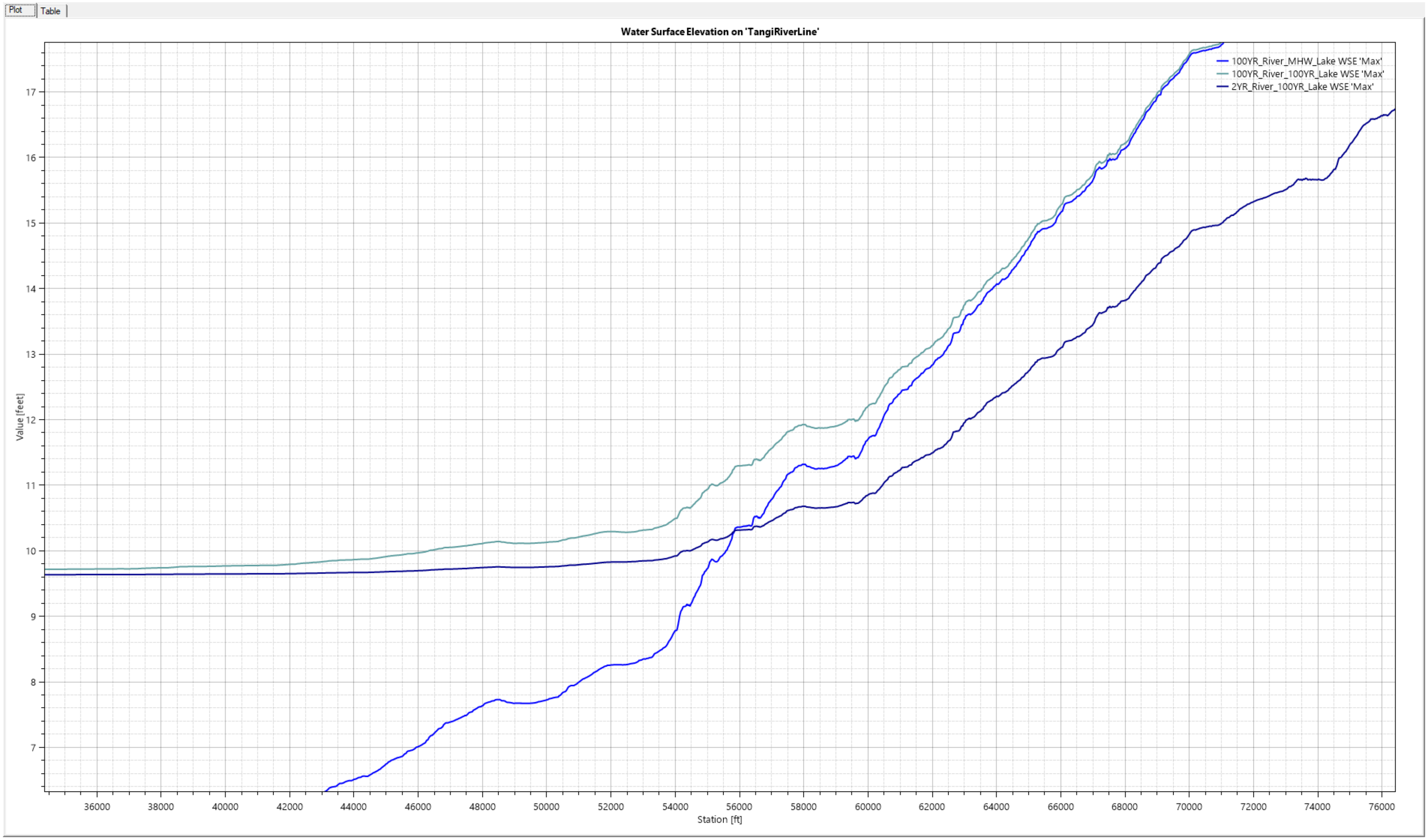

Natalbany River
Tropical Storm Lee
Stage ft NAVD88
14
12
10
8
6
4
2
0
-2
7/26/2011
8/5/2011
8/15/2011
8/25/2011
9/4/2011
9/14/2011
9/24/2011
10/4/2011
1.0 days
Lake Pontchatrain
Natalbany


Natalbany River
Tropical Storm Cristobol
Stage ft NAVD88
25
20
15
10
5
0
0.6 days
6/5/2020
6/6/2020
6/7/2020
6/8/2020
6/9/2020
6/10/2020
6/11/2020
6/12/2020
6/13/2020
Lake Pontchatrain
Natalbany

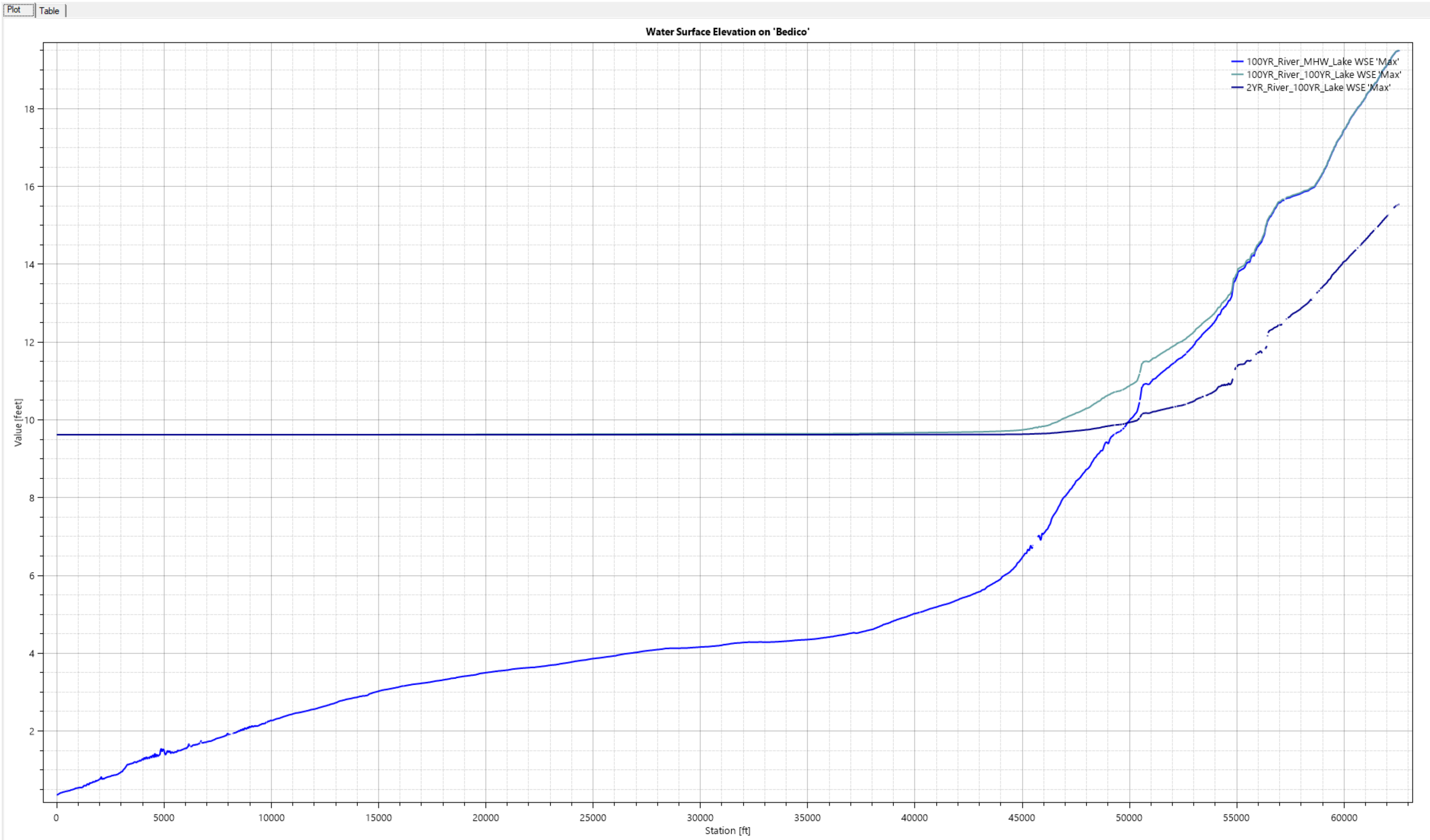
Tangipahoa River 1% AEP Event Profile



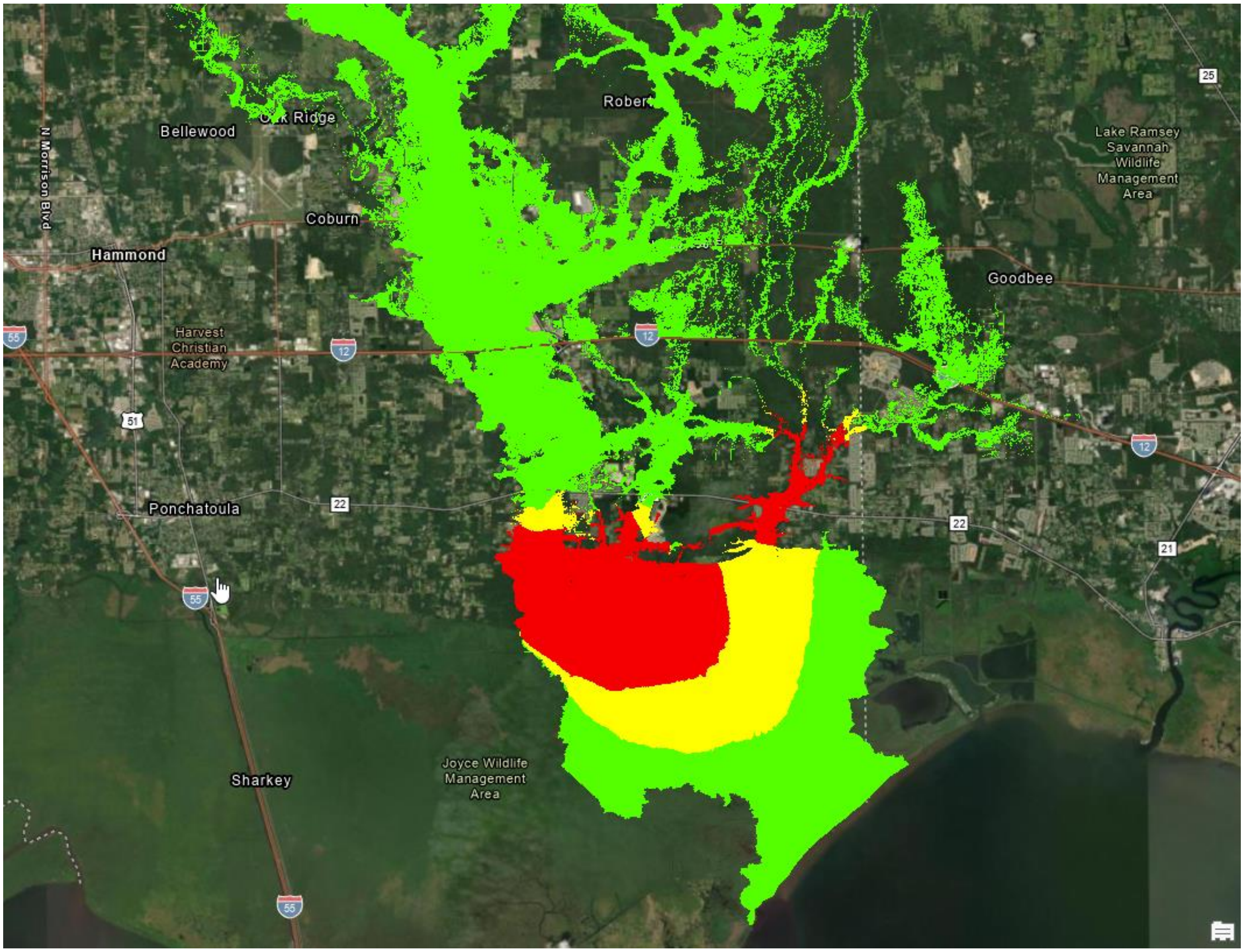
Tangipahoa River 1% AEP Event Profile Zoomed



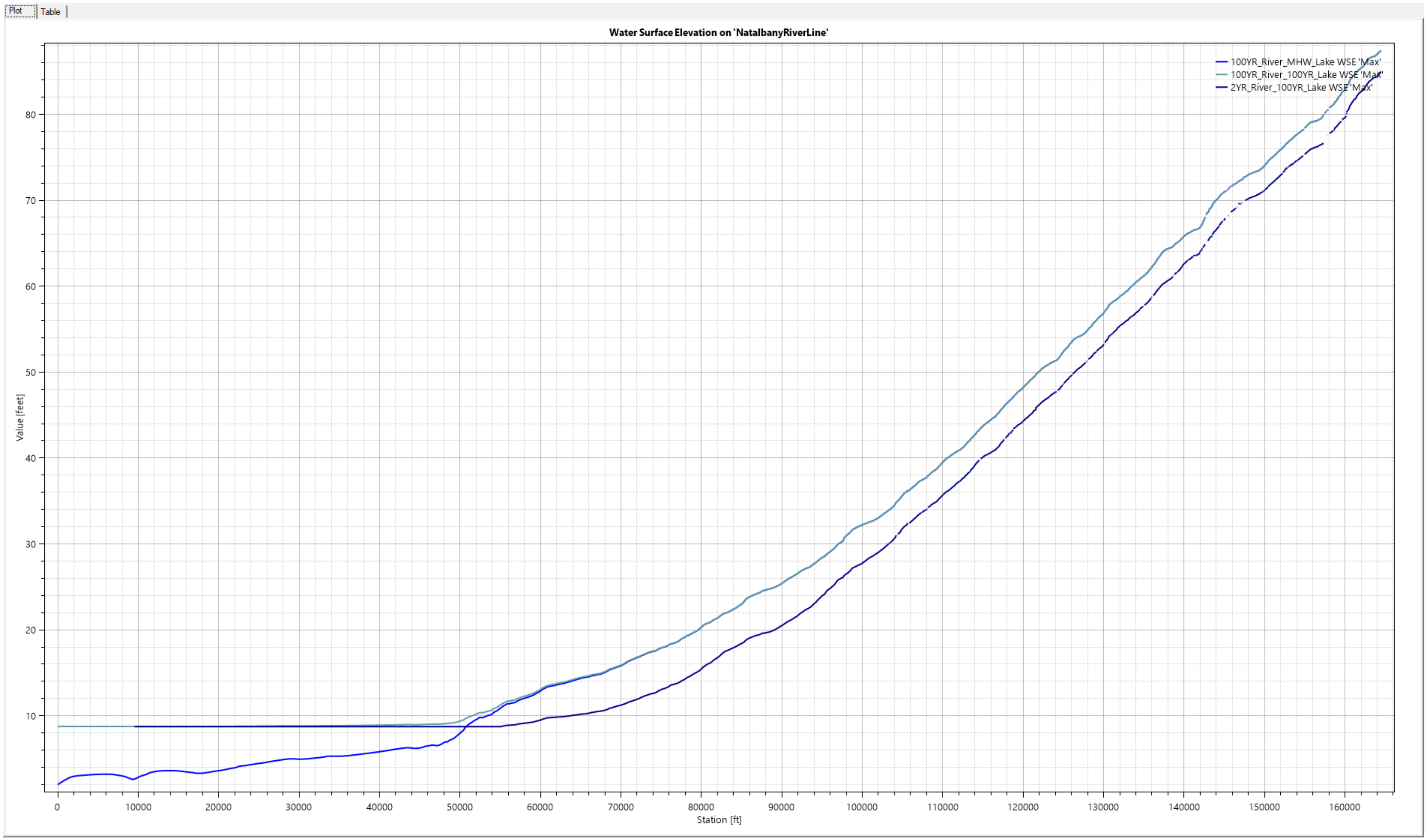
Bedico Creek 1% AEP Event Profile



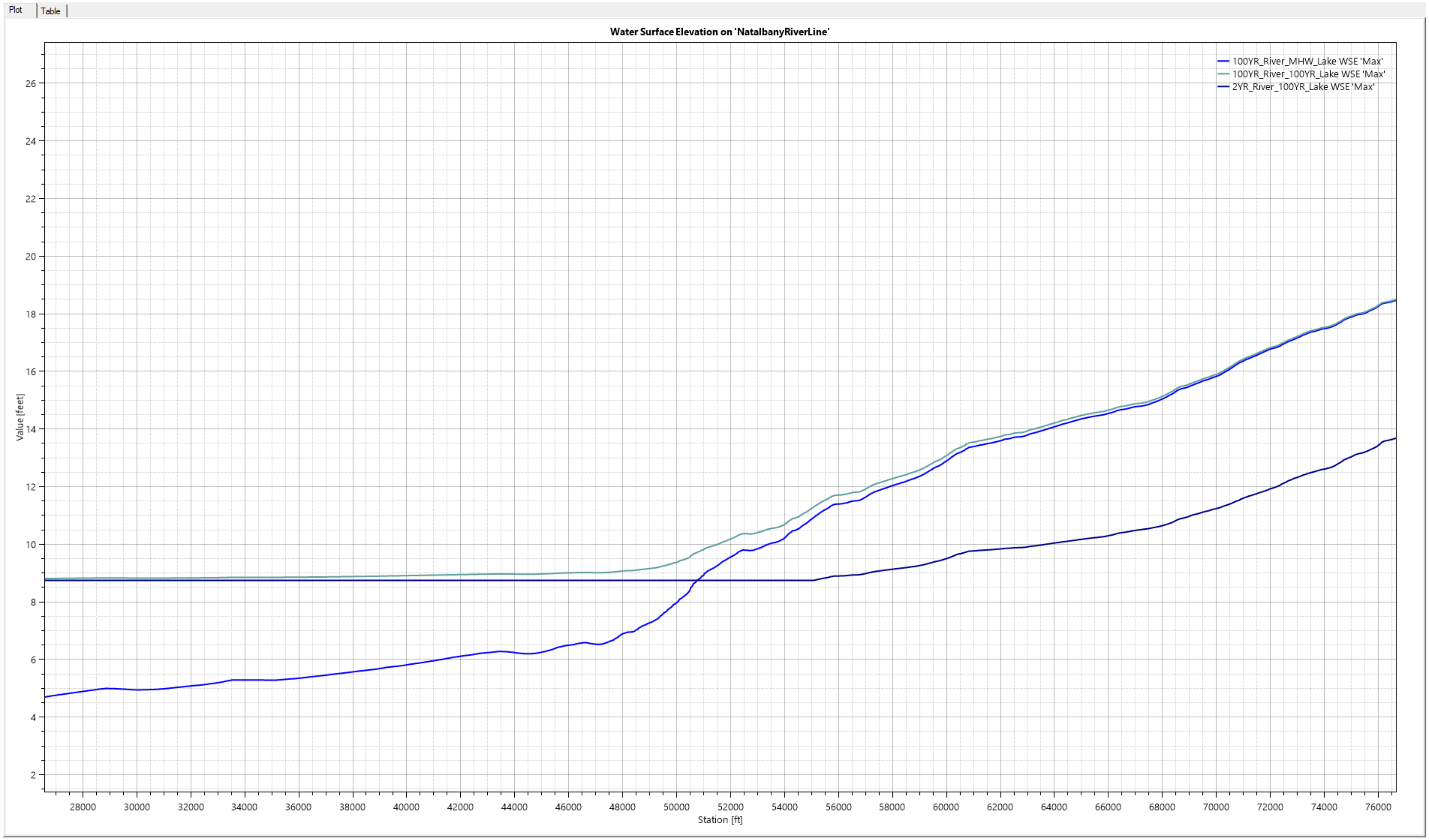
Sections of Reaches Affected by Compound Flooding in Lower Tangipahoa Model
Red (> 0.1 ft) and Yellow (0 to 0.1 ft) Compound Flooding Regions



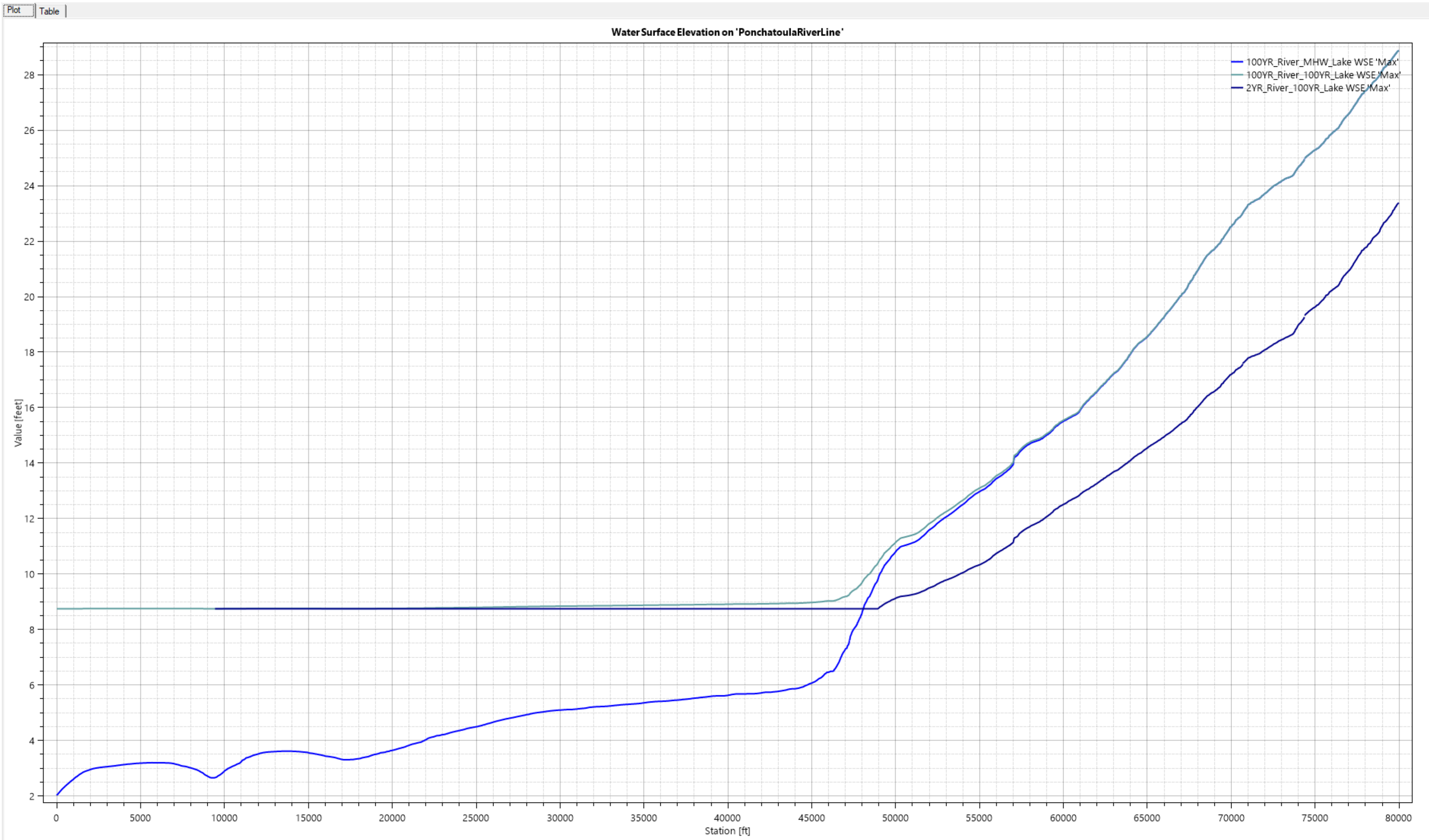
Natalbany River 1% AEP Event Profile



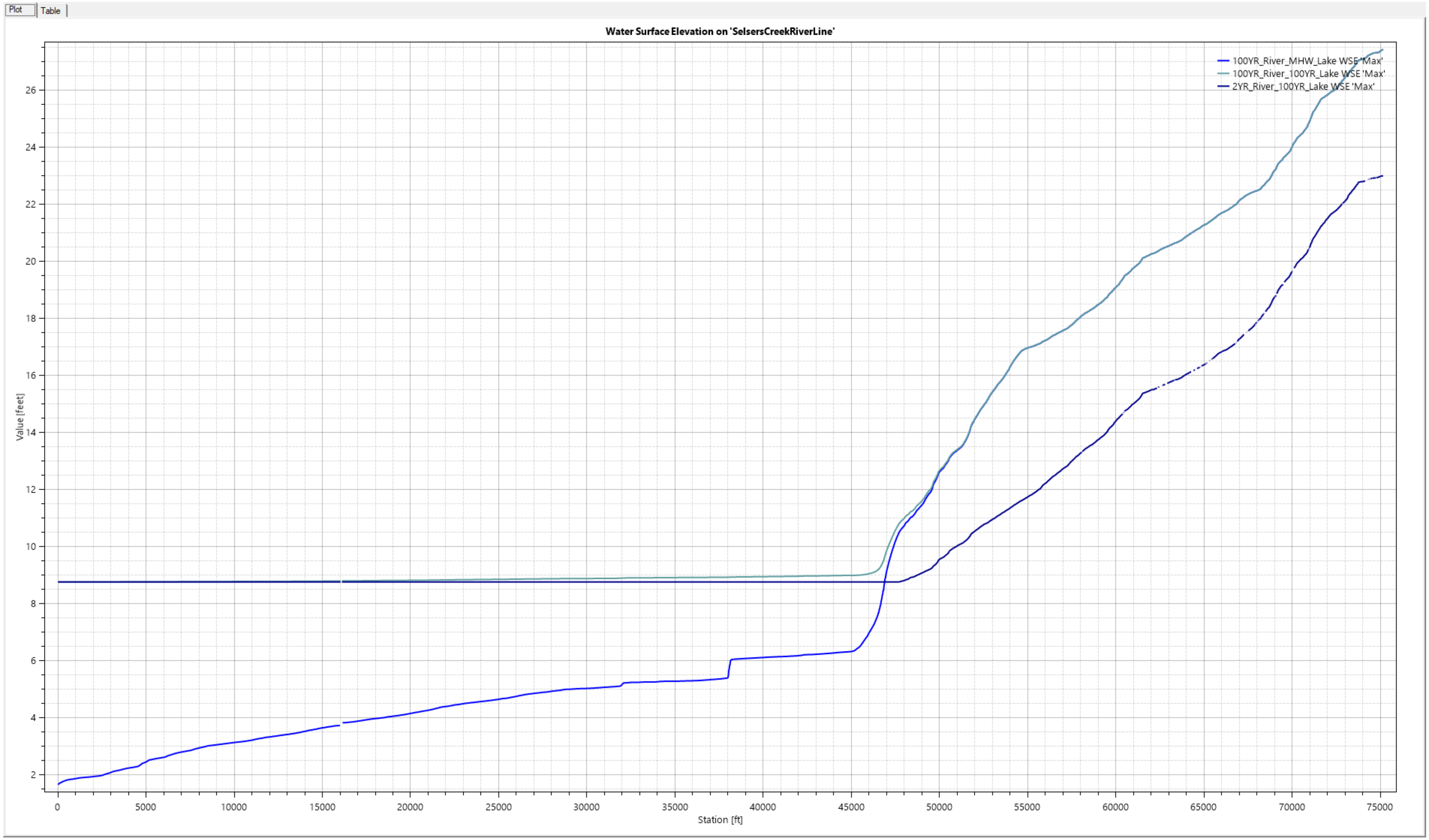
Natalbany River 1% AEP Event Profile Zoomed



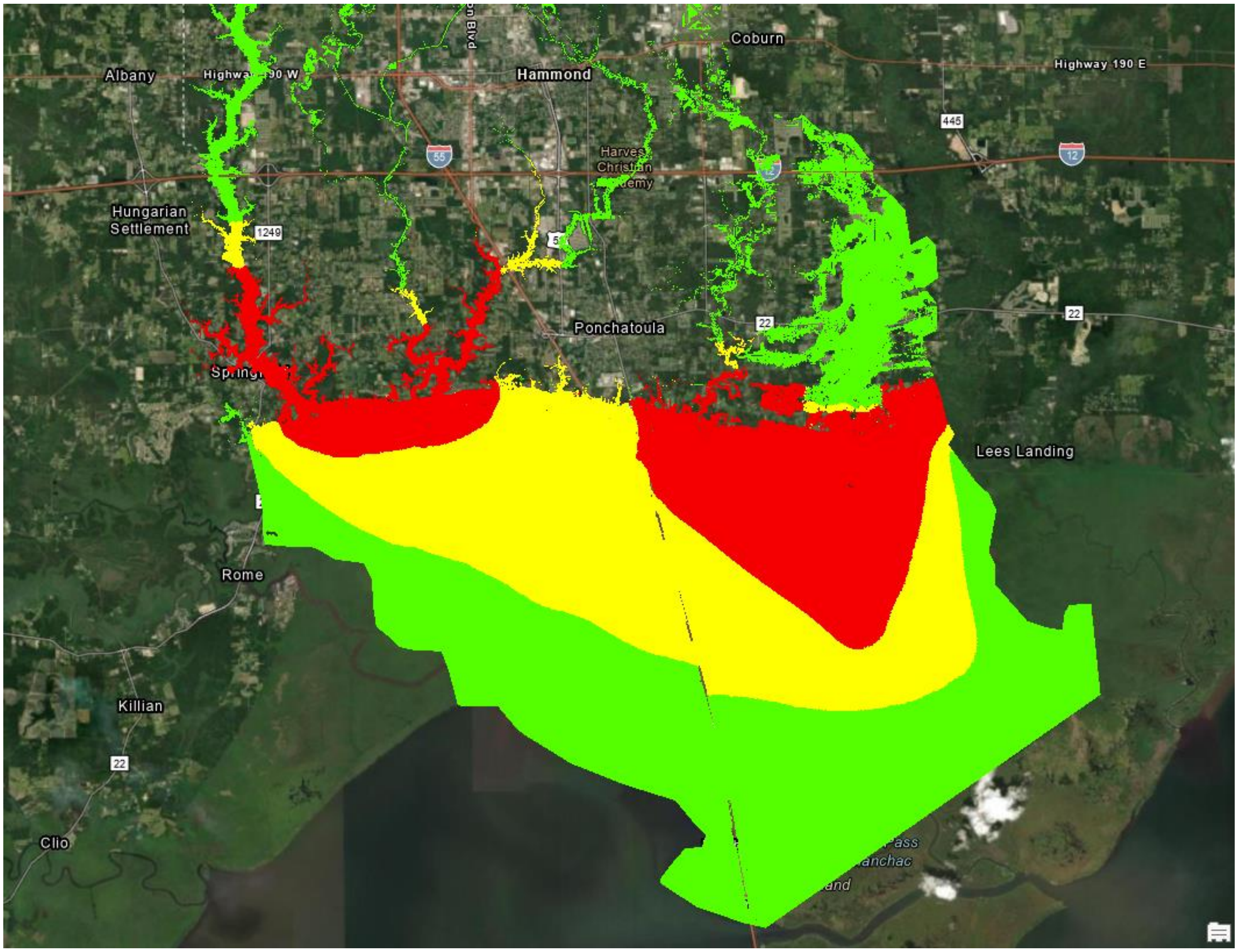
Ponchatoula Creek 1% AEP Event Profile Zoomed



Seleser's Creek 1% AEP Event Profile Zoomed

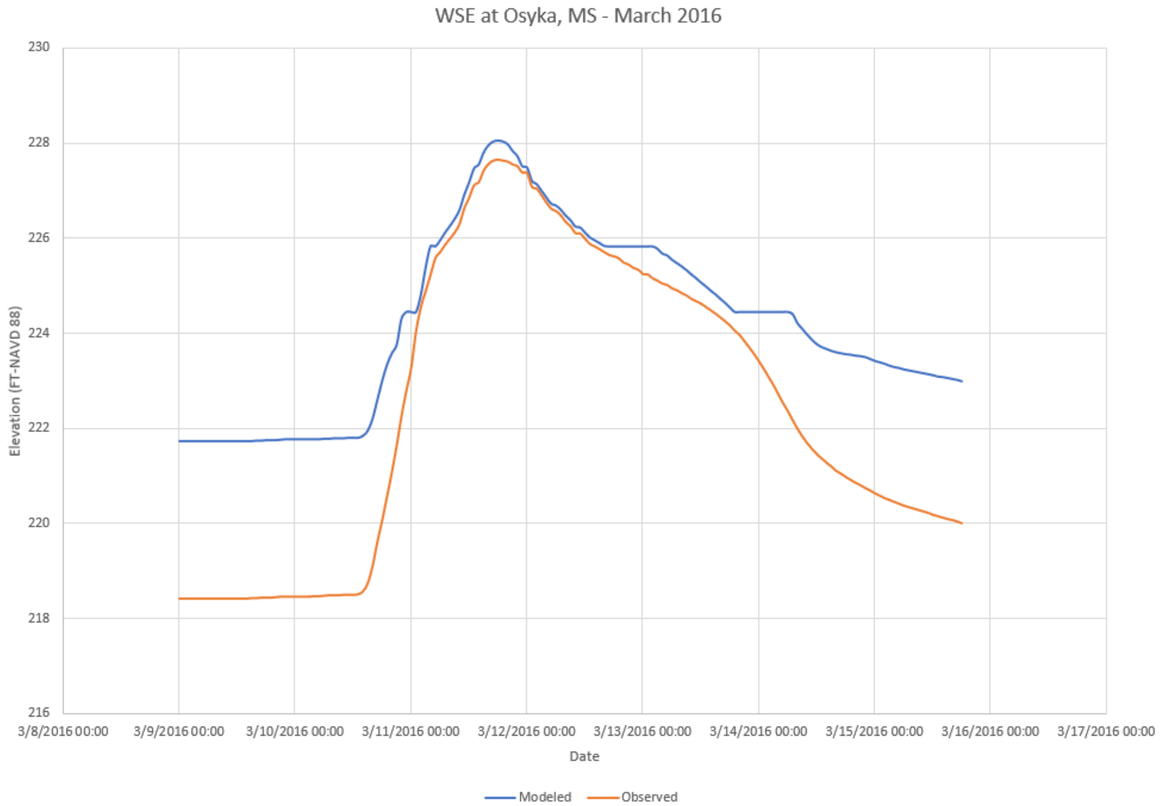


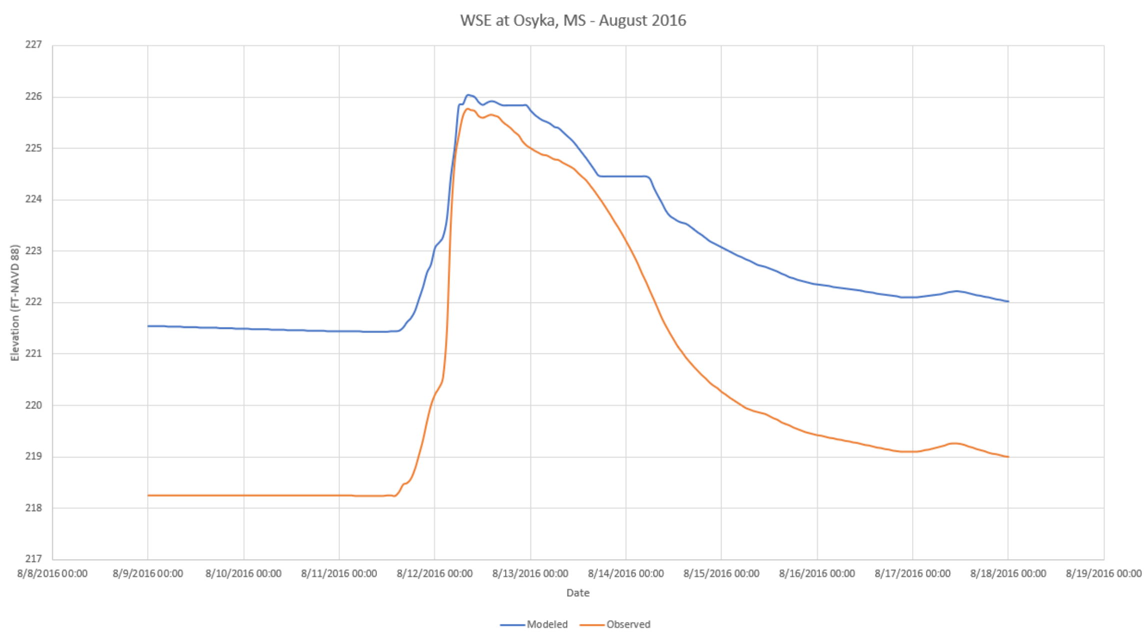
Sections of Reaches Affected by Compound Flooding in Natalbany/Selser's Creek Model
Red (> 0.1 ft) and Yellow (0 to 0.1 ft) Compound Flooding Regions

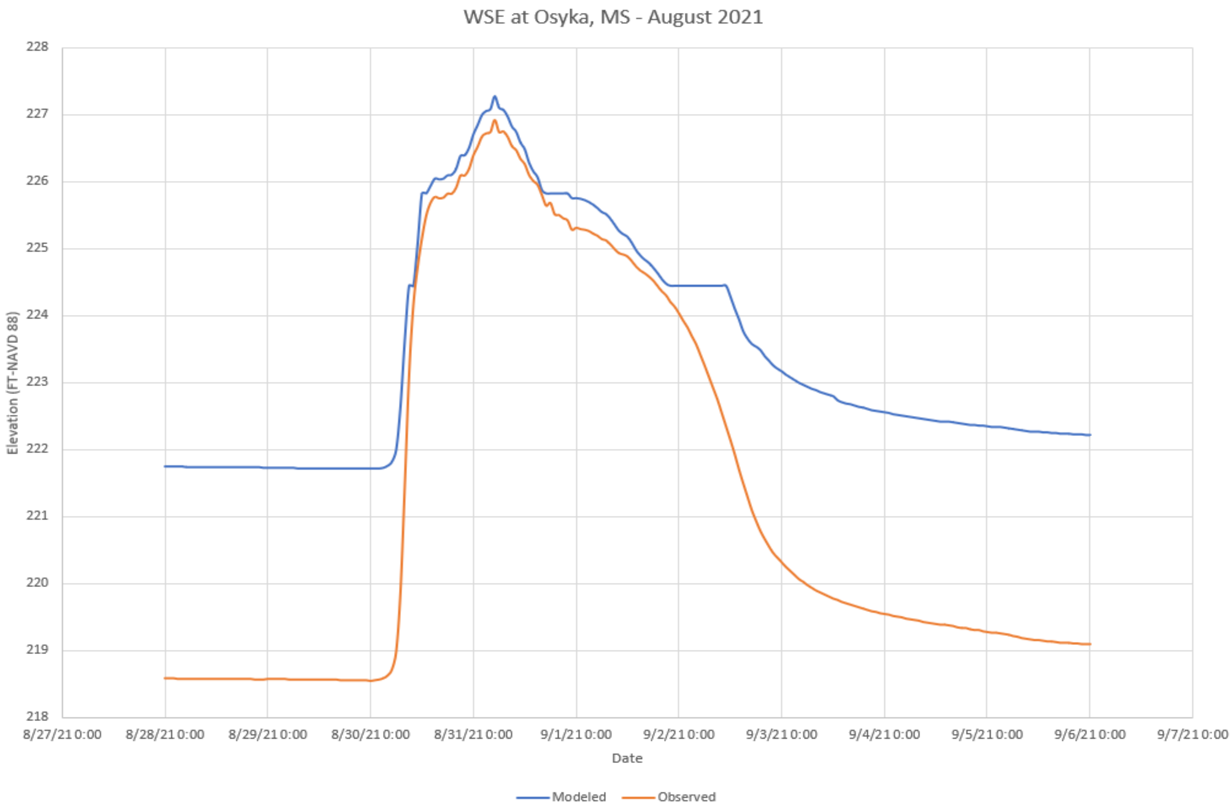


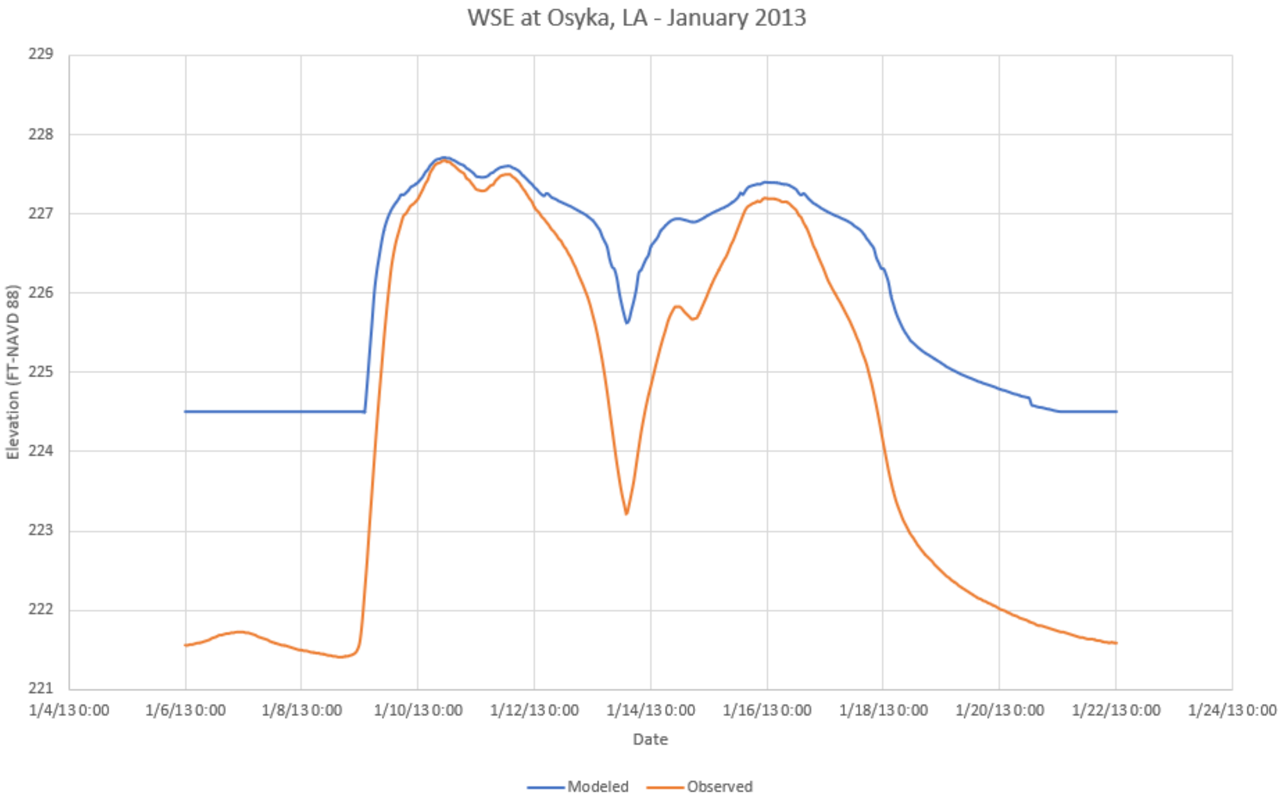
Annex C: Hydraulic Calibration Plots

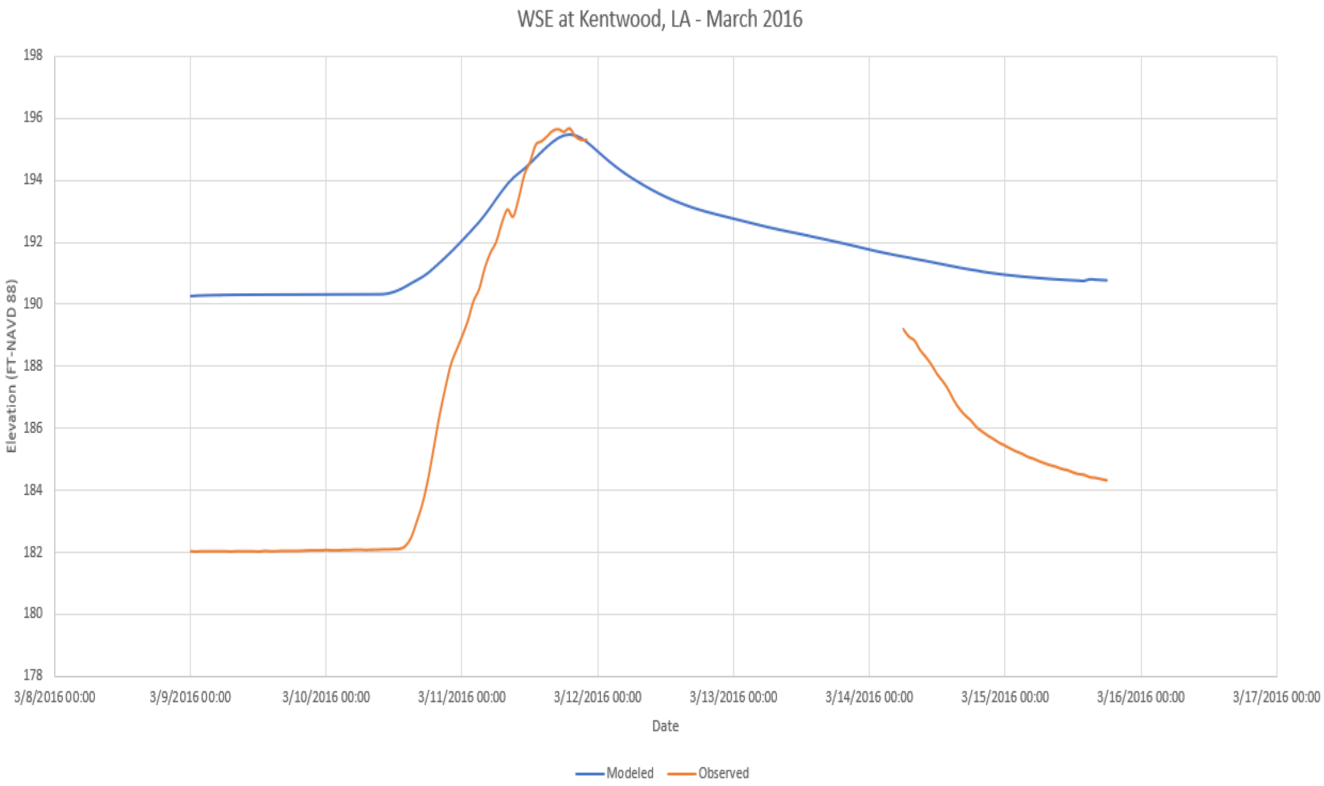
Upper Middle Tangipahoa RAS Stage Calibration

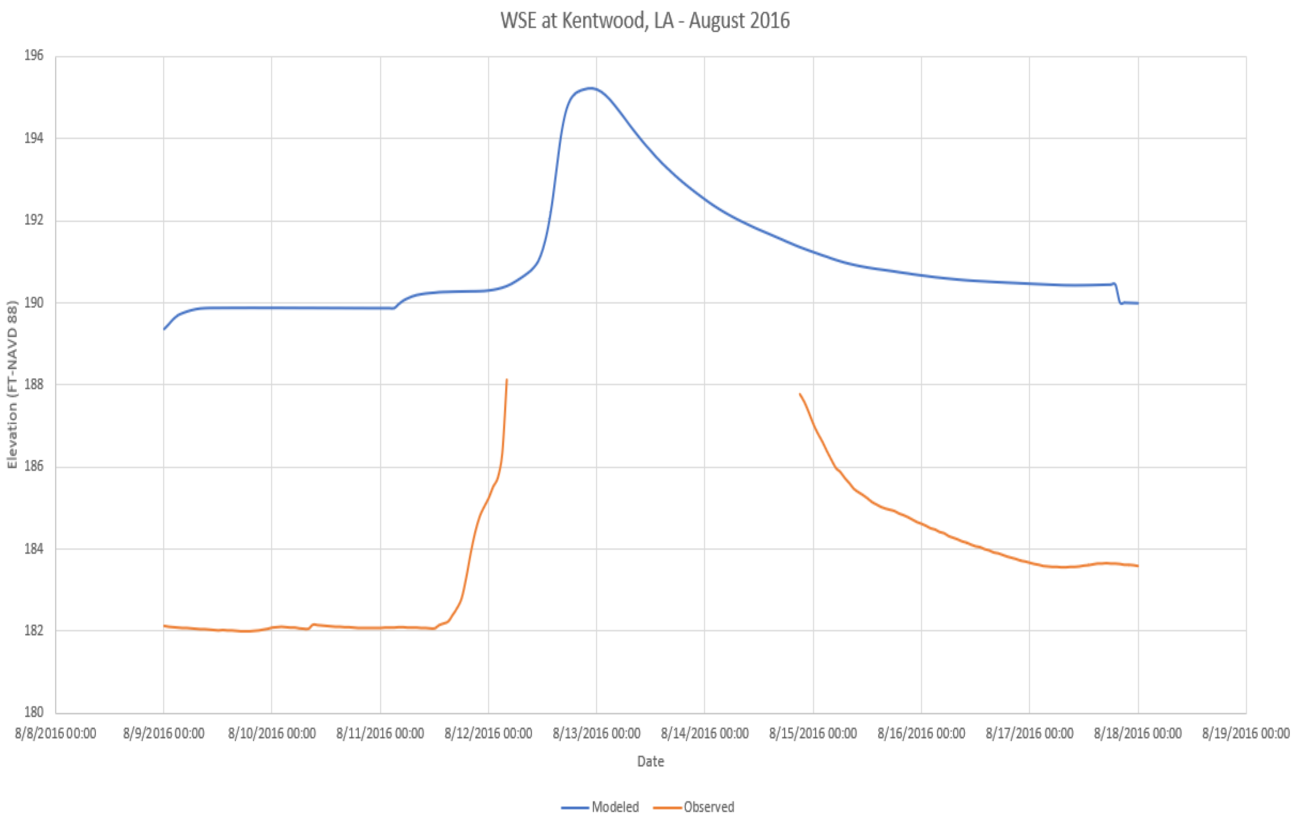




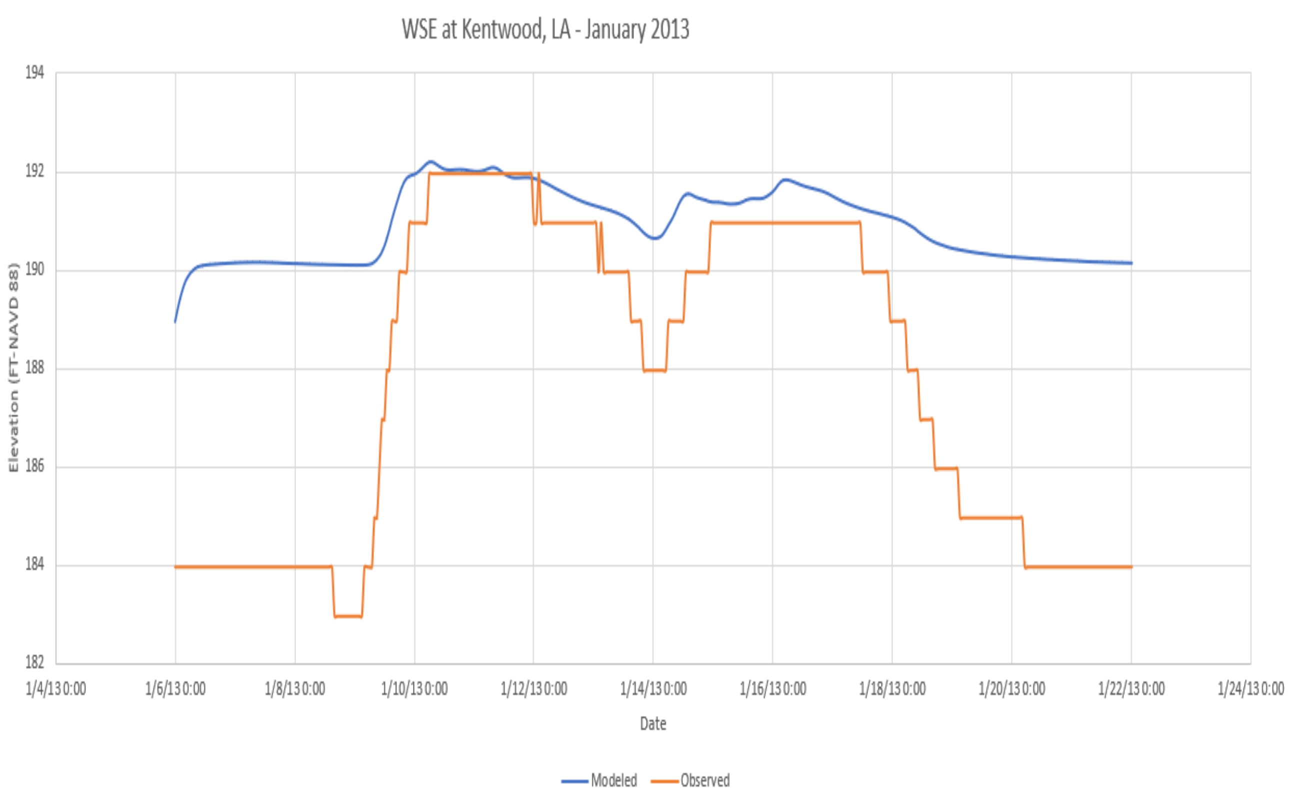

WSE at Osyka, MS - August 2021
Elevation (FT-NAVD 88)
Date
Modeled
Observed

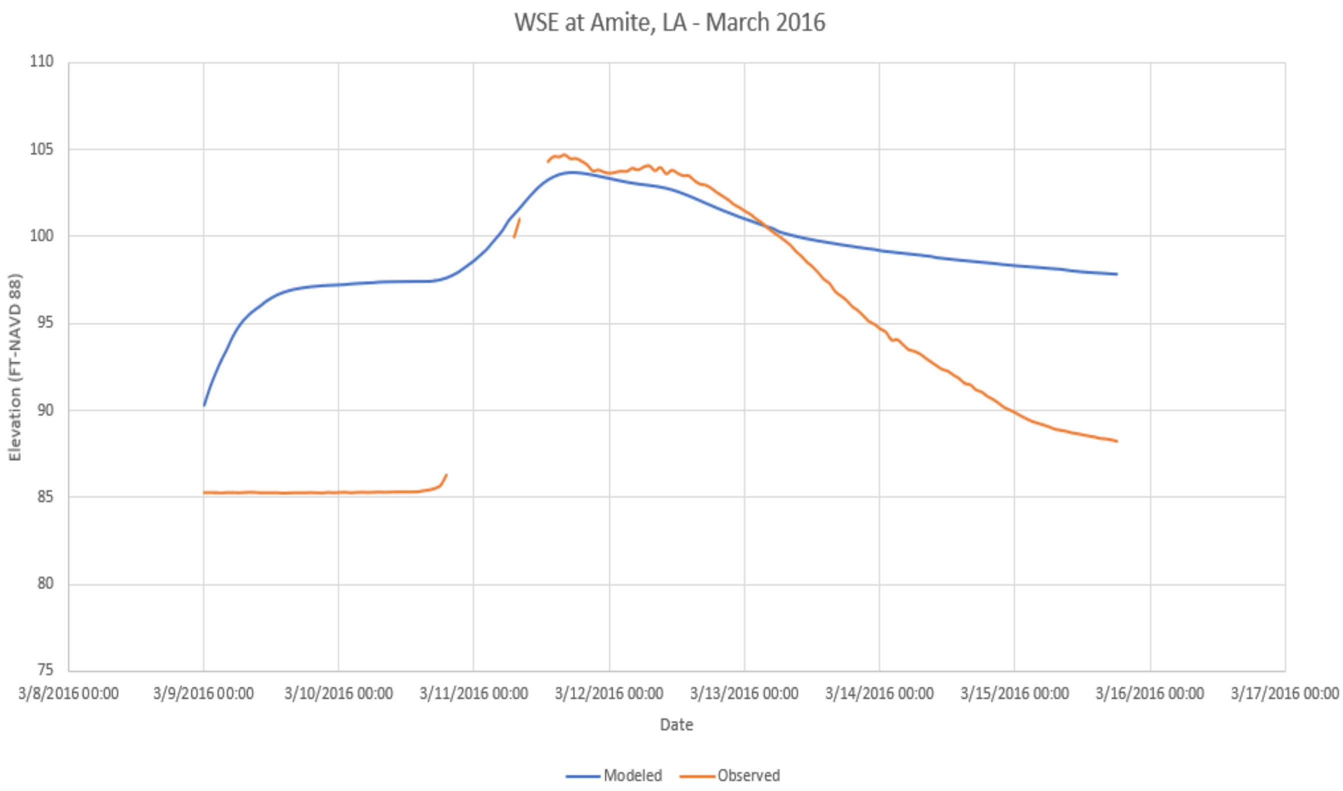

WSE at Osyka, LA - January 2013
Elevation (FT-NAVD 88)
Date
Modeled
Observed

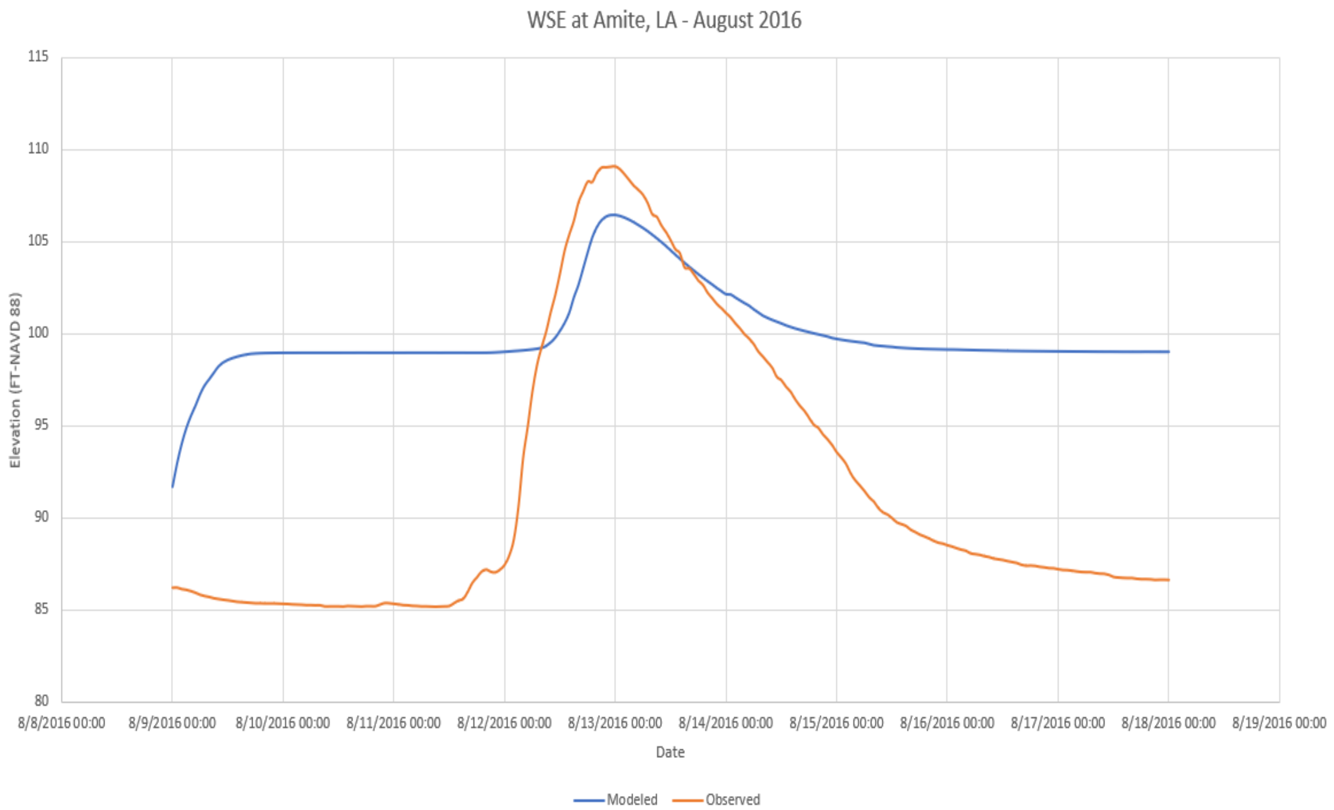

WSE at Kentwood, LA - March 2016
Elevation (FT-NAVD 88)
198
196
194
192
190
188
186
184
182
180
178
3/8/2016 00:00
3/9/2016 00:00
3/10/2016 00:00
3/11/2016 00:00
3/12/2016 00:00
3/13/2016 00:00
3/14/2016 00:00
3/15/2016 00:00
3/16/2016 00:00
3/17/2016 00:00
Date
Modeled
Observed

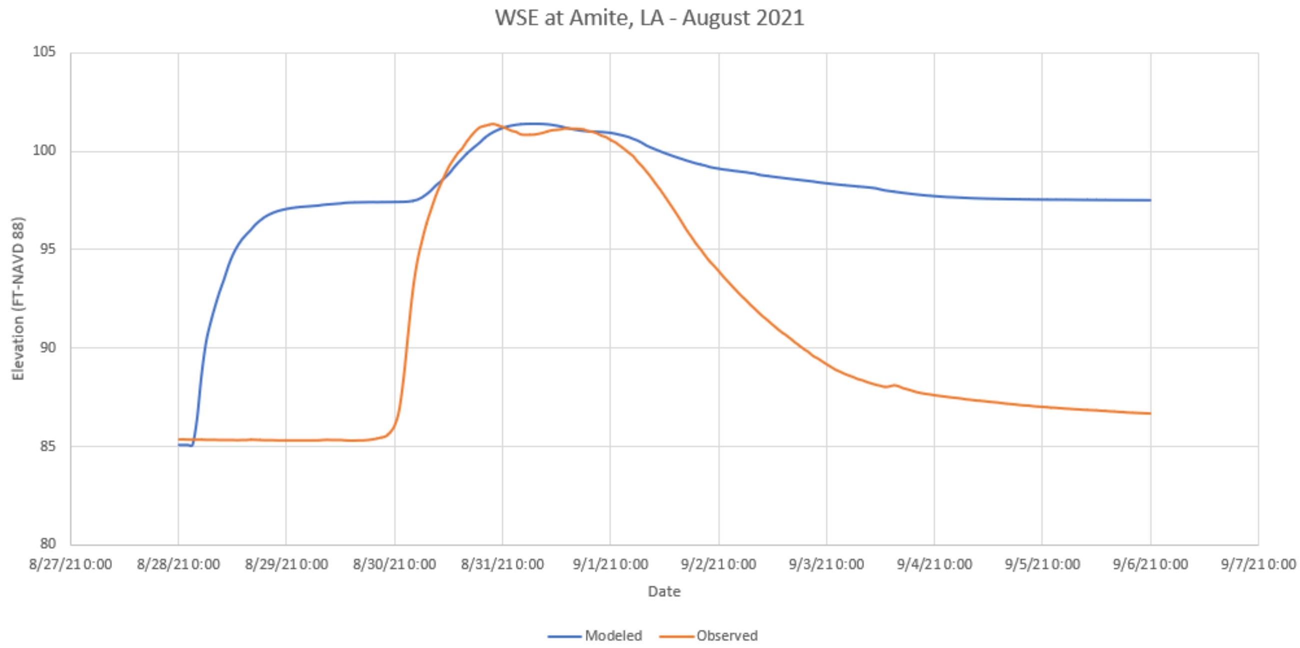

WSE at Kentwood, LA - August 2016
Elevation (FT-NAVD 88)
196
194
192
190
188
186
184
182
180
8/8/2016 00:00
8/9/2016 00:00
8/10/2016 00:00
8/11/2016 00:00
8/12/2016 00:00
8/13/2016 00:00
8/14/2016 00:00
8/15/2016 00:00
8/16/2016 00:00
8/17/2016 00:00
8/18/2016 00:00
8/19/2016 00:00
Date
Modeled
Observed


WSE at Kentwood, LA - August 2021
Elevation (FT-NAVD 88)
200
198
196
194
192
190
188
186
184
182
180
8/27/21 0:00
8/28/21 0:00
8/29/21 0:00
8/30/21 0:00
8/31/21 0:00
9/1/21 0:00
9/2/21 0:00
9/3/21 0:00
9/4/21 0:00
9/5/21 0:00
9/6/21 0:00
9/7/21 0:00
Date
Modeled
Observed

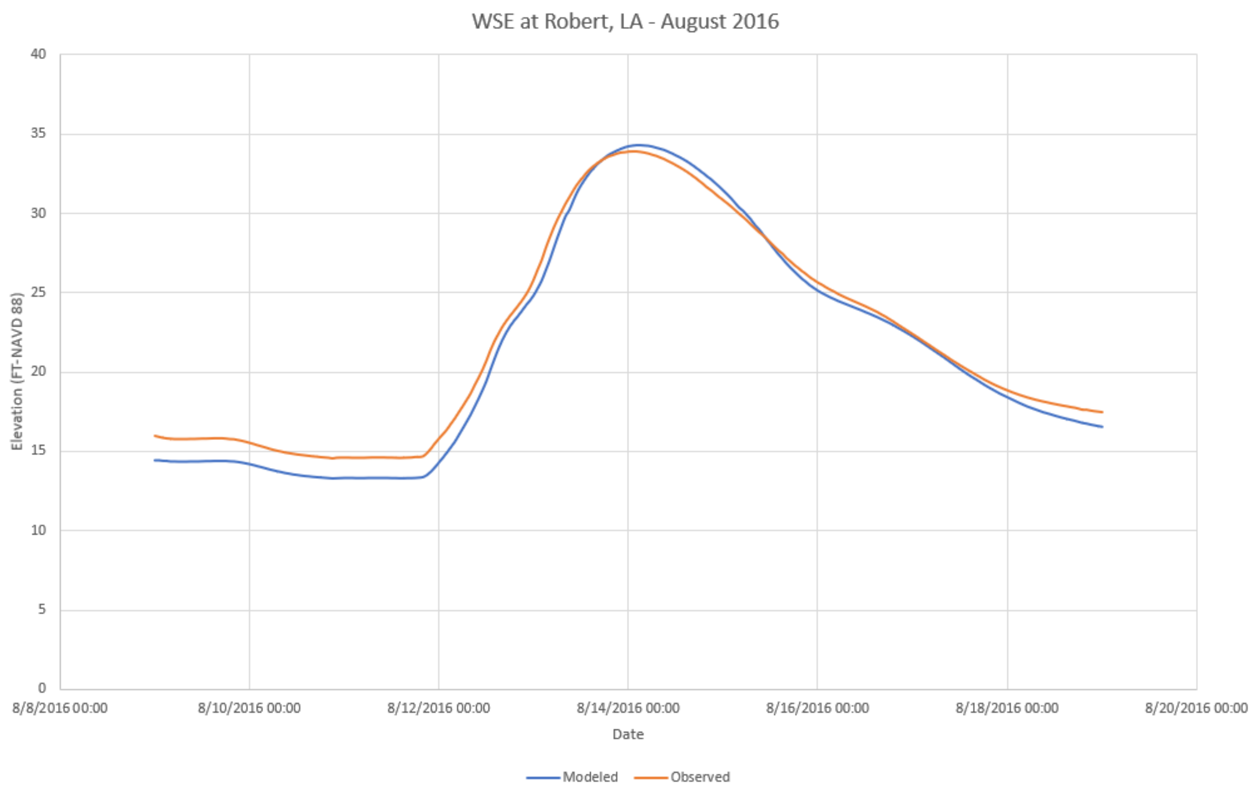

WSE at Kentwood, LA - January 2013
Elevation (FT-NAVD 88)
194
192
190
188
186
184
182
1/4/13 0:00
1/6/13 0:00
1/8/13 0:00
1/10/13 0:00
1/12/13 0:00
1/14/13 0:00
1/16/13 0:00
1/18/13 0:00
1/20/13 0:00
1/22/13 0:00
1/24/13 0:00
Date
Modeled
Observed

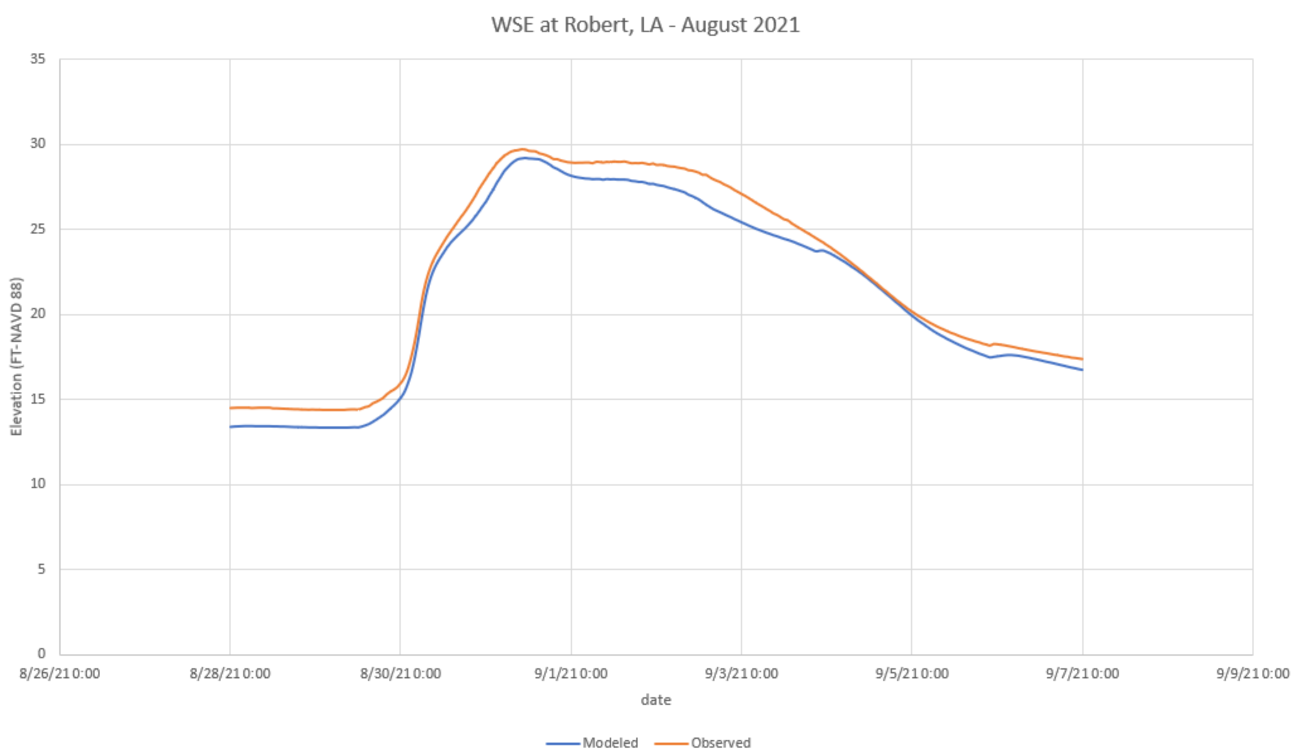

WSE at Amite, LA - March 2016
Elevation (FT-NAVD 88)
110
105
100
95
90
85
80
75
3/8/2016 00:00
3/9/2016 00:00
3/10/2016 00:00
3/11/2016 00:00
3/12/2016 00:00
3/13/2016 00:00
3/14/2016 00:00
3/15/2016 00:00
3/16/2016 00:00
3/17/2016 00:00
Date
Modeled
Observed

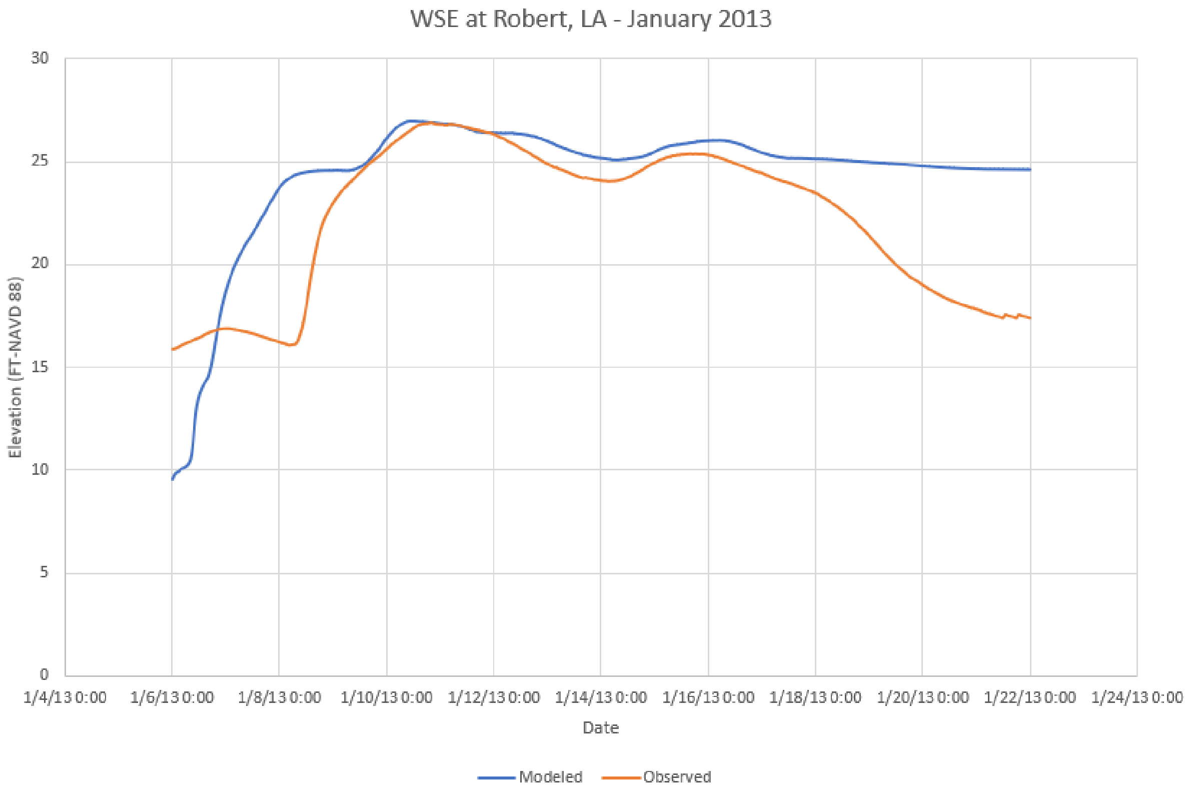

WSE at Amite, LA - August 2016
Elevation (FT-NAVD 88)
115
110
105
100
95
90
85
80
8/8/2016 00:00
8/9/2016 00:00
8/10/2016 00:00
8/11/2016 00:00
8/12/2016 00:00
8/13/2016 00:00
8/14/2016 00:00
8/15/2016 00:00
8/16/2016 00:00
8/17/2016 00:00
8/18/2016 00:00
8/19/2016 00:00
Date
Modeled
Observed

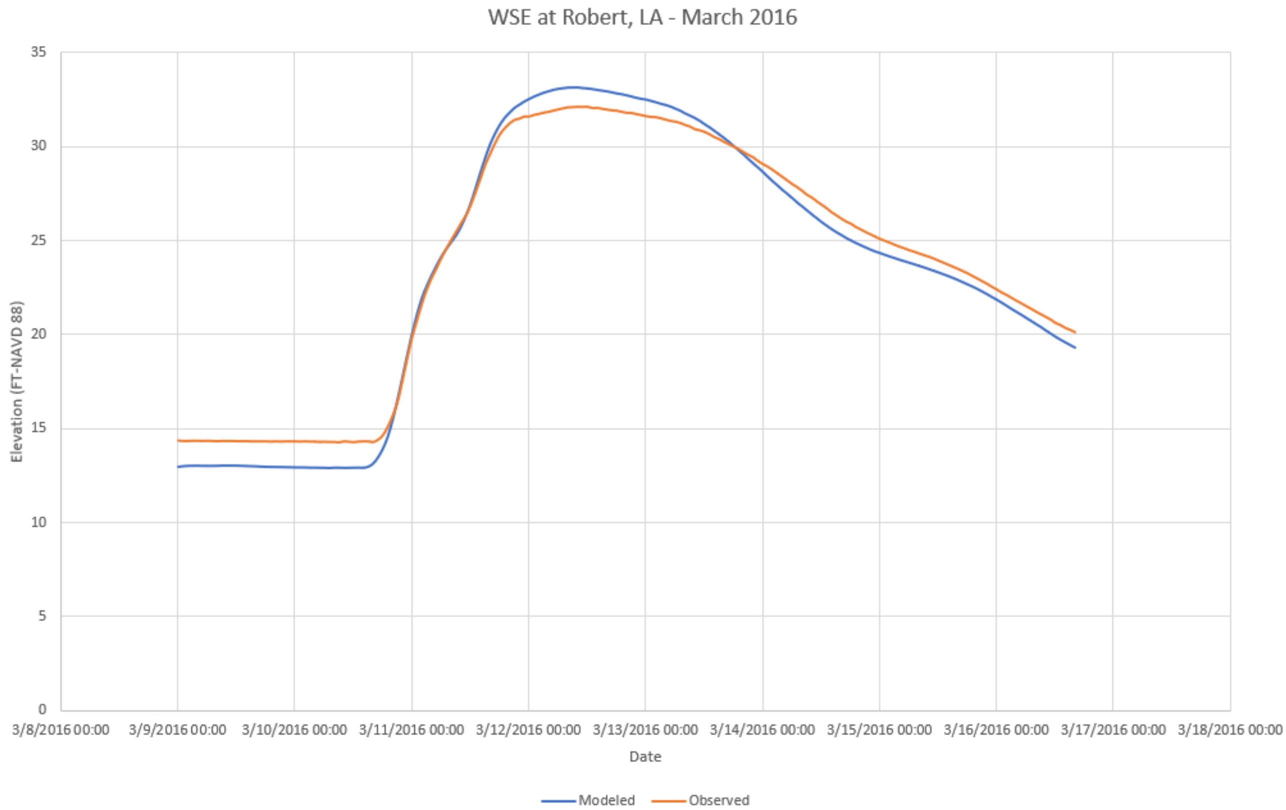

WSE at Amite, LA - August 2021
Elevation (FT-NAVD 88)
105
100
95
90
85
80
8/27/21 0:00
8/28/21 0:00
8/29/21 0:00
8/30/21 0:00
8/31/21 0:00
9/1/21 0:00
9/2/21 0:00
9/3/21 0:00
9/4/21 0:00
9/5/21 0:00
9/6/21 0:00
9/7/21 0:00
Date
Modeled
Observed

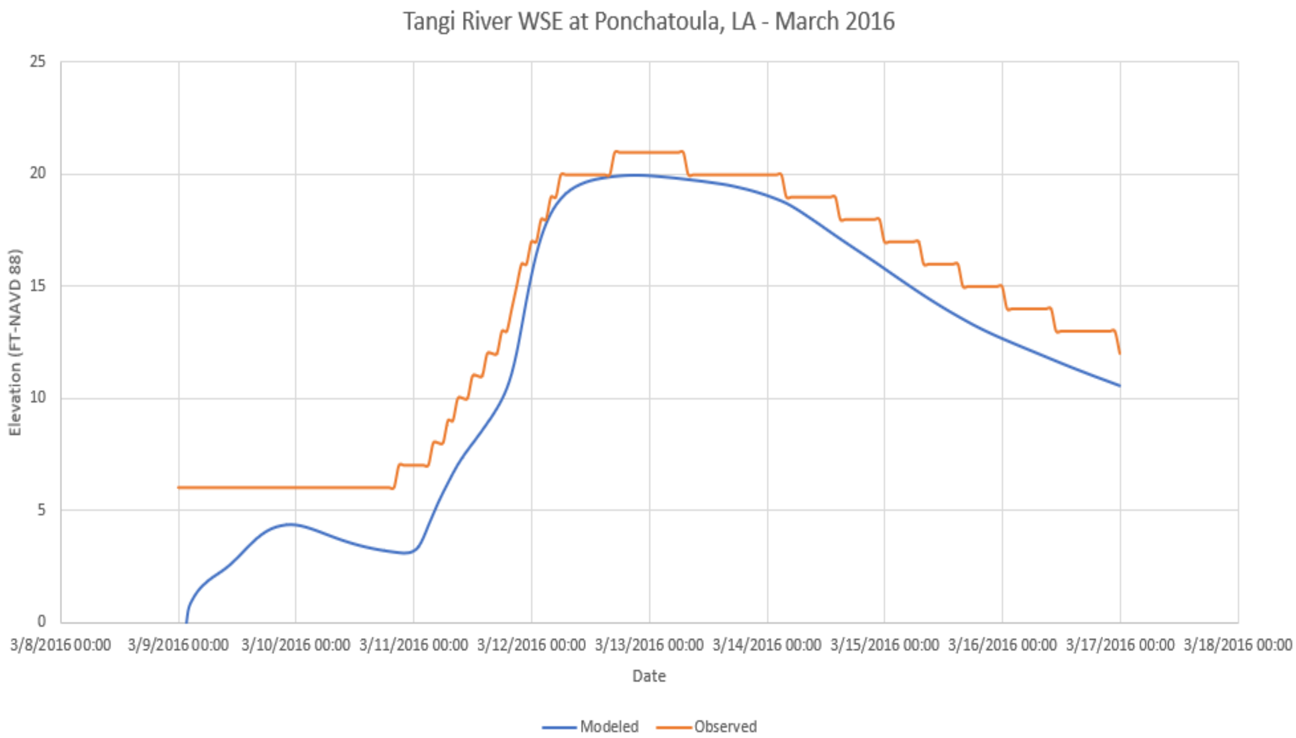
Lower Tangipahoa RAS Stage Calibration

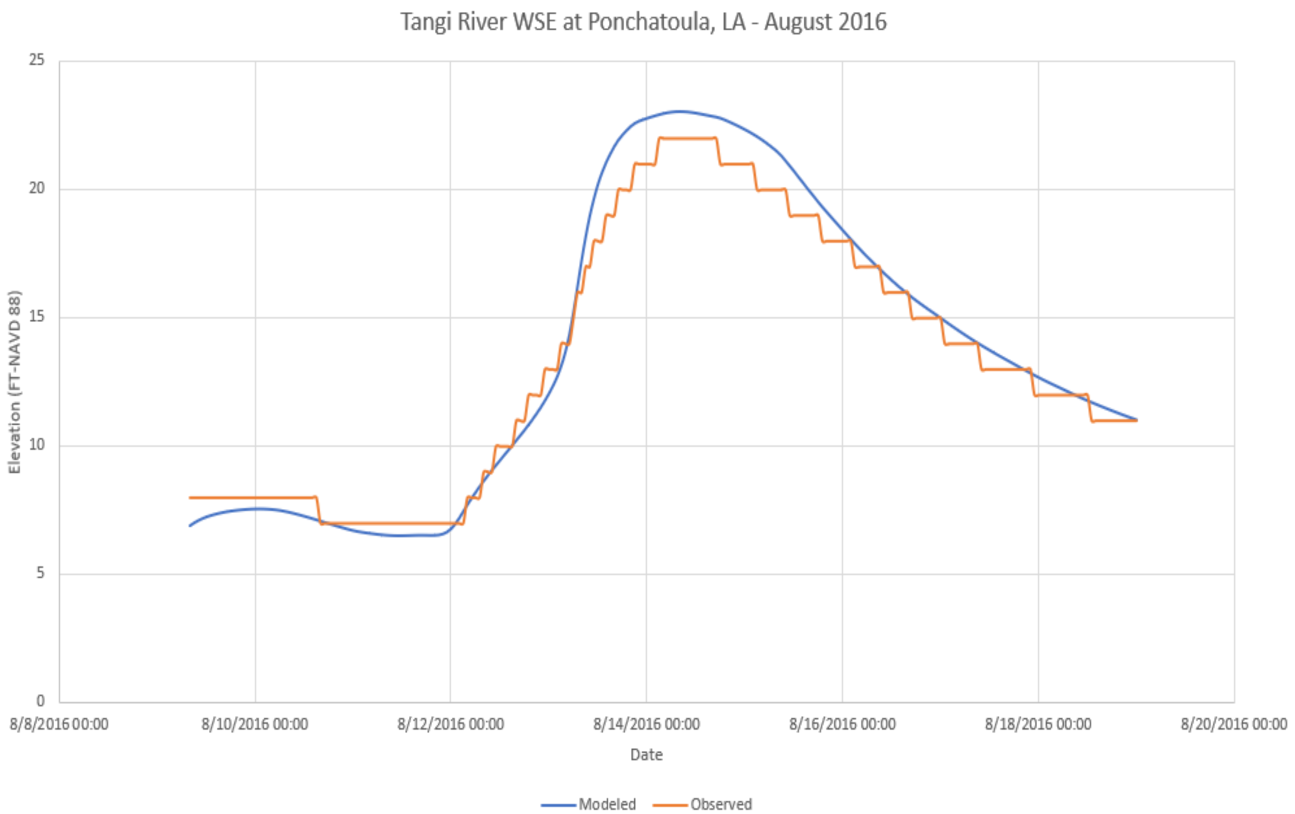


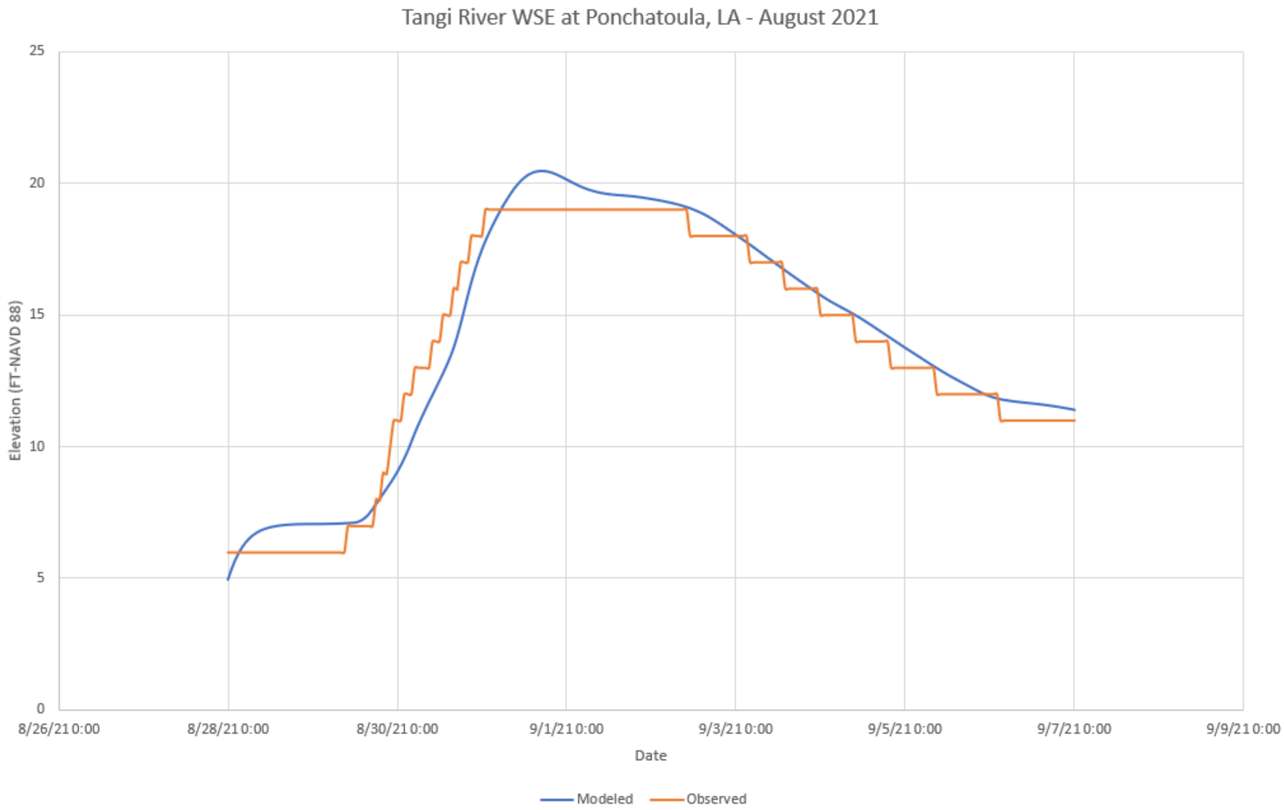



WSE at Robert, LA - January 2013
Elevation (FT-NAVD 88)
30
25
20
15
10
5
0
1/4/13 0:00
1/6/13 0:00
1/8/13 0:00
1/10/13 0:00
1/12/13 0:00
1/14/13 0:00
1/16/13 0:00
1/18/13 0:00
1/20/13 0:00
1/22/13 0:00
1/24/13 0:00
Date
Modeled
Observed

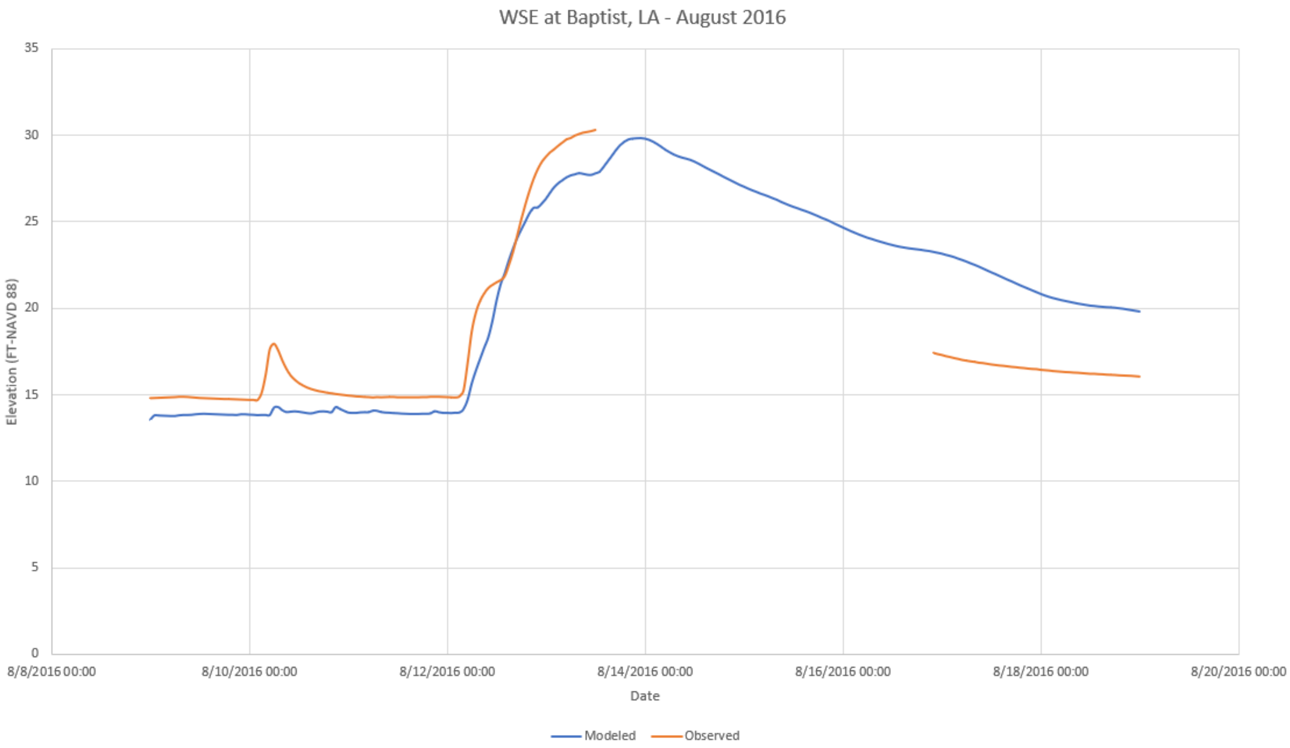

WSE at Robert, LA - March 2016
Elevation (FT-NAVD 88)
35
30
25
20
15
10
5
0
3/8/2016 00:00
3/9/2016 00:00
3/10/2016 00:00
3/11/2016 00:00
3/12/2016 00:00
3/13/2016 00:00
3/14/2016 00:00
3/15/2016 00:00
3/16/2016 00:00
3/17/2016 00:00
3/18/2016 00:00
Date
Modeled
Observed

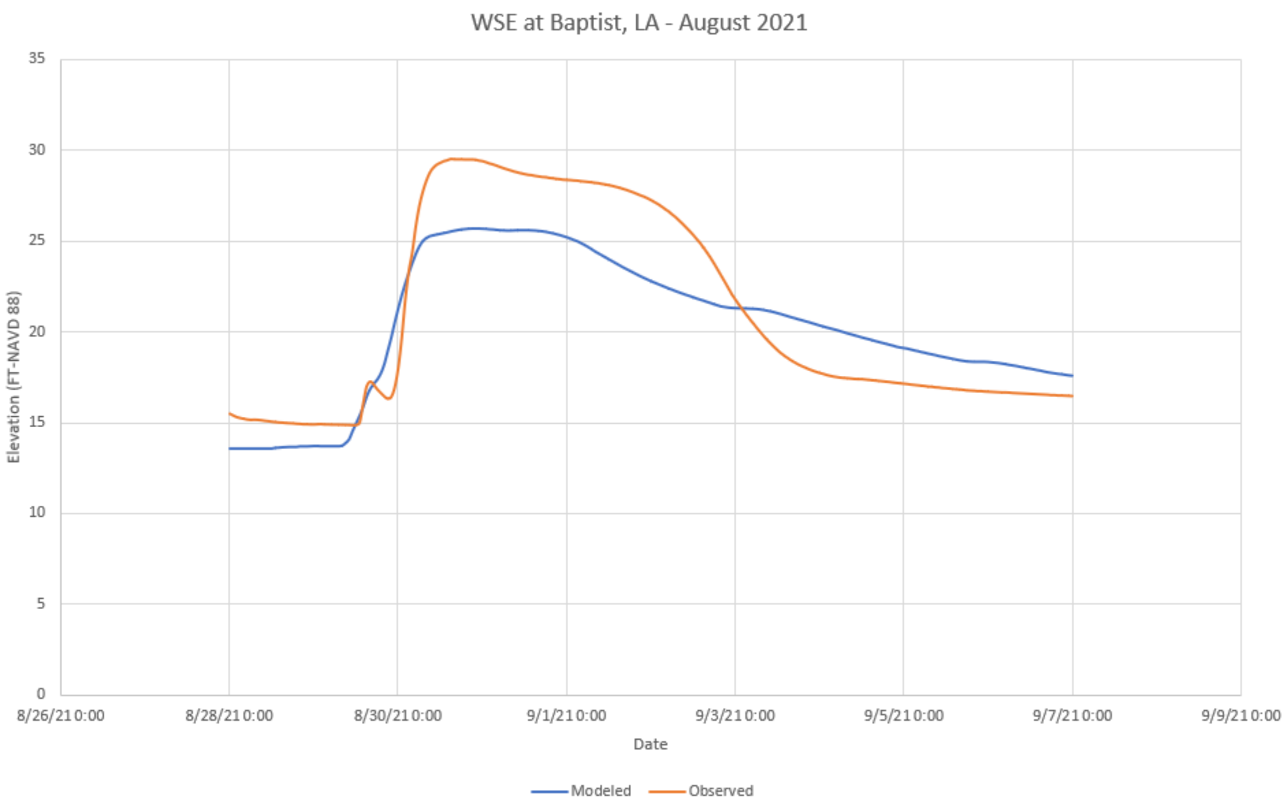

Tangi River WSE at Ponchatoula, LA - March 2016
Elevation (FT-NAVD 88)
25
20
15
10
5
0
3/8/2016 00:00
3/9/2016 00:00
3/10/2016 00:00
3/11/2016 00:00
3/12/2016 00:00
3/13/2016 00:00
3/14/2016 00:00
3/15/2016 00:00
3/16/2016 00:00
3/17/2016 00:00
3/18/2016 00:00
Date
Modeled
Observed

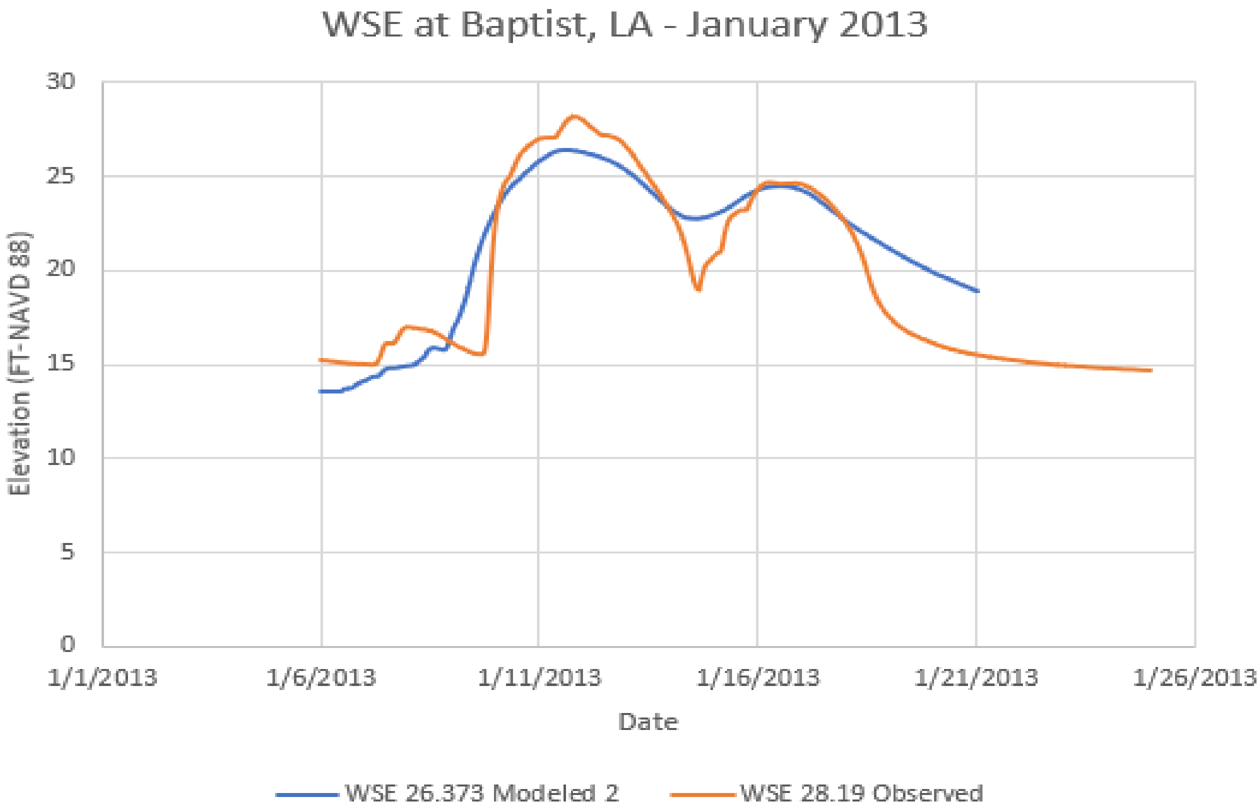

Tangi River WSE at Ponchatoula, LA - August 2016
Elevation (FT-NAVD 88)
25
20
15
10
5
0
8/8/2016 00:00
8/10/2016 00:00
8/12/2016 00:00
8/14/2016 00:00
8/16/2016 00:00
8/18/2016 00:00
8/20/2016 00:00
Date
Modeled
Observed


Tangi River WSE at Ponchatoula, LA - August 2021
Elevation (FT-NAVD 88)
25
20
15
10
5
0
8/26/21 0:00
8/28/21 0:00
8/30/21 0:00
9/1/21 0:00
9/3/21 0:00
9/5/21 0:00
9/7/21 0:00
9/9/21 0:00
Date
Modeled
Observed

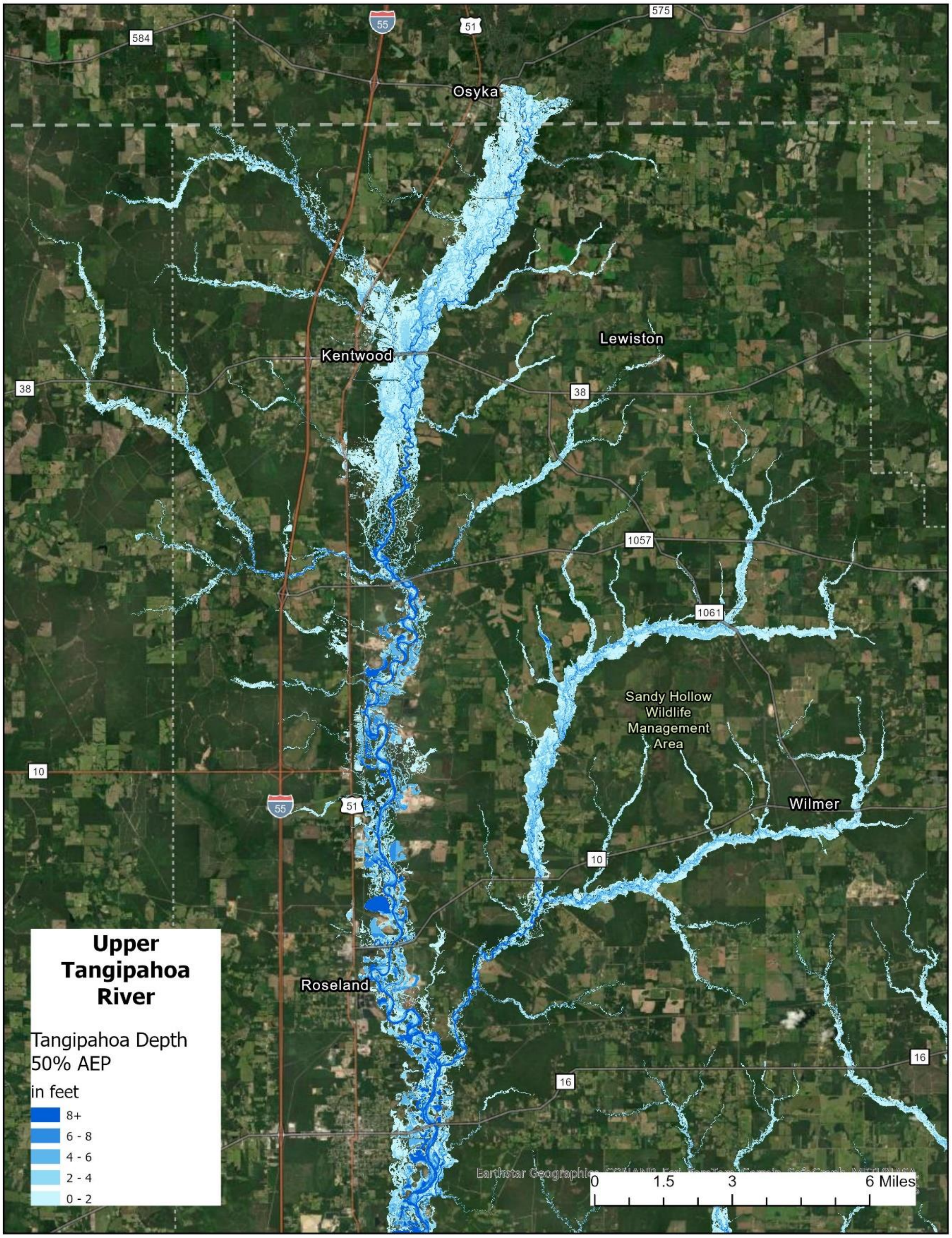
Natalbany River RAS Stage Calibration

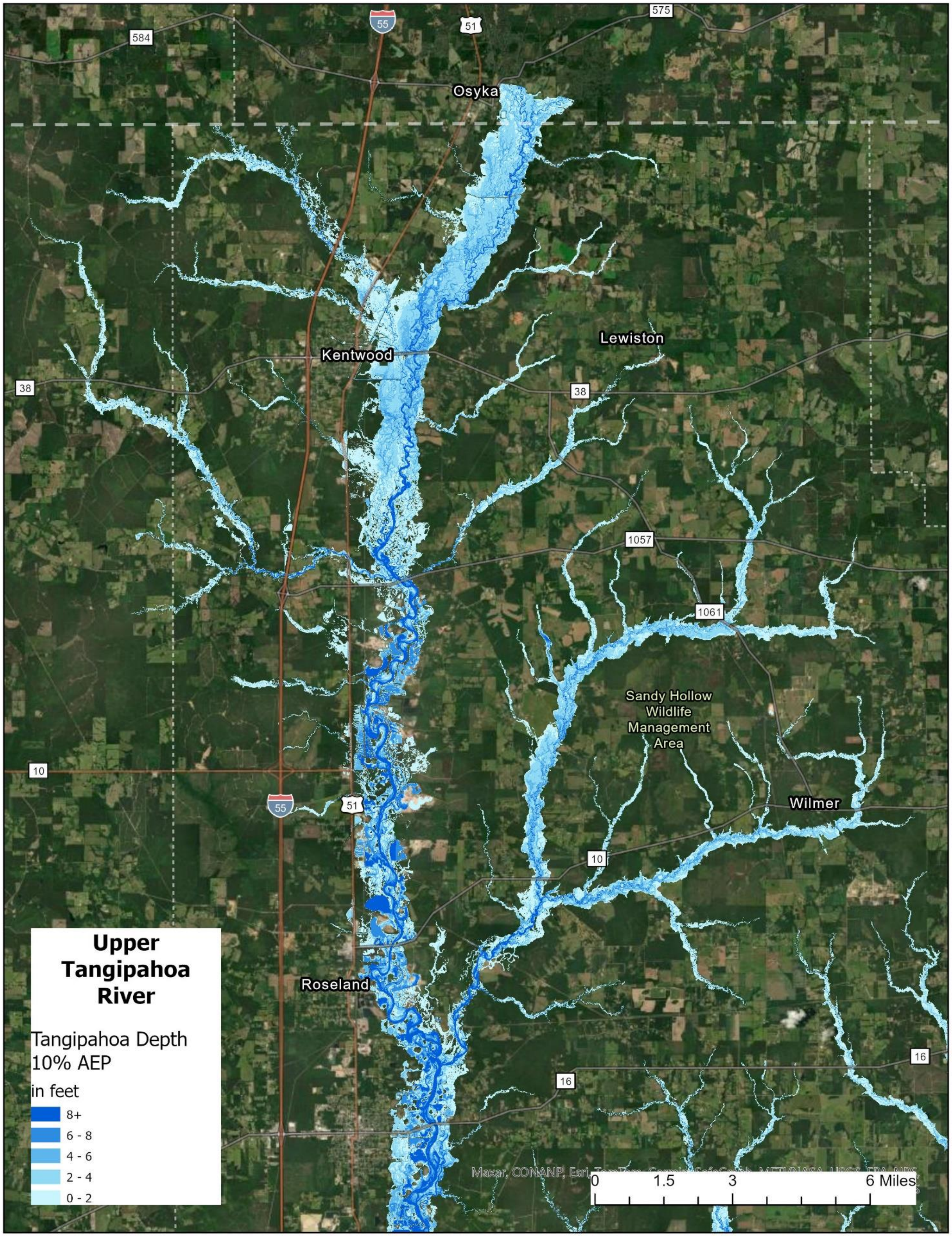


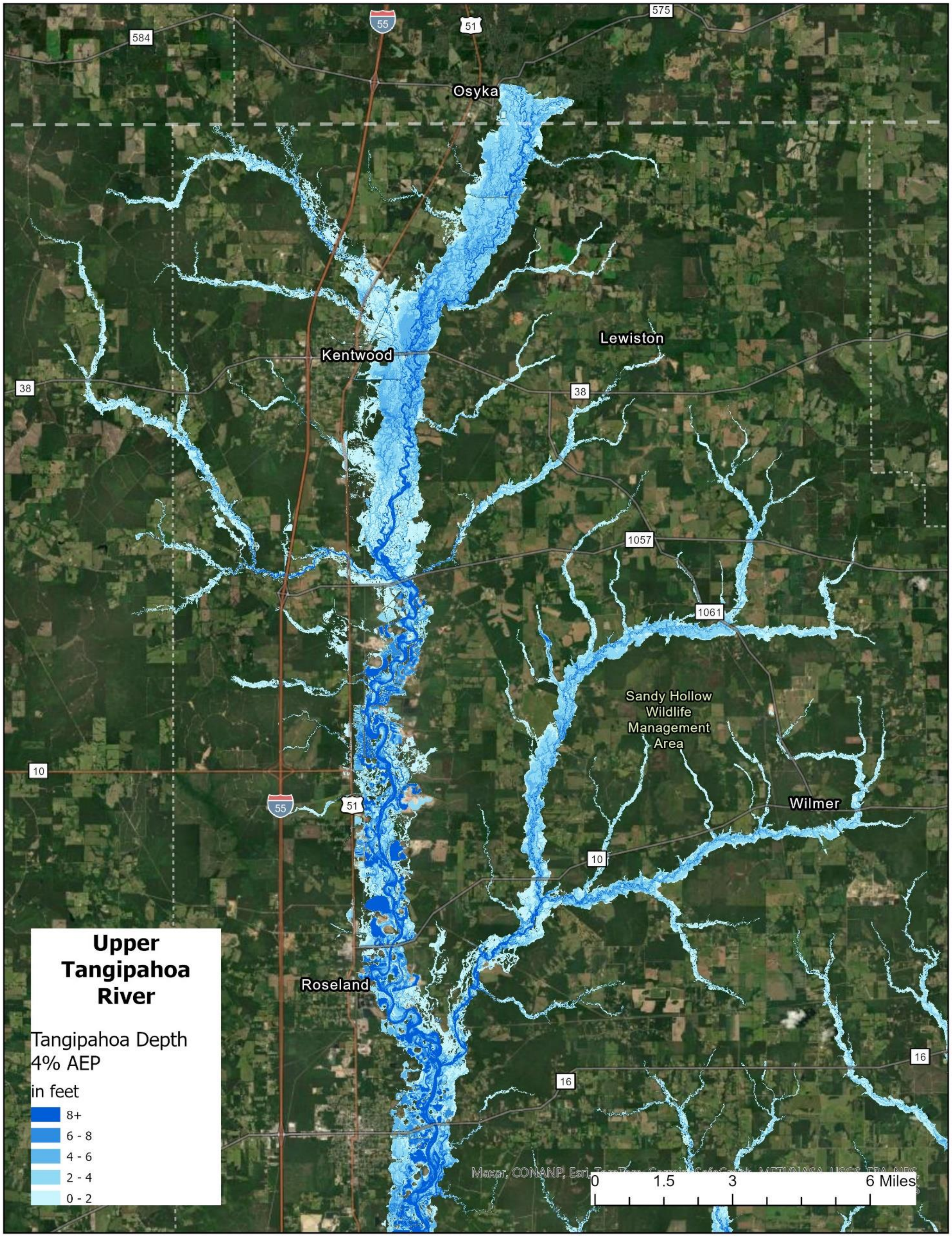


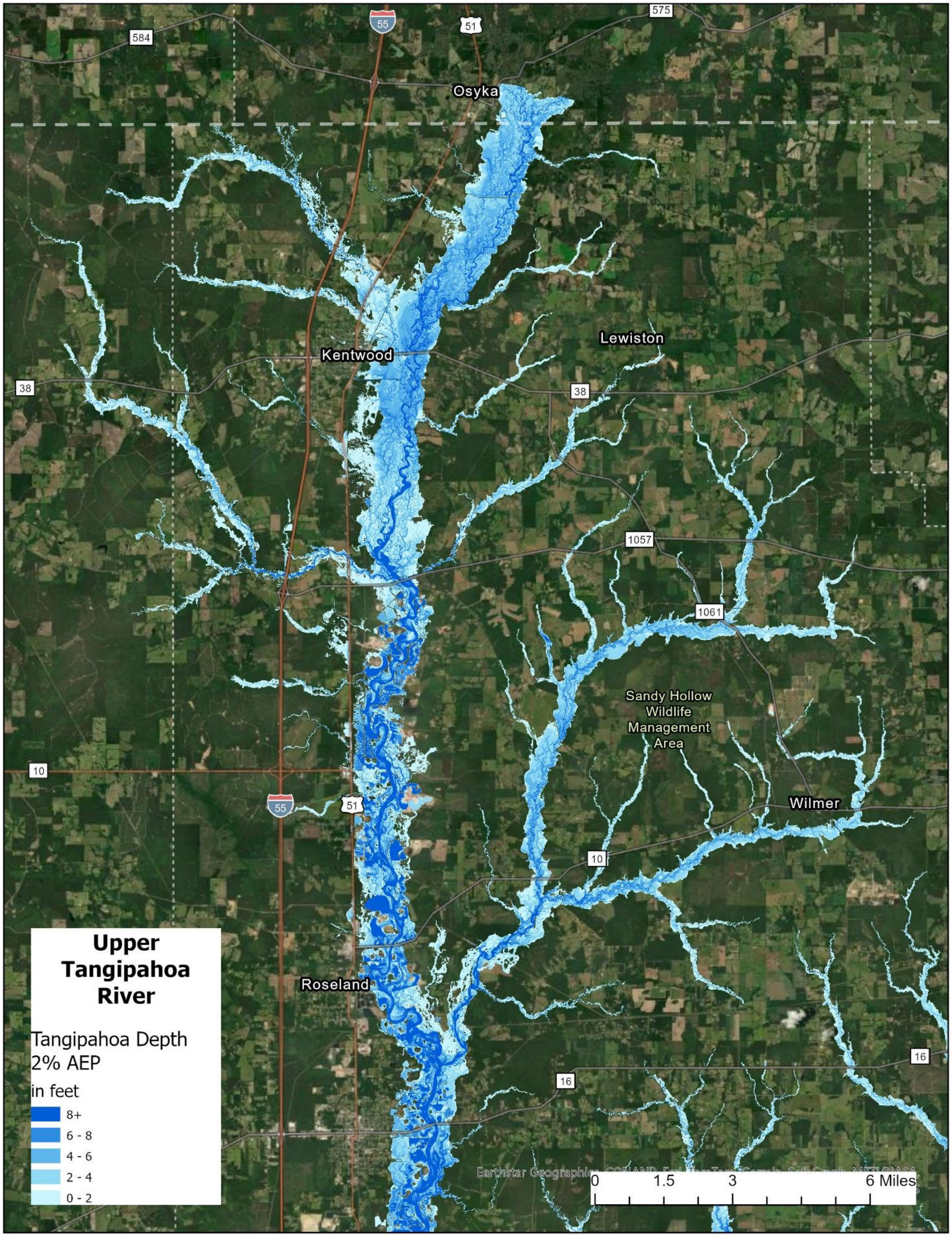

WSE at Baptist, LA - January 2013
Elevation (FT-NAVD 88)
30
25
20
15
10
5
0
1/1/2013
1/6/2013
1/11/2013
1/16/2013
1/21/2013
1/26/2013
Date
WSE 26.373 Modeled 2
WSE 28.19 Observed

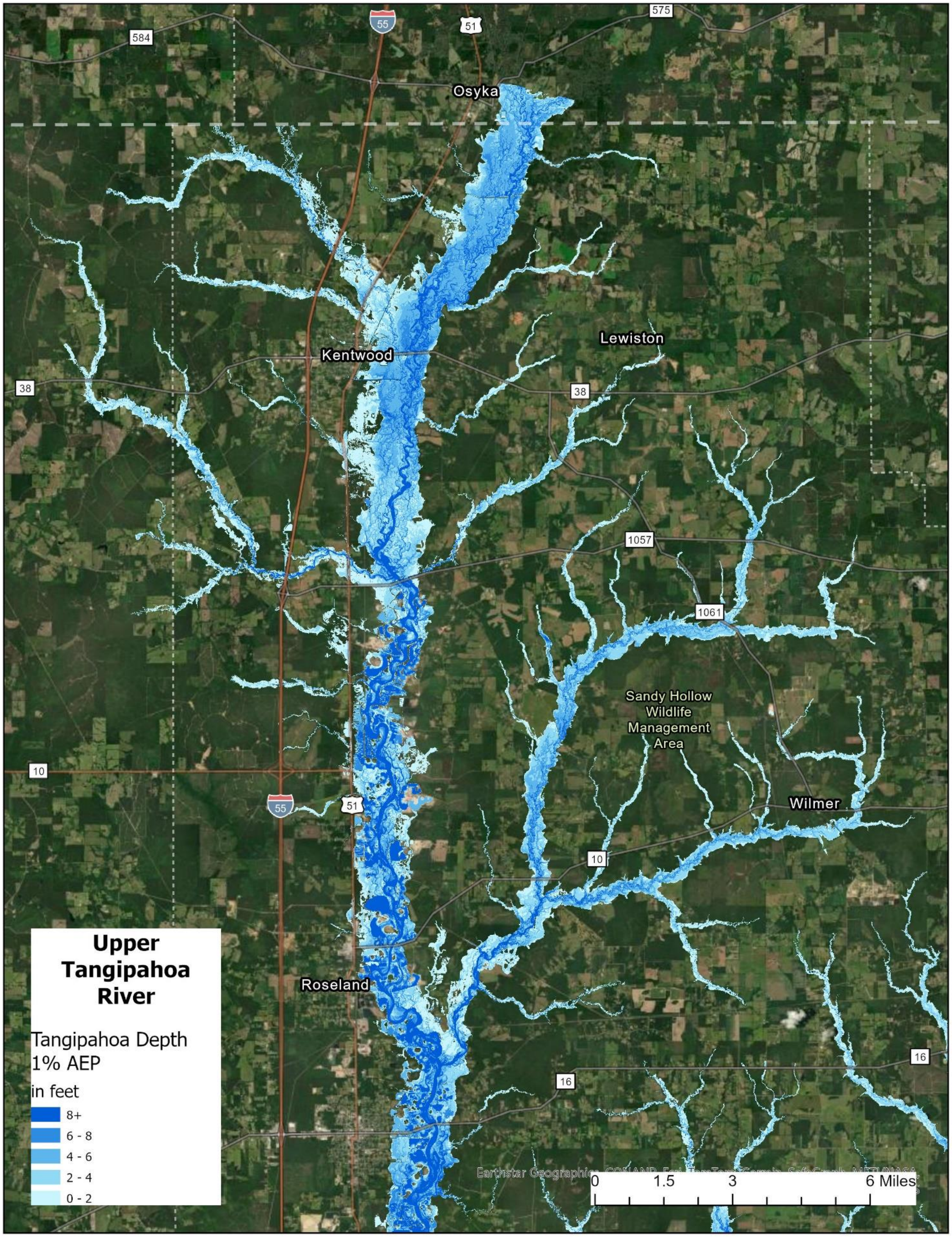
Annex D: Frequency Flood Depth Maps

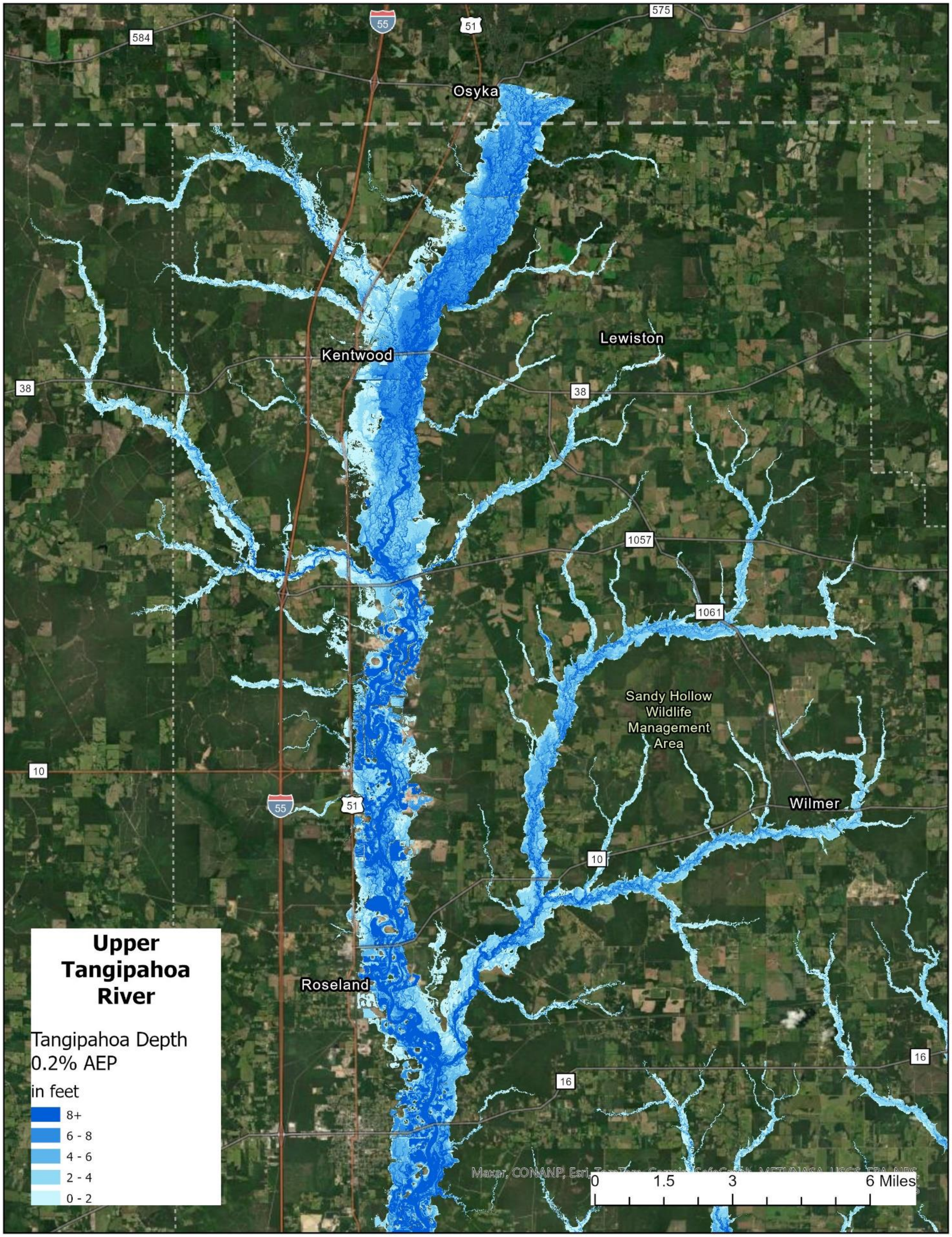


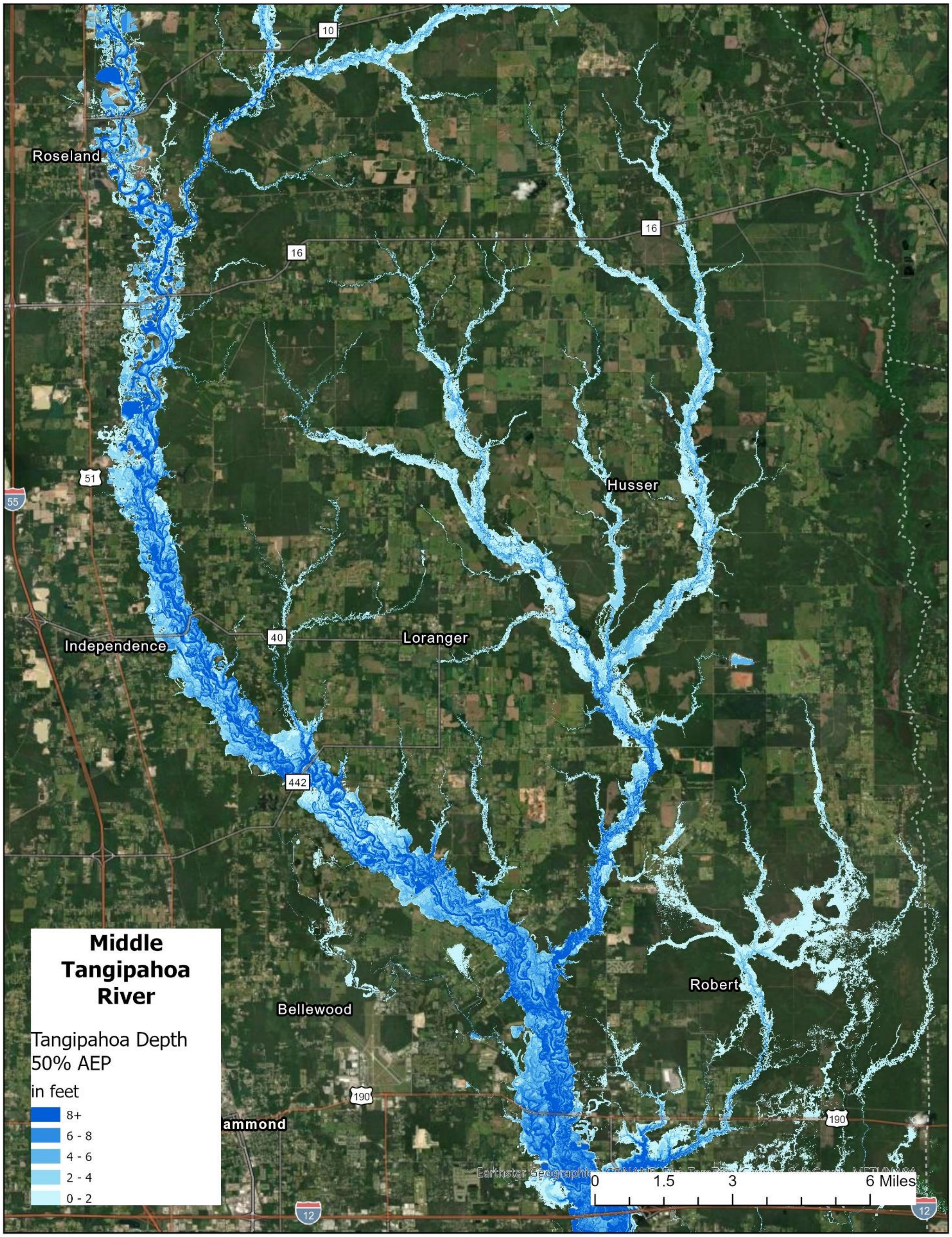

575
55
51
584
Osyka
Kentwood
Lewiston
38
38
1057
1061
Sandy Hollow
Wildlife
Management
Area
10
55
51
Wilmer
10
Roseland
16
16
Upper
Tangipahoa
River
Tangipahoa Depth
10% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0
1.5
3
6 Miles

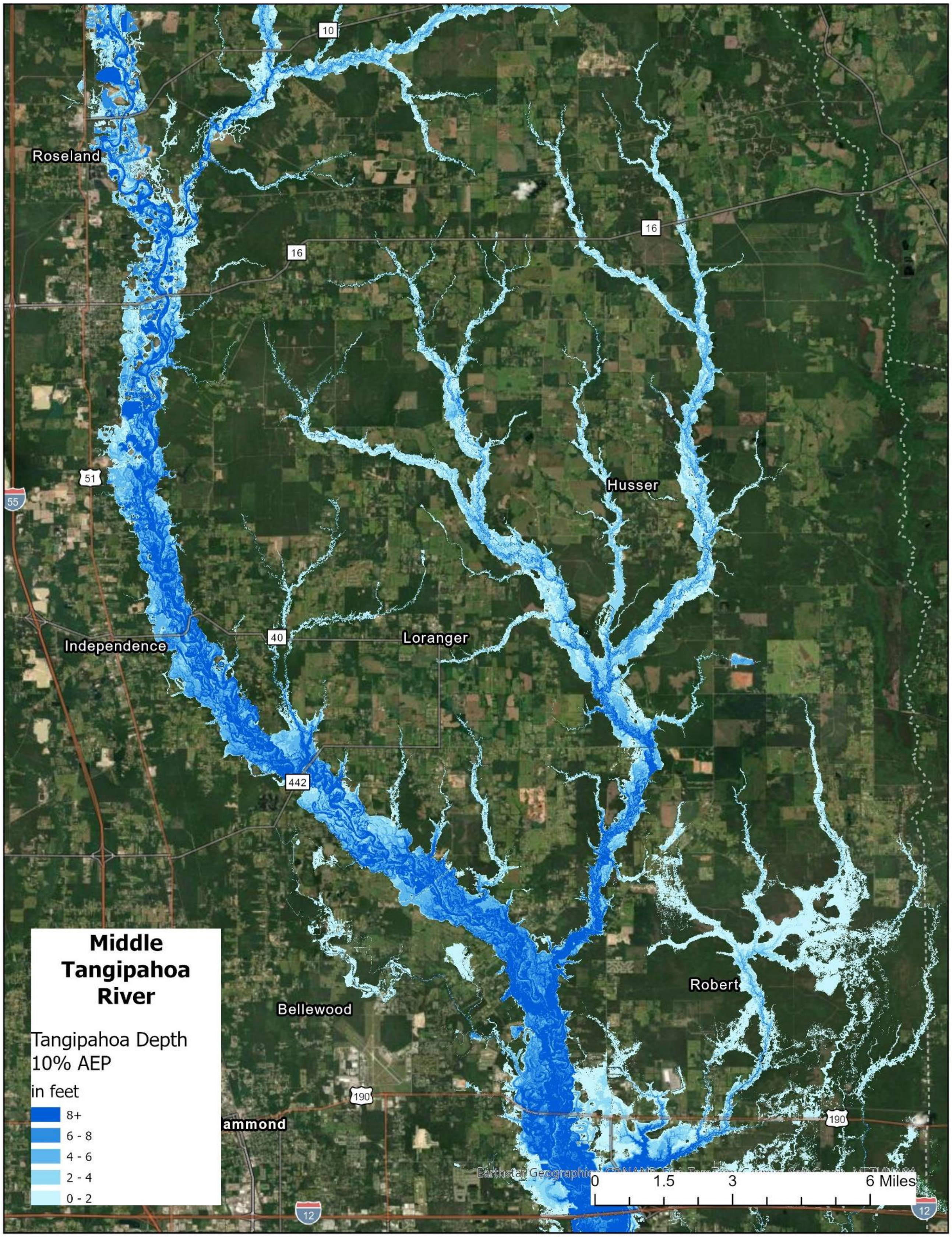

Upper Tangipahoa River
Tangipahoa Depth
4% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Osyka
Kentwood
Lewiston
Sandy Hollow Wildlife Management Area
Wilmer
Roseland
584
55
51
575
38
38
1057
1061
10
10
55
51
16
16
0
1.5
3
6 Miles

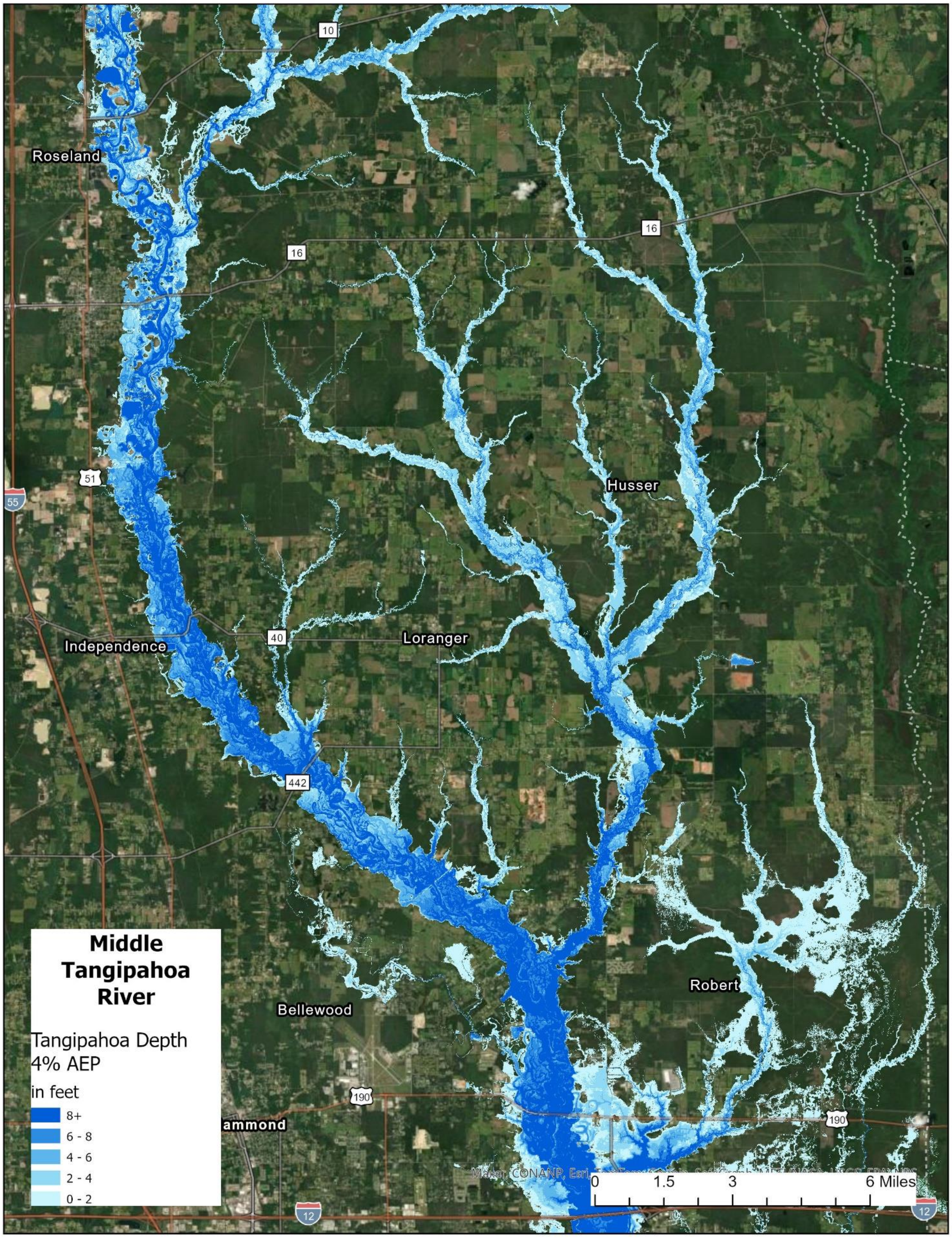

Upper Tangipahoa River
Tangipahoa Depth
2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Osyka
Kentwood
Lewiston
Sandy Hollow Wildlife Management Area
Wilmer
Roseland
575
584
55
51
38
1057
1061
10
16
0
1.5
3
6 Miles

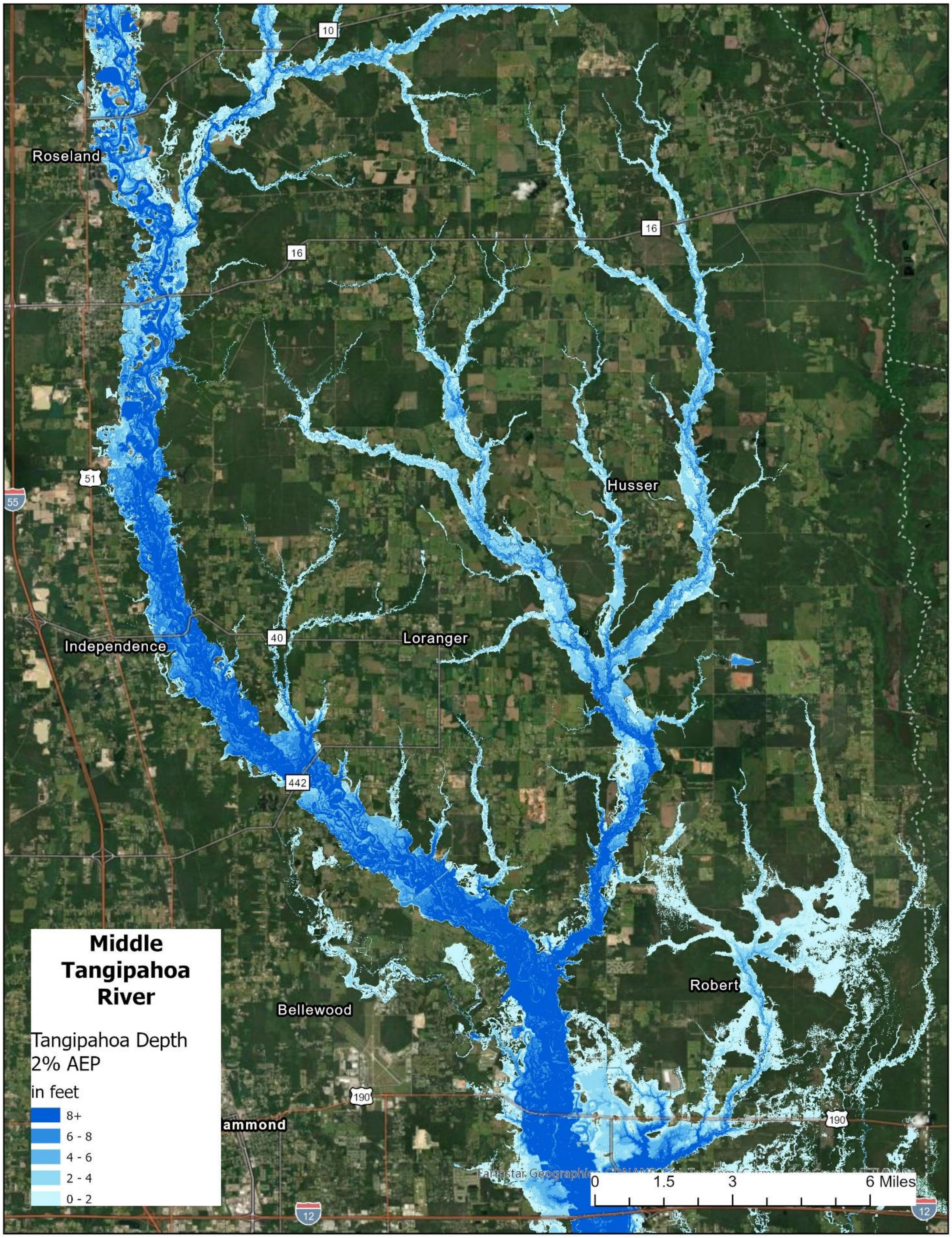

Upper Tangipahoa River
Tangipahoa Depth 1% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Osyka
Kentwood
Lewiston
Sandy Hollow Wildlife Management Area
Wilmer
Roseland
584
55
51
575
38
1057
1061
10
16
0
1.5
3
6 Miles

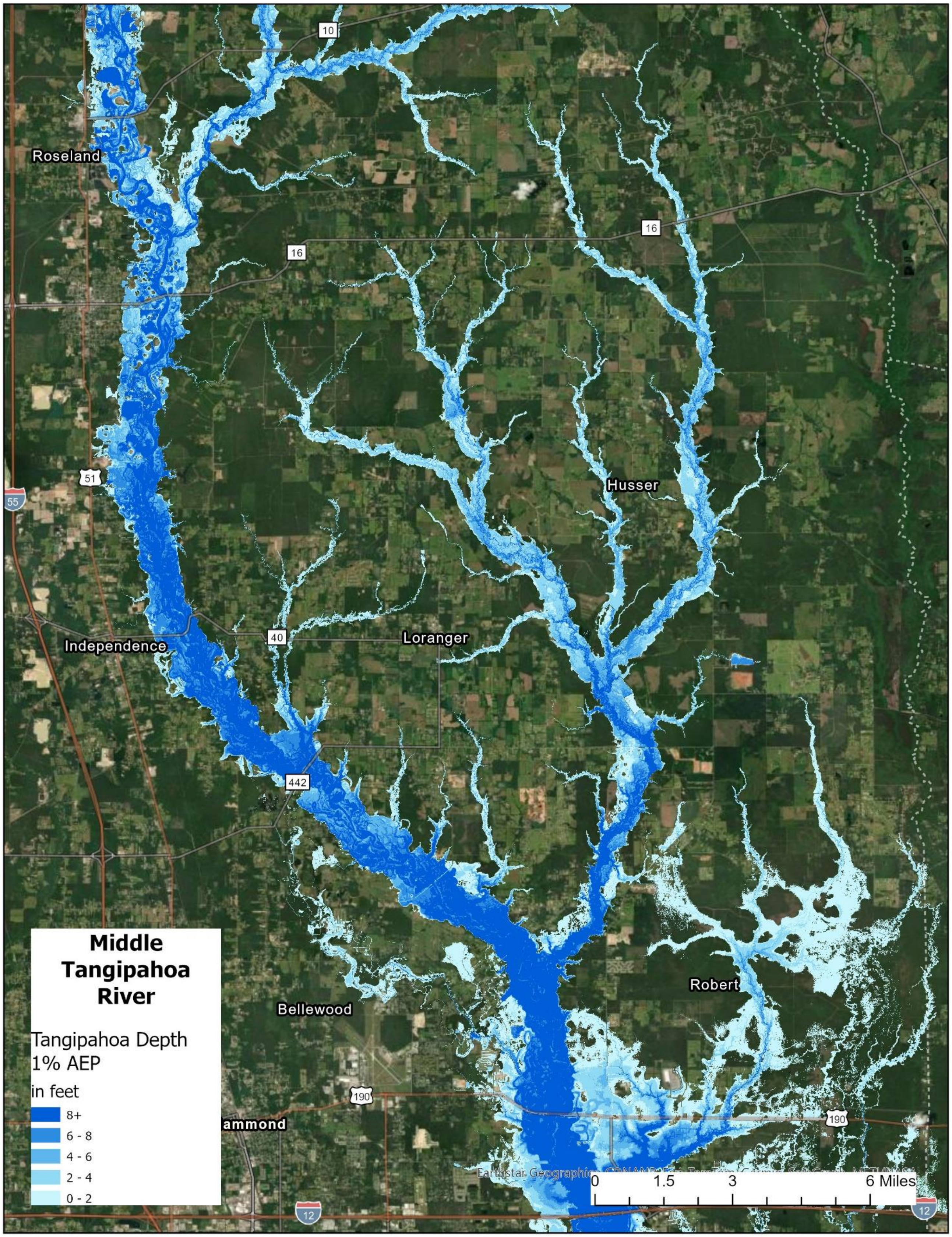

575
55
51
584
Osyka
Lewiston
Kentwood
38
38
1057
1061
Sandy Hollow Wildlife Management Area
10
55
51
Wilmer
10
Upper Tangipahoa River
Tangipahoa Depth
0.2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Roseland
16
16
0 1.5 3 6 Miles

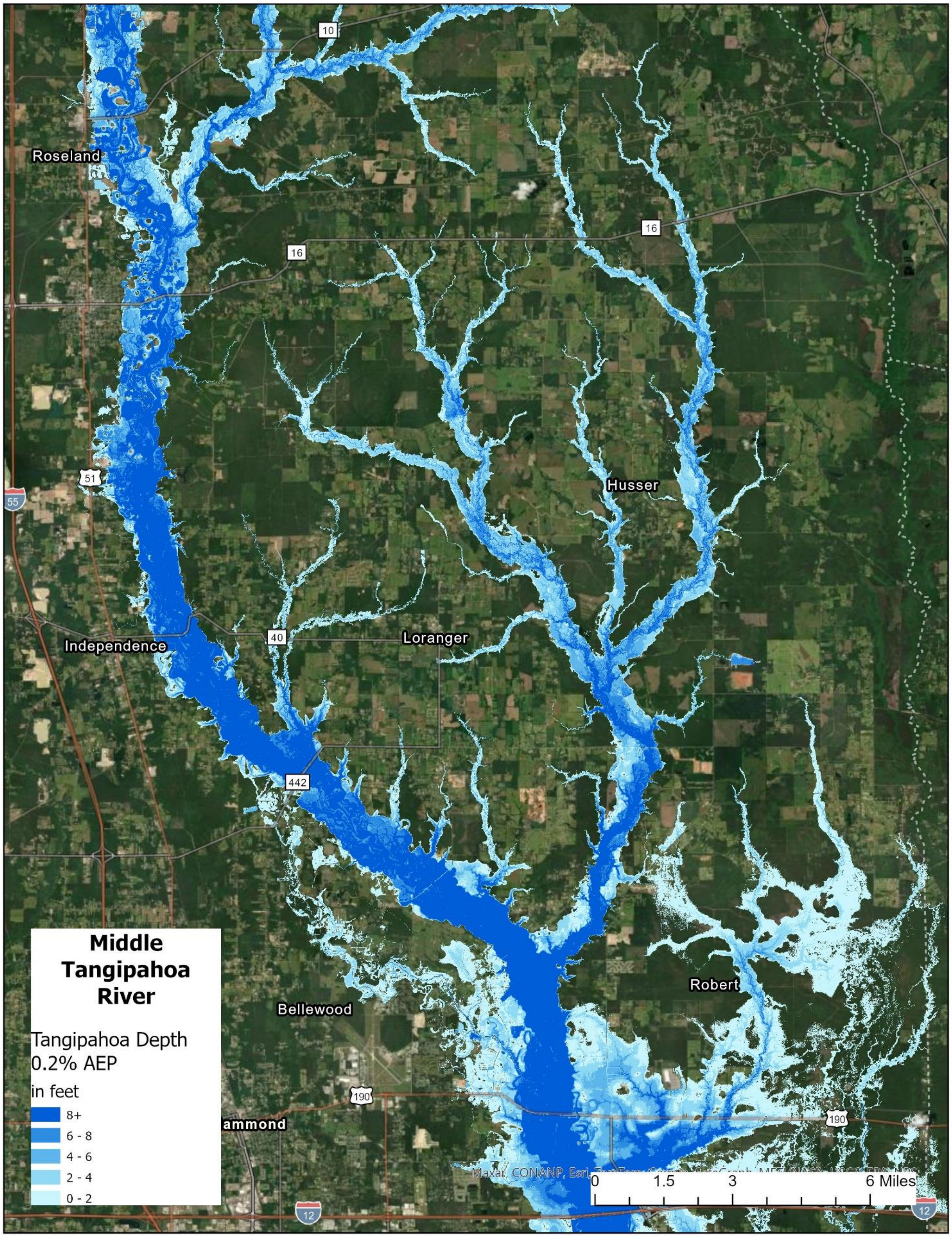

Middle Tangipahoa River
Tangipahoa Depth 50% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Roseland
Husser
Independence
Loranger
Robert
Bellewood
ammond
10
16
16
51
55
40
442
190
190
12
12
0
1.5
3
6 Miles

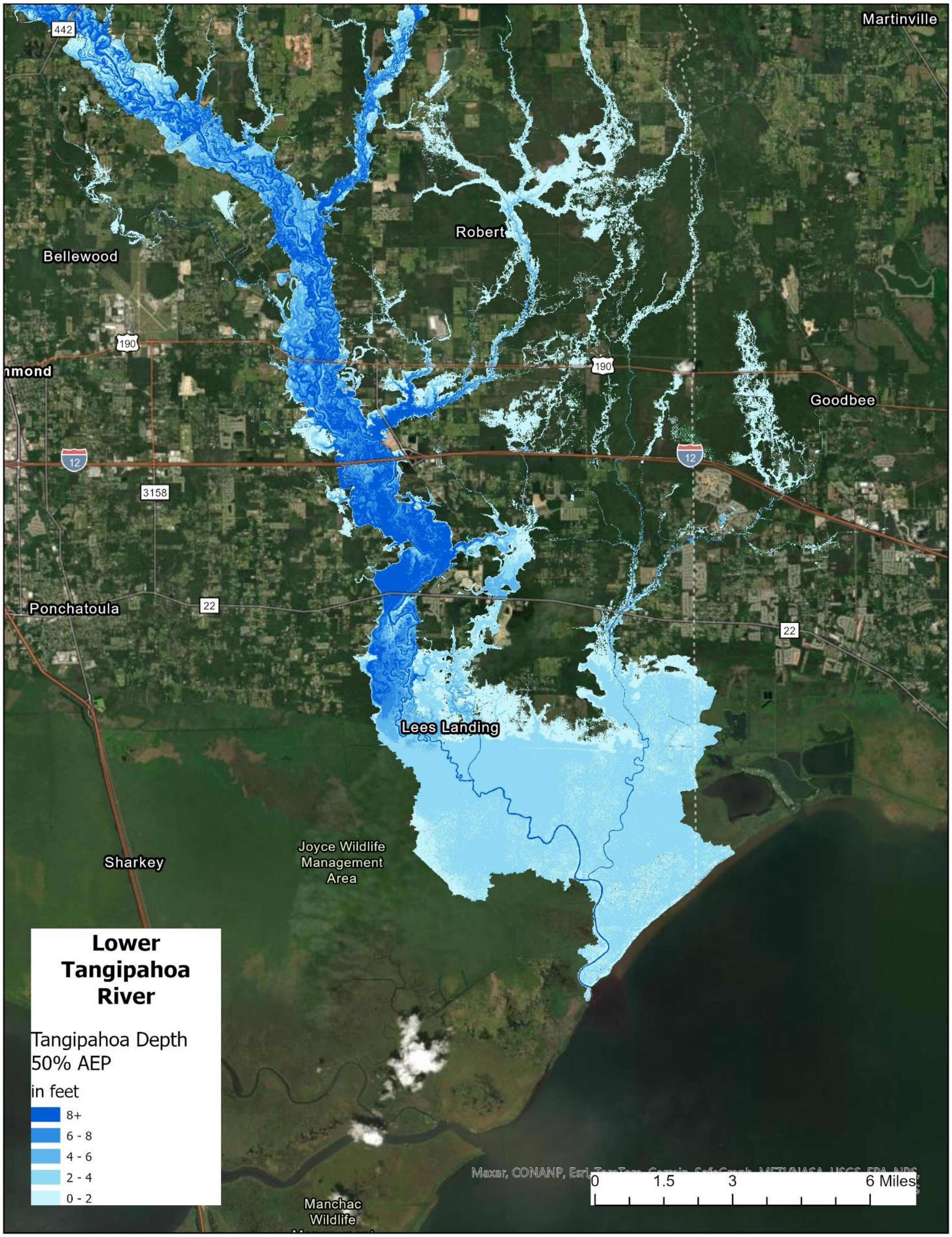

Middle Tangipahoa River
Tangipahoa Depth
10% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Roseland
Independence
Loranger
Husser
Robert
Bellewood
ammond
10
16
16
40
442
51
55
190
190
12
12
0
1.5
3
6 Miles

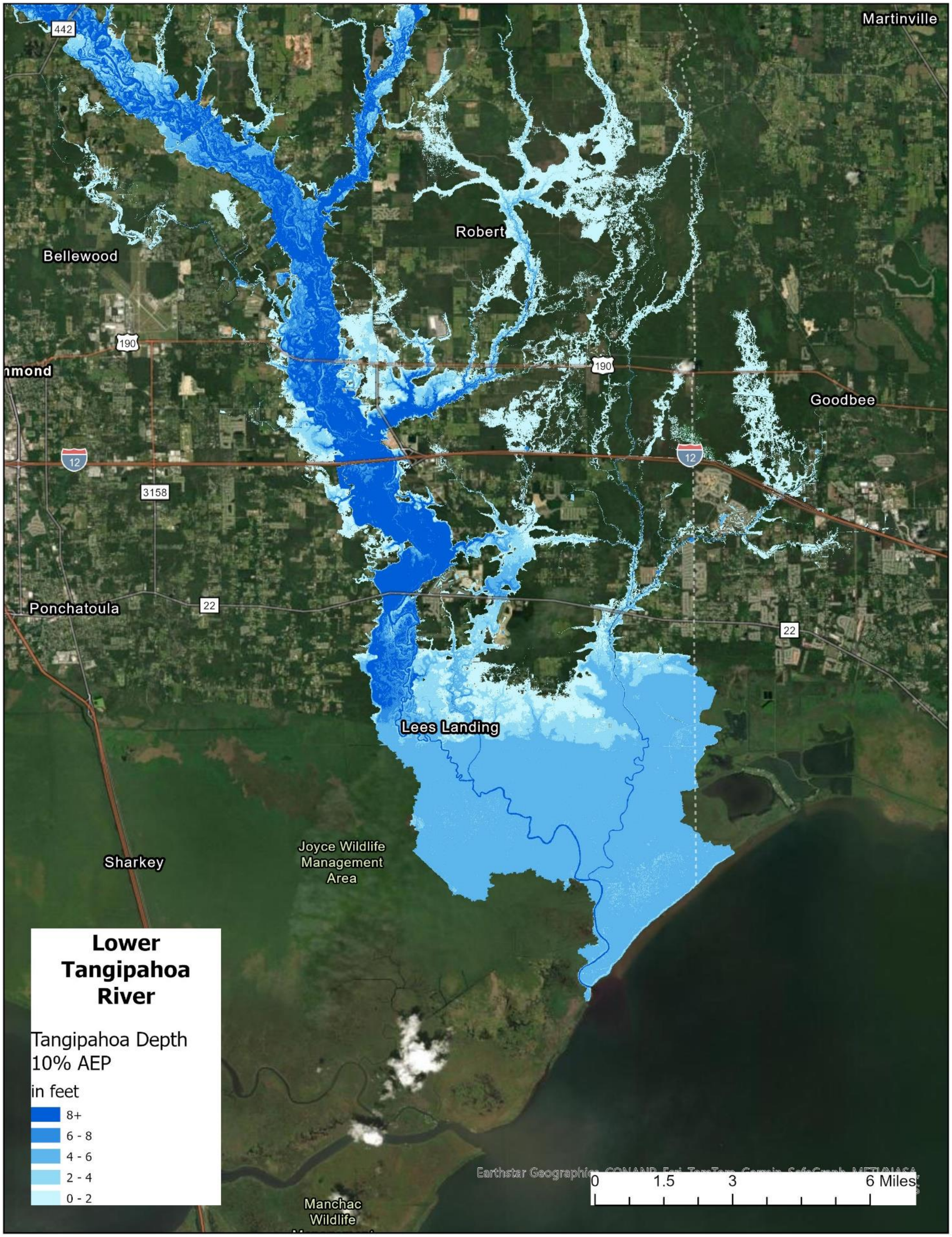

Middle Tangipahoa River
Tangipahoa Depth 4% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Roseland
Independence
Loranger
Husser
Bellewood
Robert
ammond
10
16
16
51
55
40
442
190
190
12
12
0
1.5
3
6 Miles

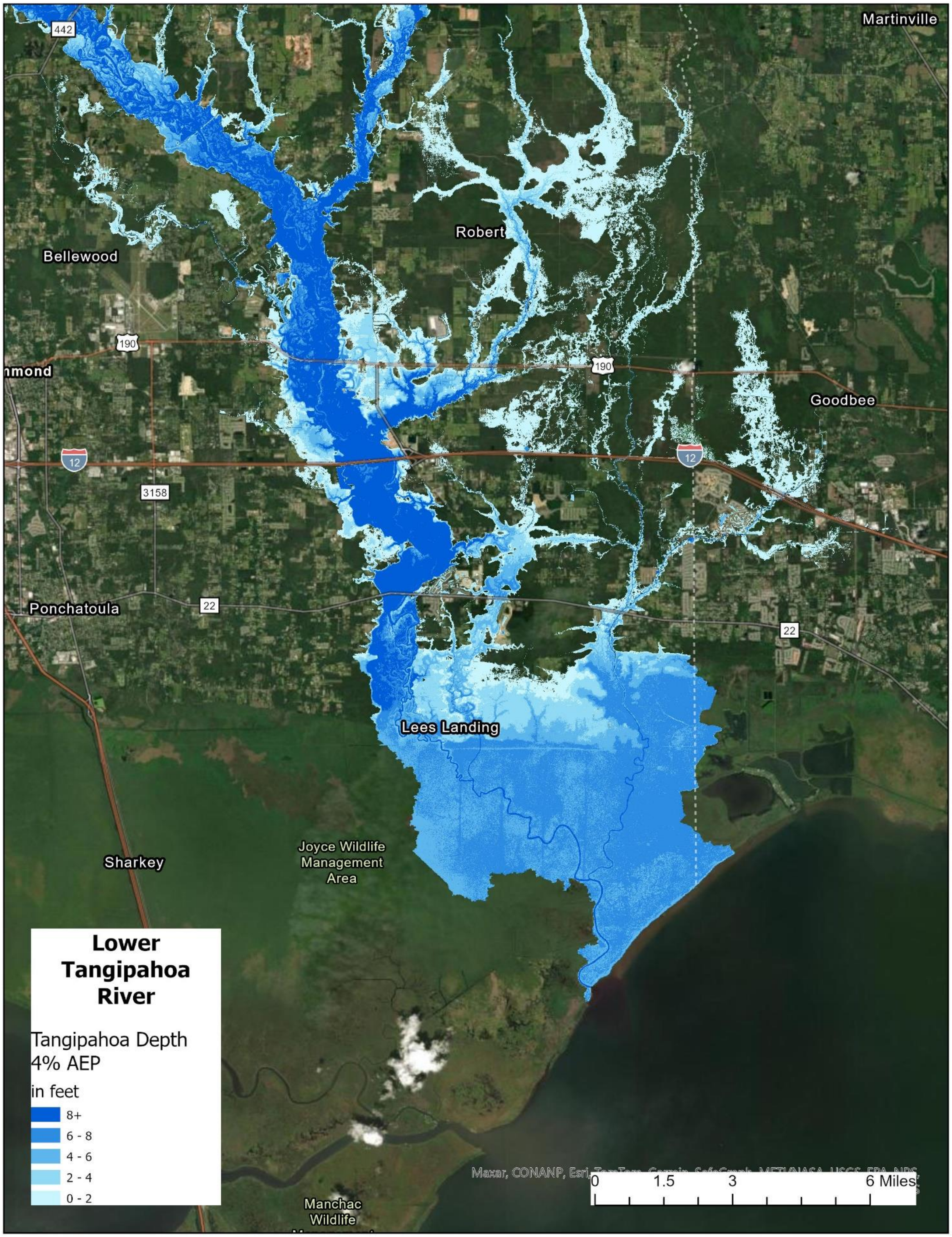

10
Roseland
16
16
51
55
Husser
Independence
40
Loranger
442
Middle Tangipahoa River
Tangipahoa Depth
2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Bellewood
Robert
190
190
ammond
12
12
0
1.5
3
6 Miles

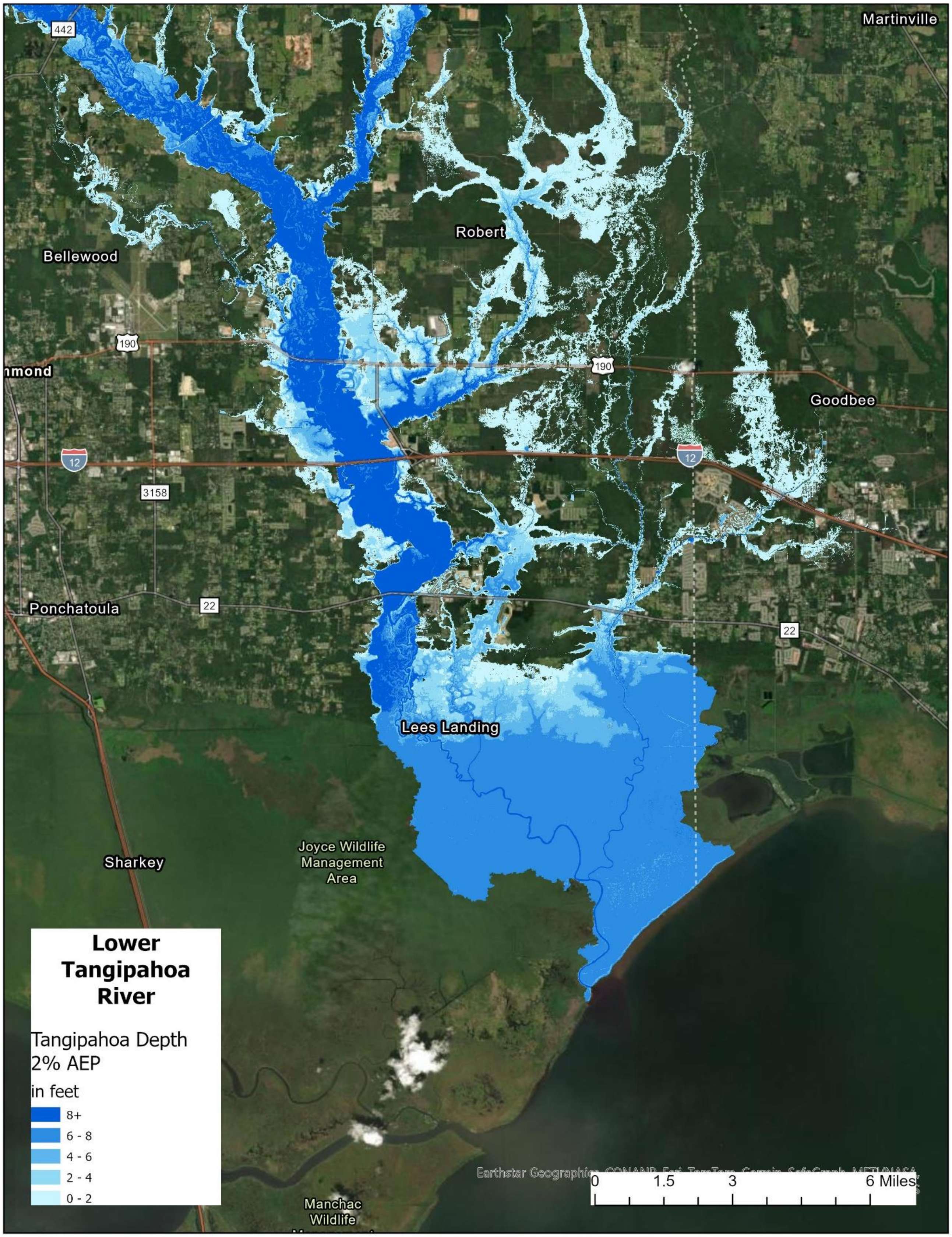

Middle Tangipahoa River
Tangipahoa Depth
1% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Roseland
Husser
Independence
Loranger
Robert
Bellewood
ammond
10
16
16
51
55
40
442
190
190
12
12
0
1.5
3
6 Miles

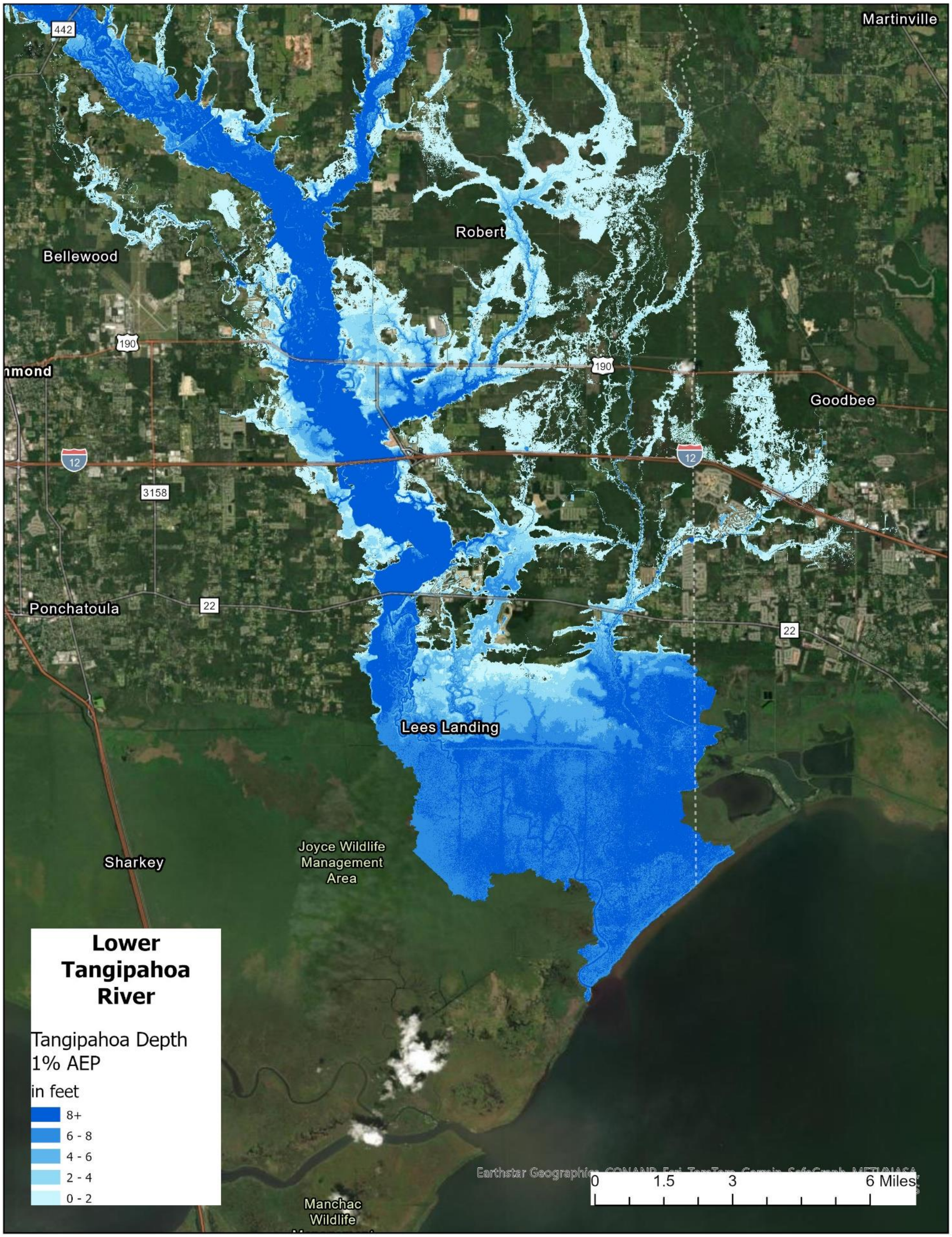

Middle Tangipahoa River
Tangipahoa Depth
0.2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Roseland
Independence
Loranger
Husser
Robert
Bellewood
ammond
10
16
16
40
442
51
55
190
190
12
12
0
1.5
3
6 Miles

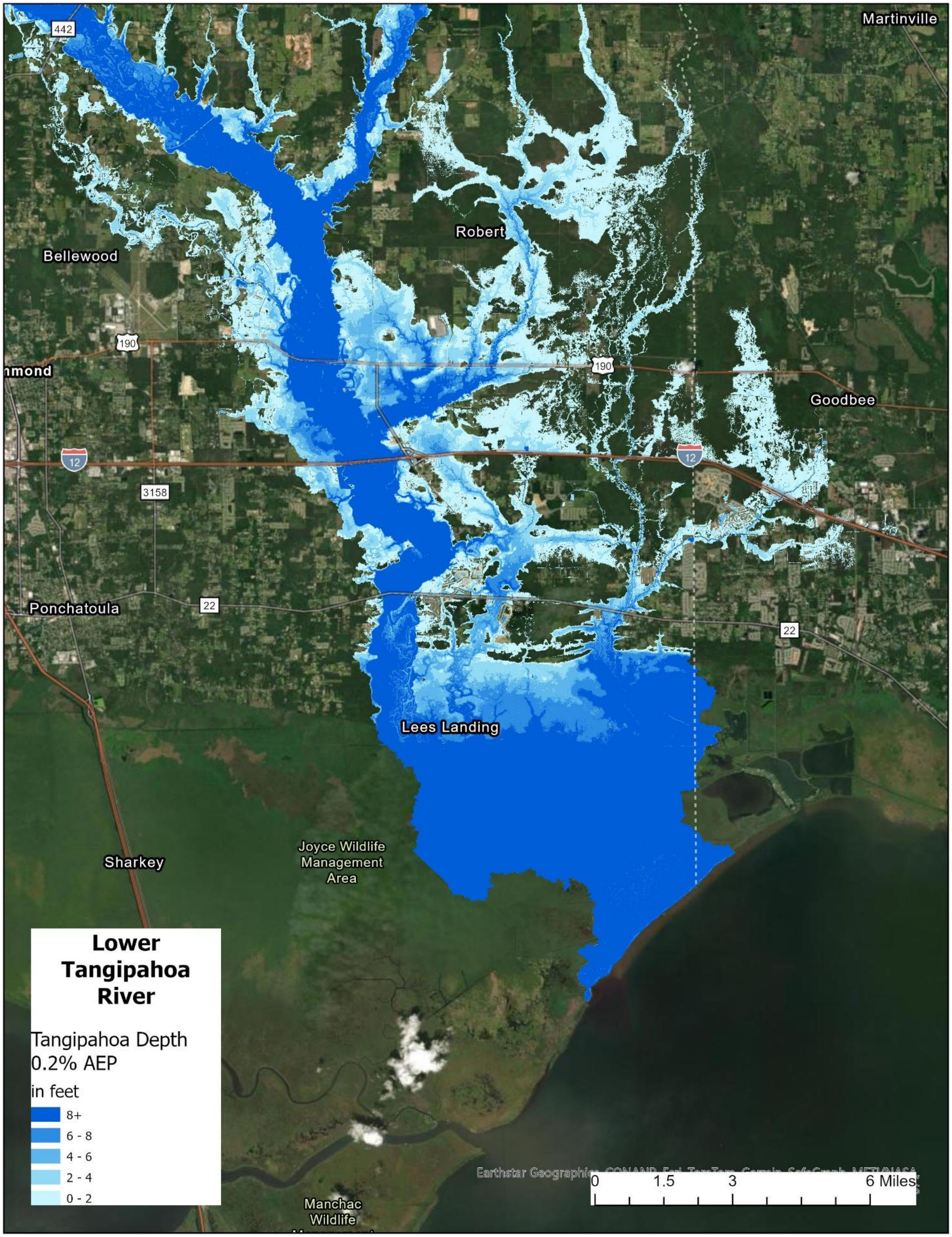

Martinville
442
Robert
Bellewood
190
190
mond
Goodbee
12
12
3158
Ponchatoula
22
22
Lees Landing
Joyce Wildlife
Management
Area
Sharkey
Lower
Tangipahoa
River
Tangipahoa Depth
50% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0 1.5 3 6 Miles
Manchac
Wildlife

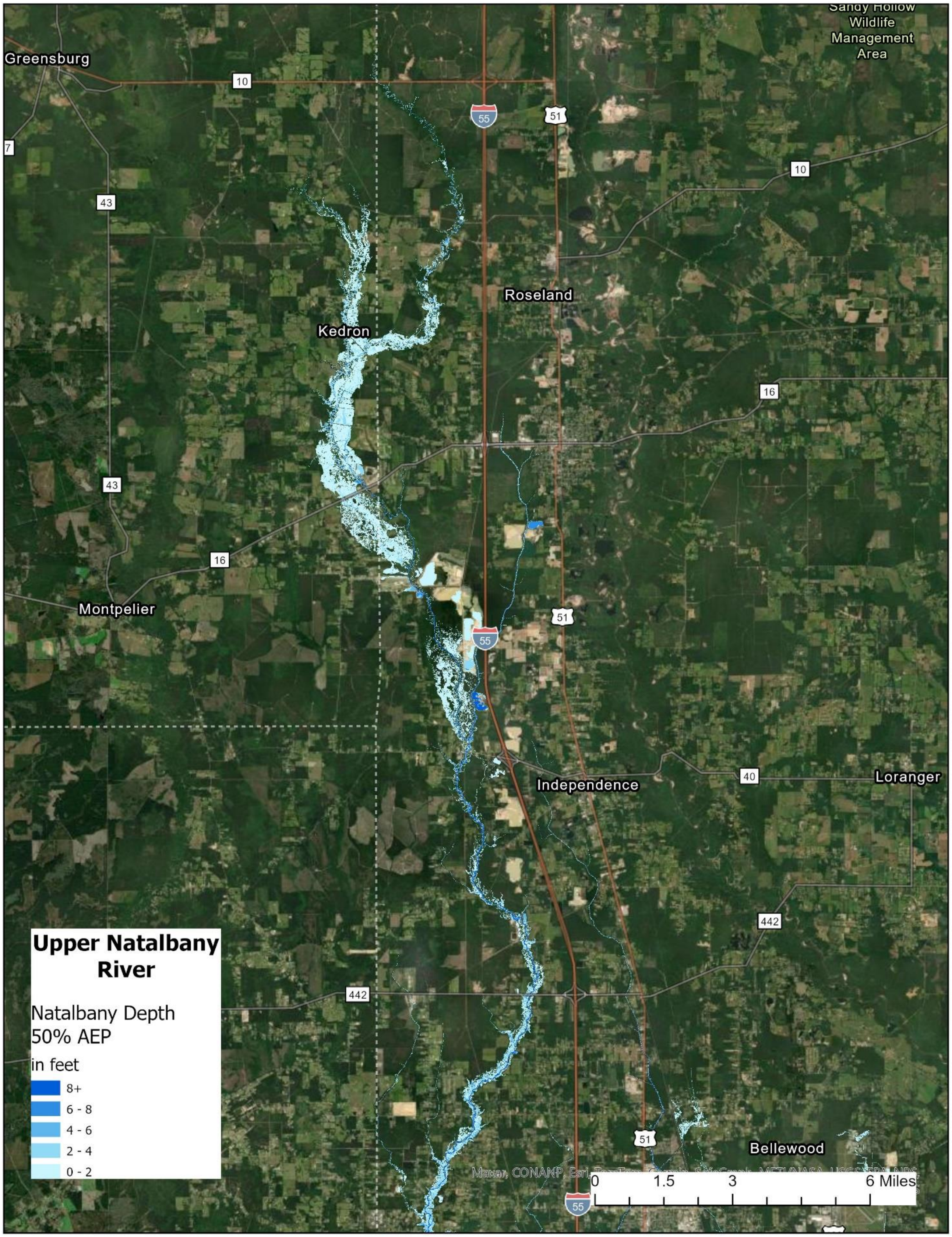

Martinville
Robert
Bellewood
mmond
Goodbee
Ponchatoula
Lees Landing
Sharkey
Joyce Wildlife Management Area
Manchac Wildlife
442
190
12
3158
22
Lower Tangipahoa River
Tangipahoa Depth 10% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0
1.5
3
6 Miles

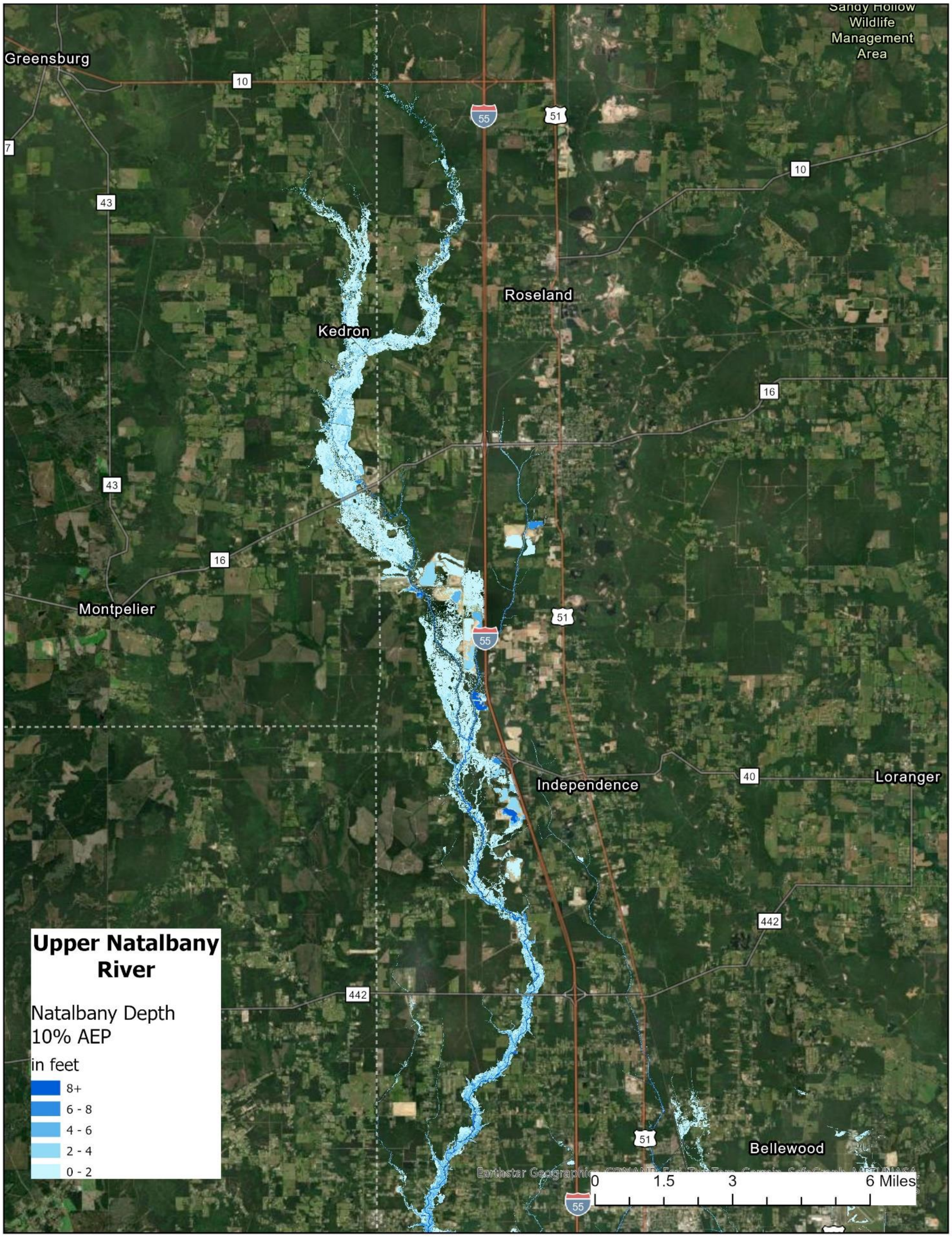

Martinville
442
Robert
Bellewood
190
190
nmond
Goodbee
12
12
3158
Ponchatoula
22
22
Lees Landing
Joyce Wildlife
Management
Area
Sharkey
Lower
Tangipahoa
River
Tangipahoa Depth
4% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Manchac
Wildlife
0
1.5
3
6 Miles

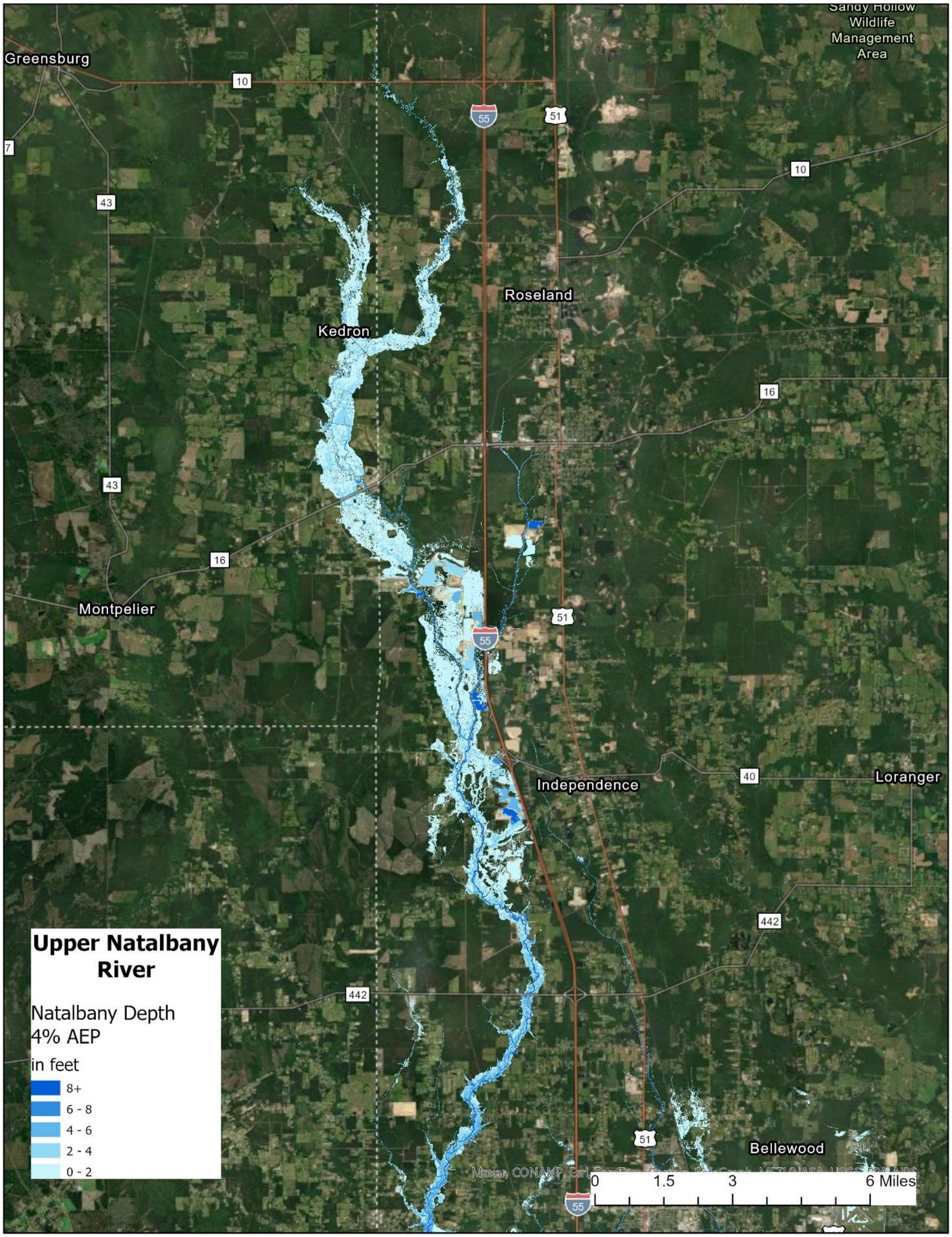

Martinville
Robert
Bellewood
nmond
Goodbee
Ponchatoula
Lees Landing
Sharkey
Joyce Wildlife Management Area
Manchac Wildlife
442
190
12
3158
22
Lower Tangipahoa River
Tangipahoa Depth 2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0
1.5
3
6 Miles

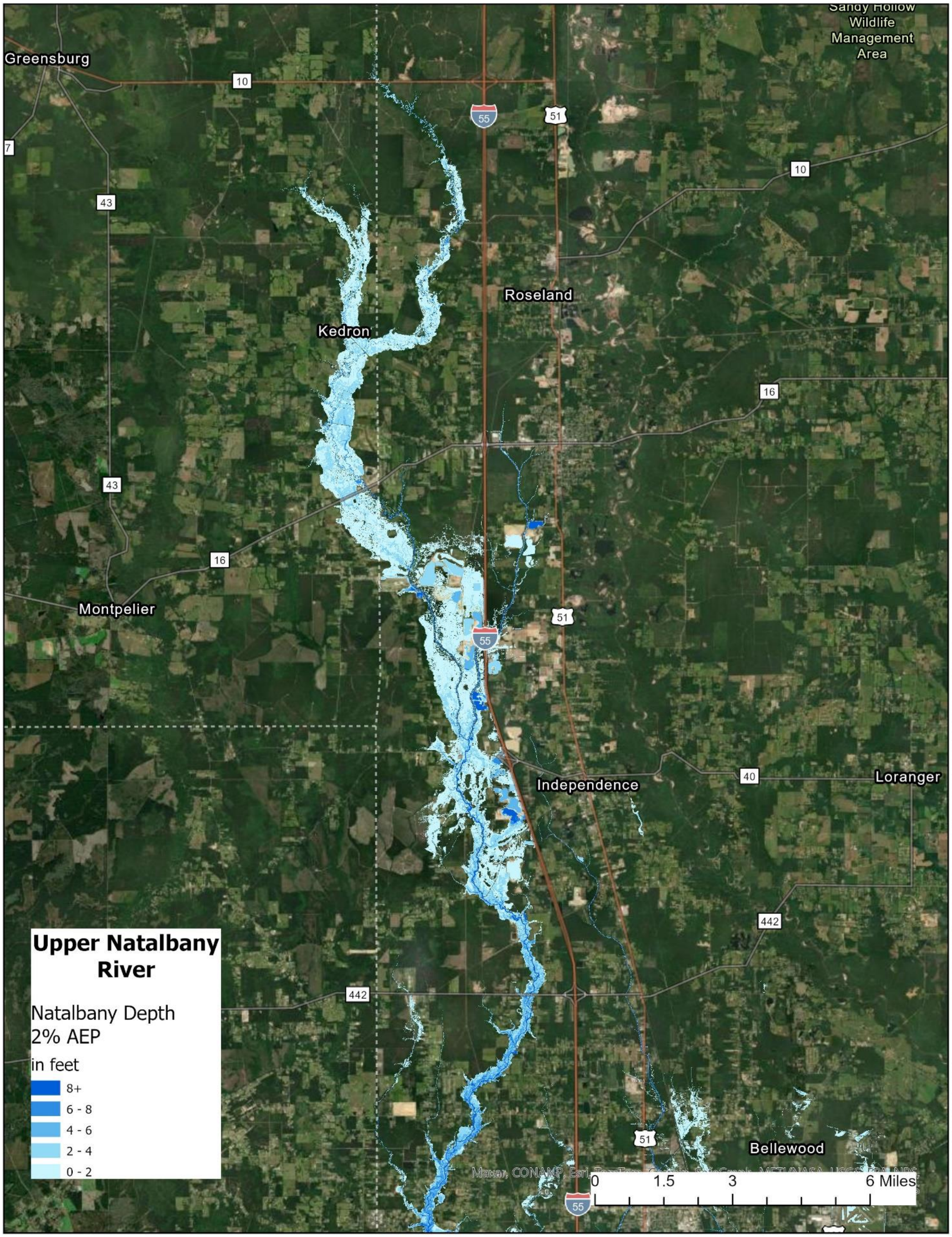

Martinville
Robert
Bellewood
mond
Goodbee
Ponchatoula
Lees Landing
Sharkey
Joyce Wildlife
Management
Area
Manchac
Wildlife
442
190
12
3158
22
Lower
Tangipahoa
River
Tangipahoa Depth
1% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0
1.5
3
6 Miles

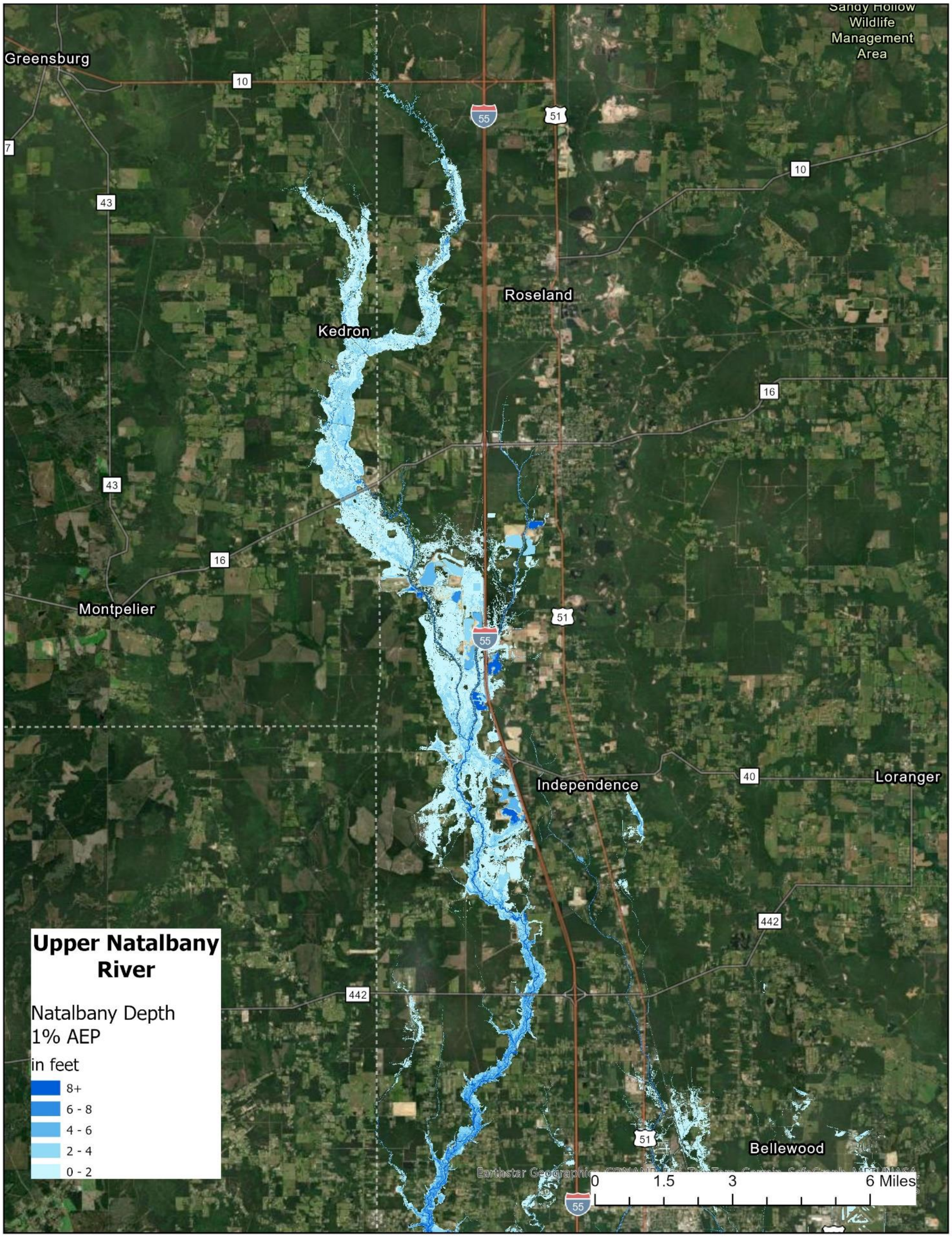

Martinville
442
Robert
Bellewood
190
mmond
190
Goodbee
12
12
3158
Ponchatoula
22
22
Lees Landing
Joyce Wildlife Management Area
Sharkey
Lower Tangipahoa River
Tangipahoa Depth 0.2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0
1.5
3
6 Miles
Manchac Wildlife

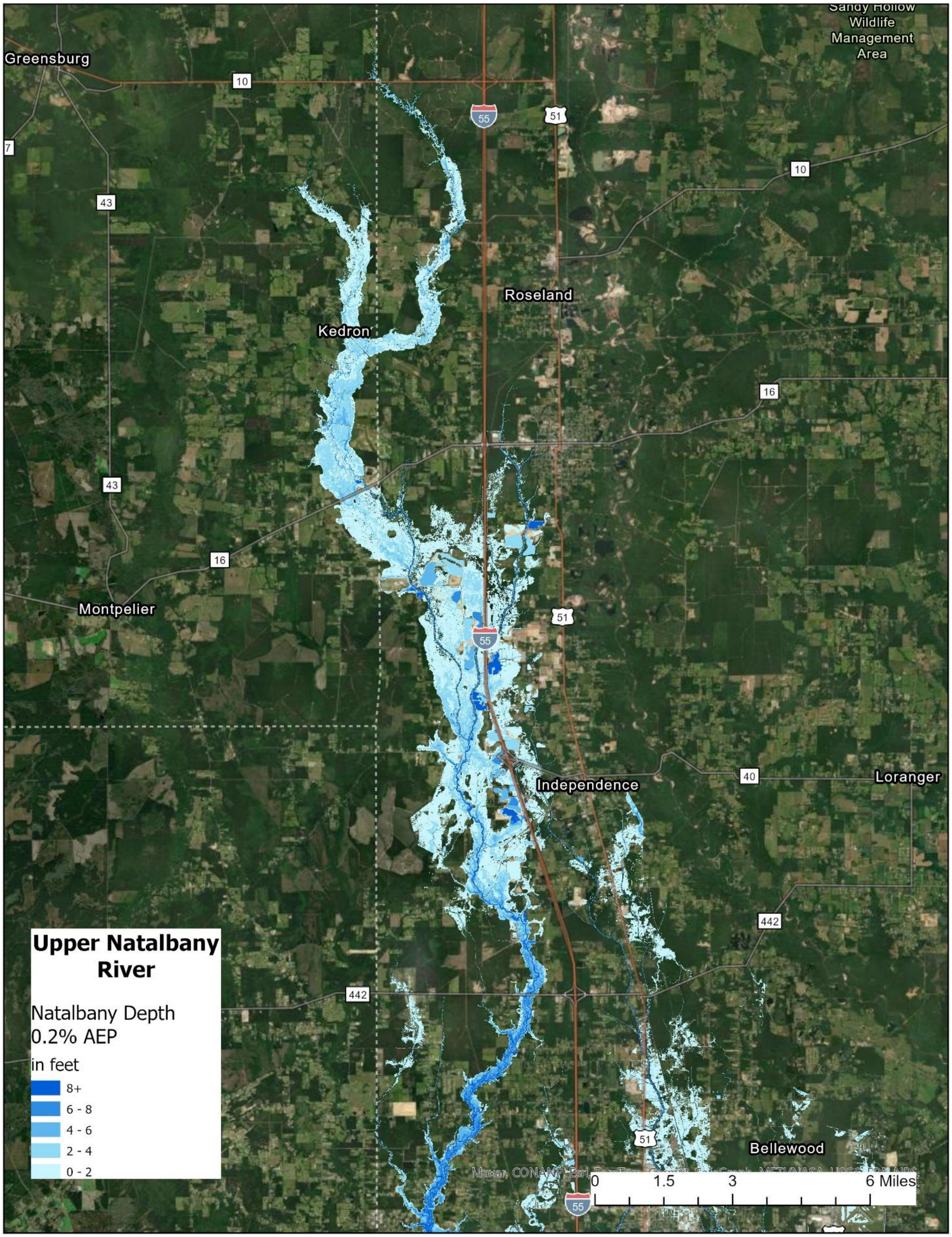

Upper Natalbany River
Natalbany Depth 50% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Greensburg
Sandy Hollow Wildlife Management Area
Kedron
Roseland
Montpelier
Independence
Loranger
Bellewood
10
55
51
43
16
40
442
0
1.5
3
6 Miles

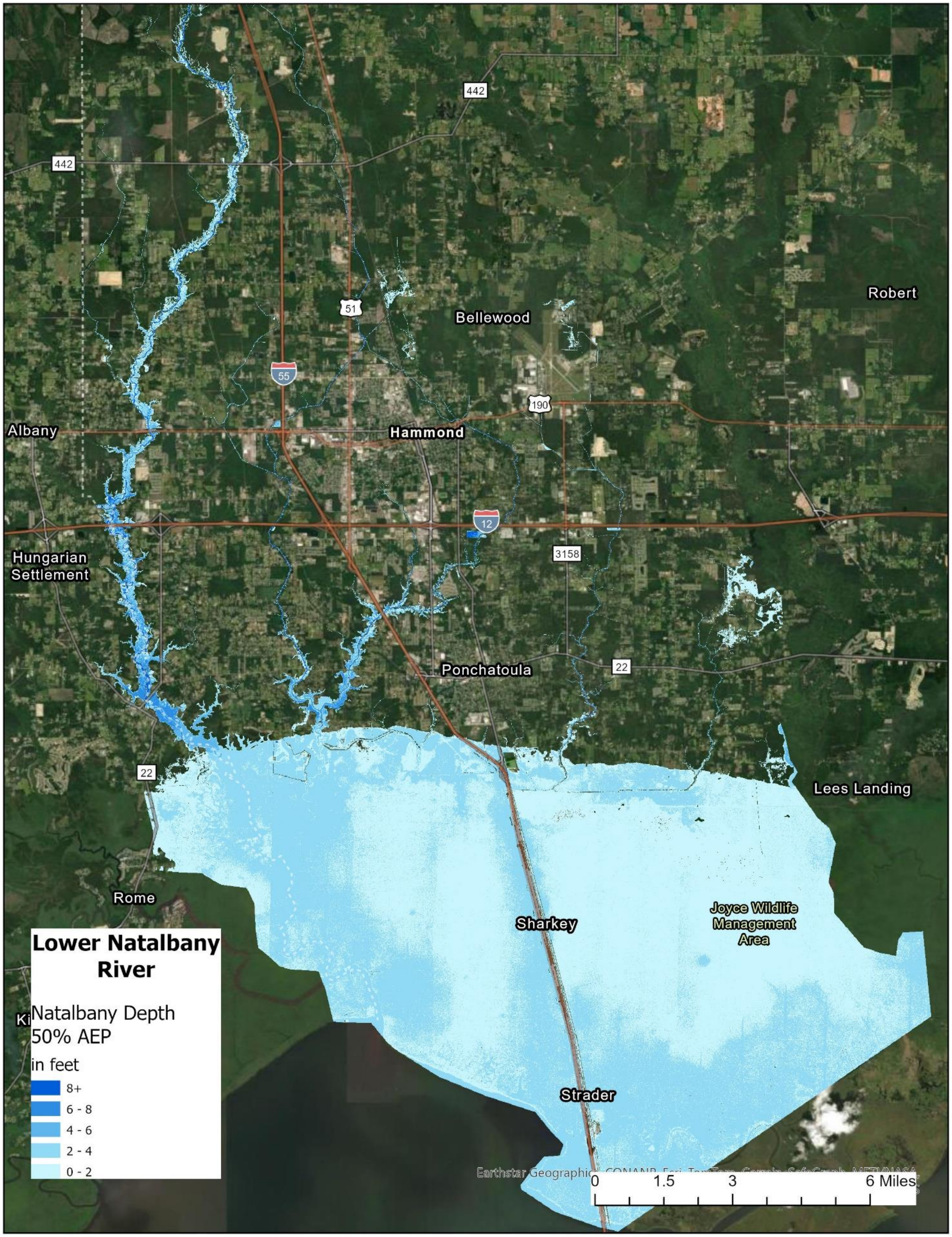

Sandy Hollow Wildlife Management Area
Greensburg
Roseland
Kedron
Montpelier
Independence
Loranger
Bellewood
Upper Natalbany River
Natalbany Depth 10% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0 1.5 3 6 Miles


Sandy Hollow Wildlife Management Area
Greensburg
Roseland
Kedron
Montpelier
Independence
Loranger
Bellewood
Upper Natalbany River
Natalbany Depth
4% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0
1.5
3
6 Miles

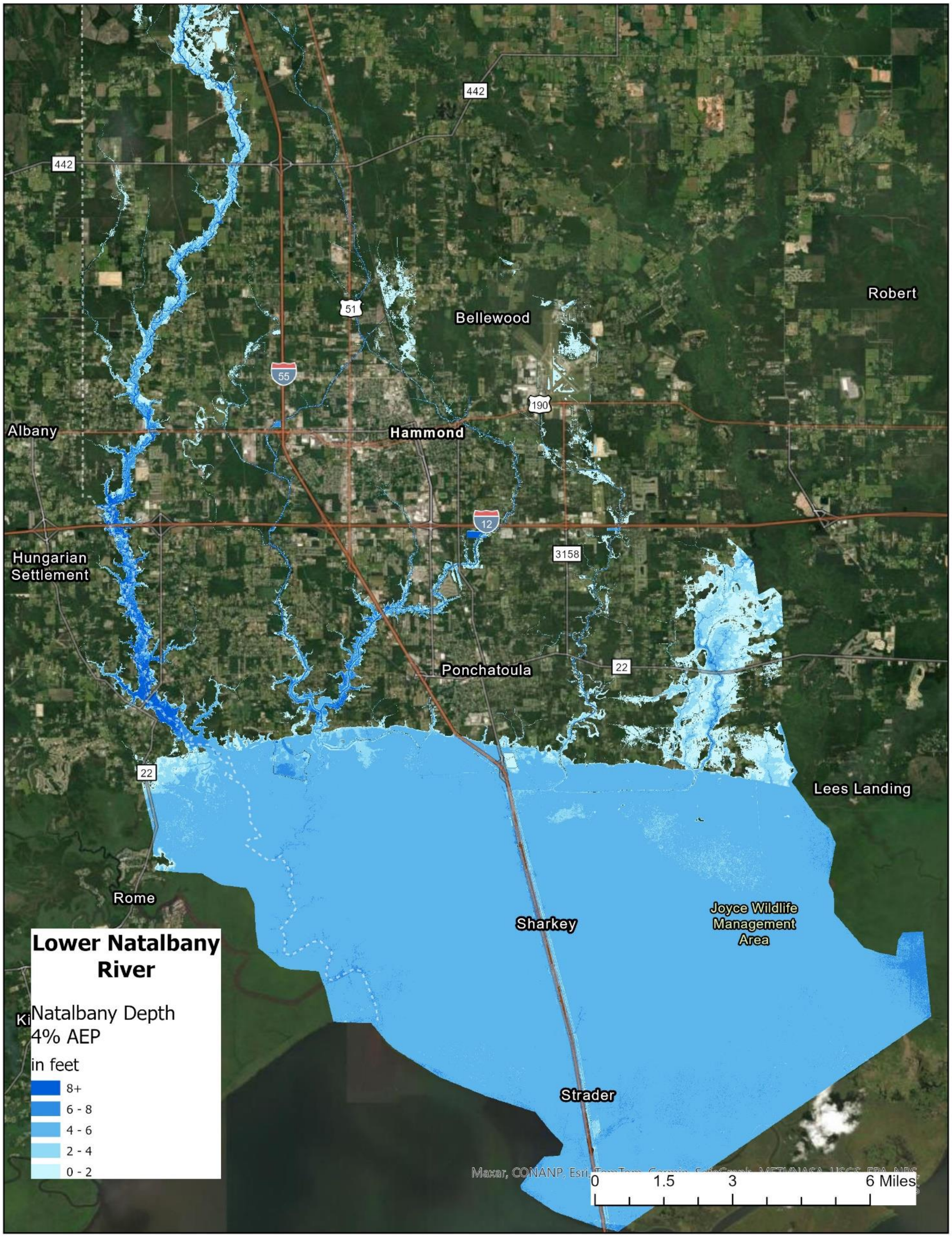

Sandy Hollow Wildlife Management Area
Greensburg
Roseland
Kedron
Montpelier
Independence
Loranger
Bellewood
Upper Natalbany River
Natalbany Depth
2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
0
1.5
3
6 Miles

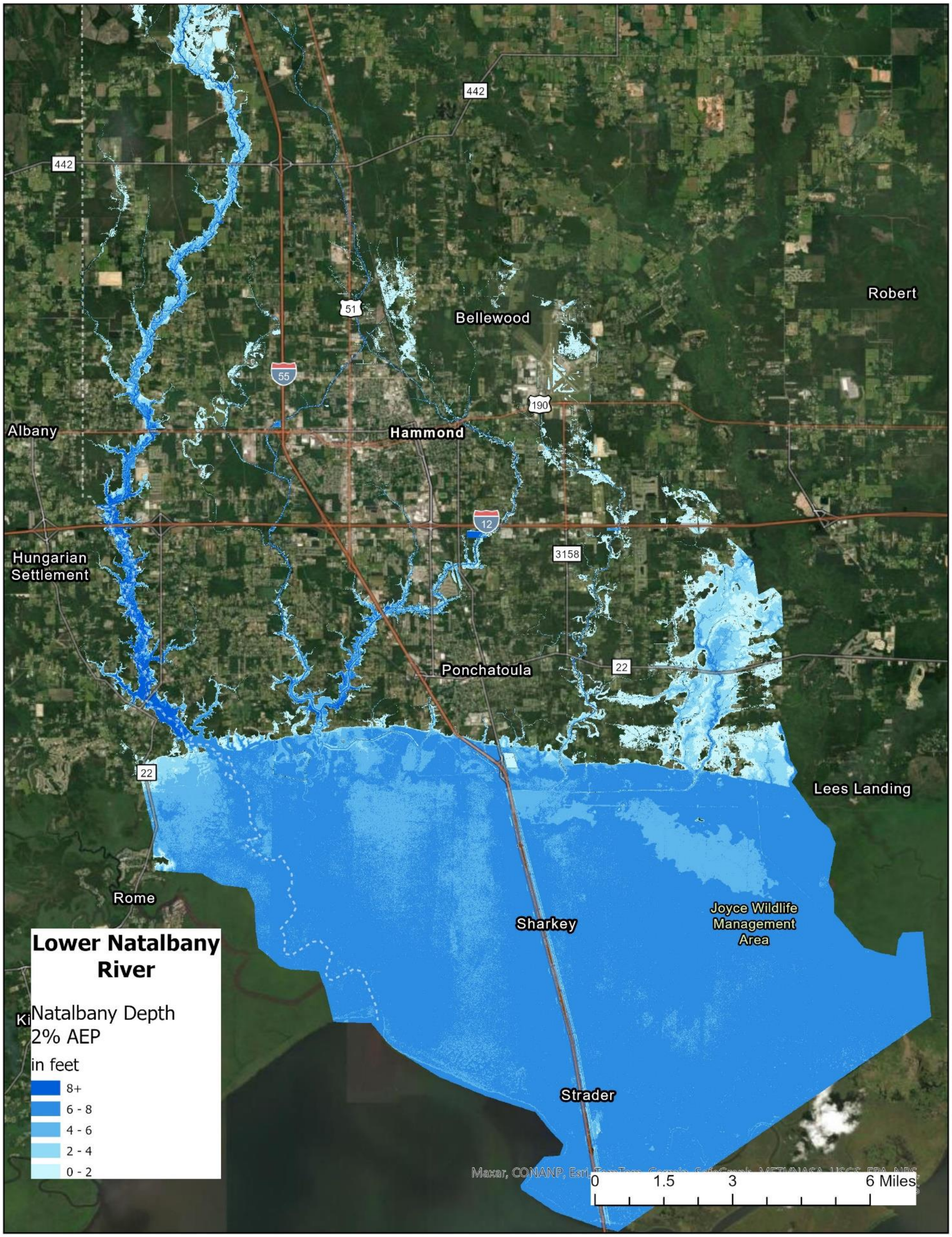

Upper Natalbany River
Natalbany Depth
1% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Greensburg
Sandy Hollow Wildlife Management Area
Roseland
Kedron
Montpelier
Independence
Loranger
Bellewood
10
55
51
43
16
40
442
0
1.5
3
6 Miles

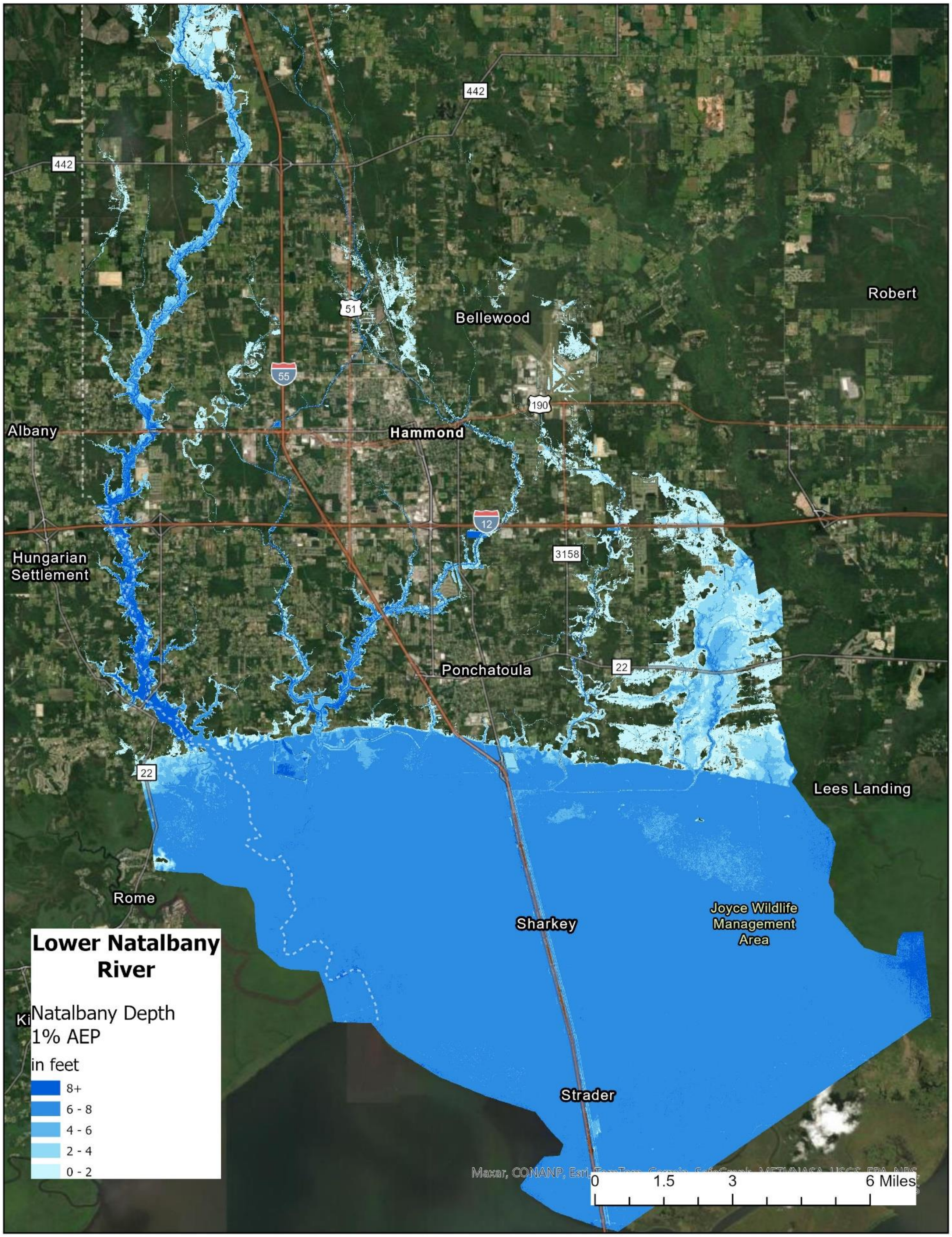

Upper Natalbany River
Natalbany Depth
0.2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Greensburg
Sandy Hollow Wildlife Management Area
Roseland
Kedron
Montpelier
Independence
Loranger
Bellewood
0
1.5
3
6 Miles

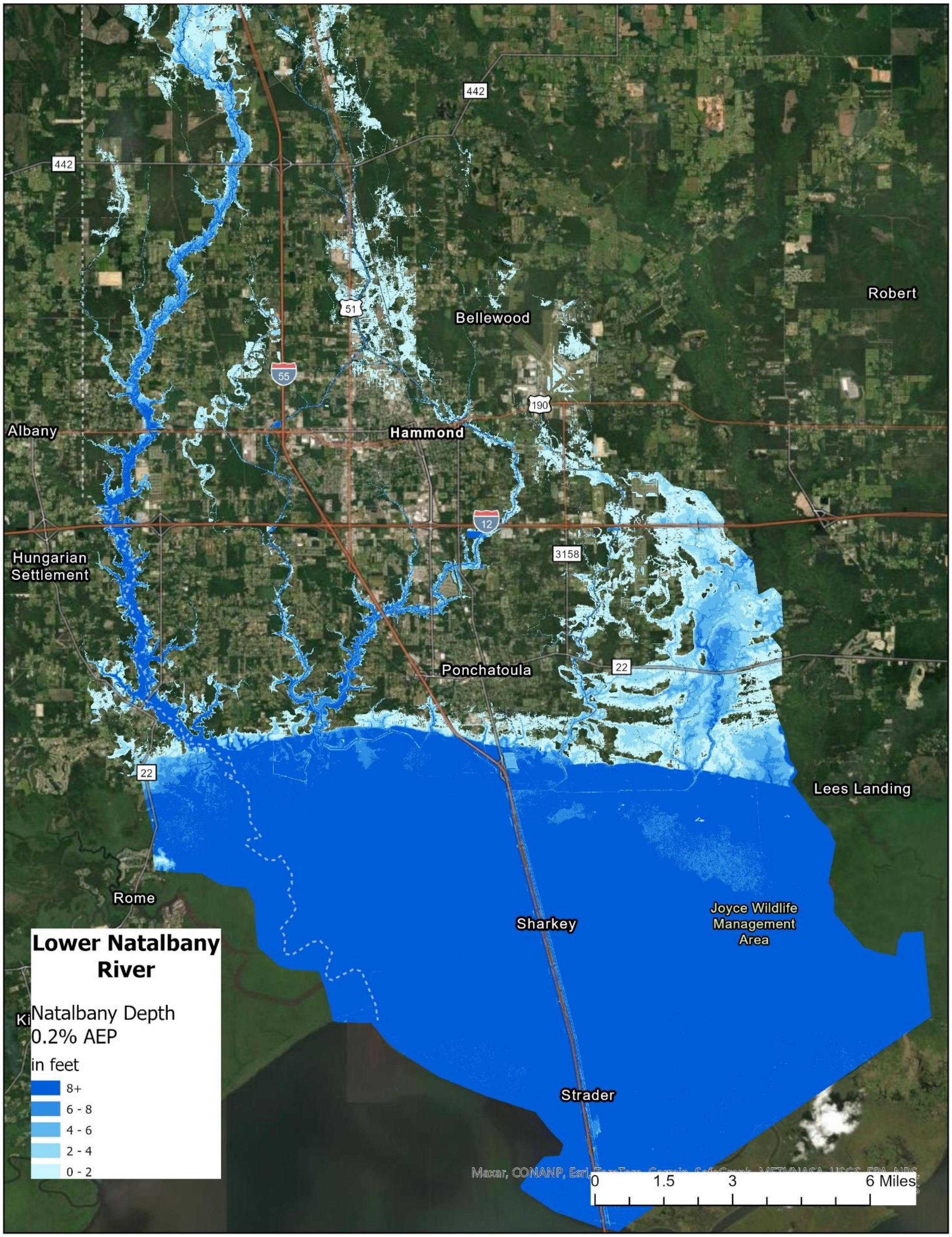

Lower Natalbany River
Natalbany Depth 50% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
442
442
51
55
190
12
3158
22
22
Robert
Bellewood
Albany
Hammond
Hungarian Settlement
Ponchatoula
Lees Landing
Rome
Sharkey
Joyce Wildlife Management Area
Strader
0
1.5
3
6 Miles


Lower Natalbany River
Natalbany Depth
10% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Robert
Bellewood
Albany
Hammond
Hungarian Settlement
Ponchatoula
Lees Landing
Rome
Sharkey
Joyce Wildlife Management Area
Strader
442
51
55
190
12
3158
22
0
1.5
3
6 Miles


Lower Natalbany River
Natalbany Depth
4% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
442
51
55
190
12
3158
22
Robert
Bellewood
Albany
Hammond
Hungarian Settlement
Ponchatoula
Lees Landing
Rome
Sharkey
Joyce Wildlife Management Area
Strader
0
1.5
3
6 Miles


Lower Natalbany River
Natalbany Depth
2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Robert
Bellewood
Albany
Hammond
Hungarian Settlement
Ponchatoula
Lees Landing
Rome
Sharkey
Joyce Wildlife Management Area
Strader
442
51
55
190
12
3158
22
0
1.5
3
6 Miles


Lower Natalbany River
Natalbany Depth
1% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
442
51
55
190
12
3158
22
Robert
Bellewood
Albany
Hammond
Hungarian Settlement
Ponchatoula
Lees Landing
Rome
Sharkey
Joyce Wildlife Management Area
Strader
0
1.5
3
6 Miles

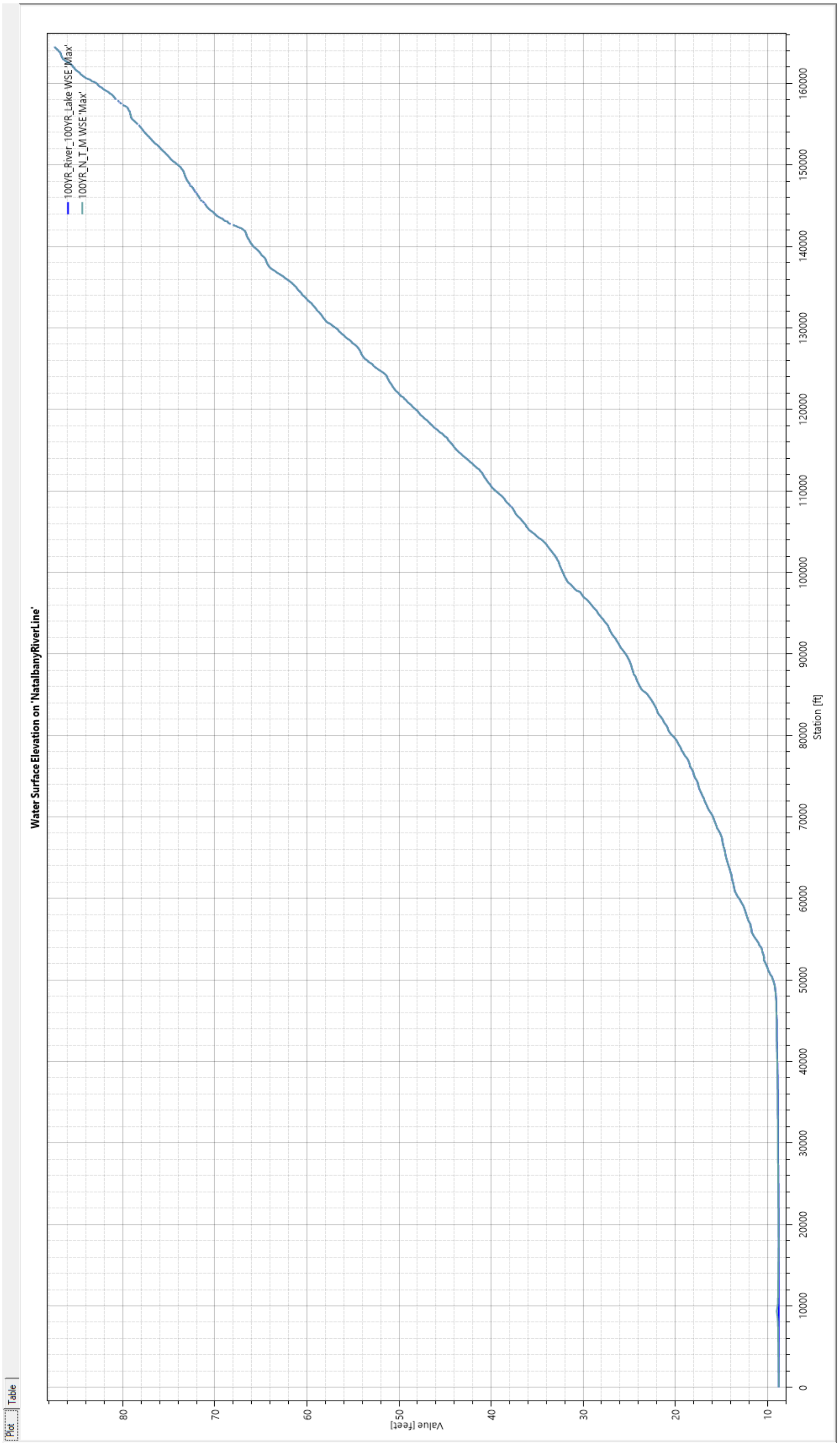

Lower Natalbany River
Natalbany Depth 0.2% AEP
in feet
8+
6 - 8
4 - 6
2 - 4
0 - 2
Robert
Bellewood
Albany
Hammond
Hungarian Settlement
Ponchatoula
Lees Landing
Rome
Sharkey
Joyce Wildlife Management Area
Strader
442
51
55
190
12
3158
22
0
1.5
3
6 Miles

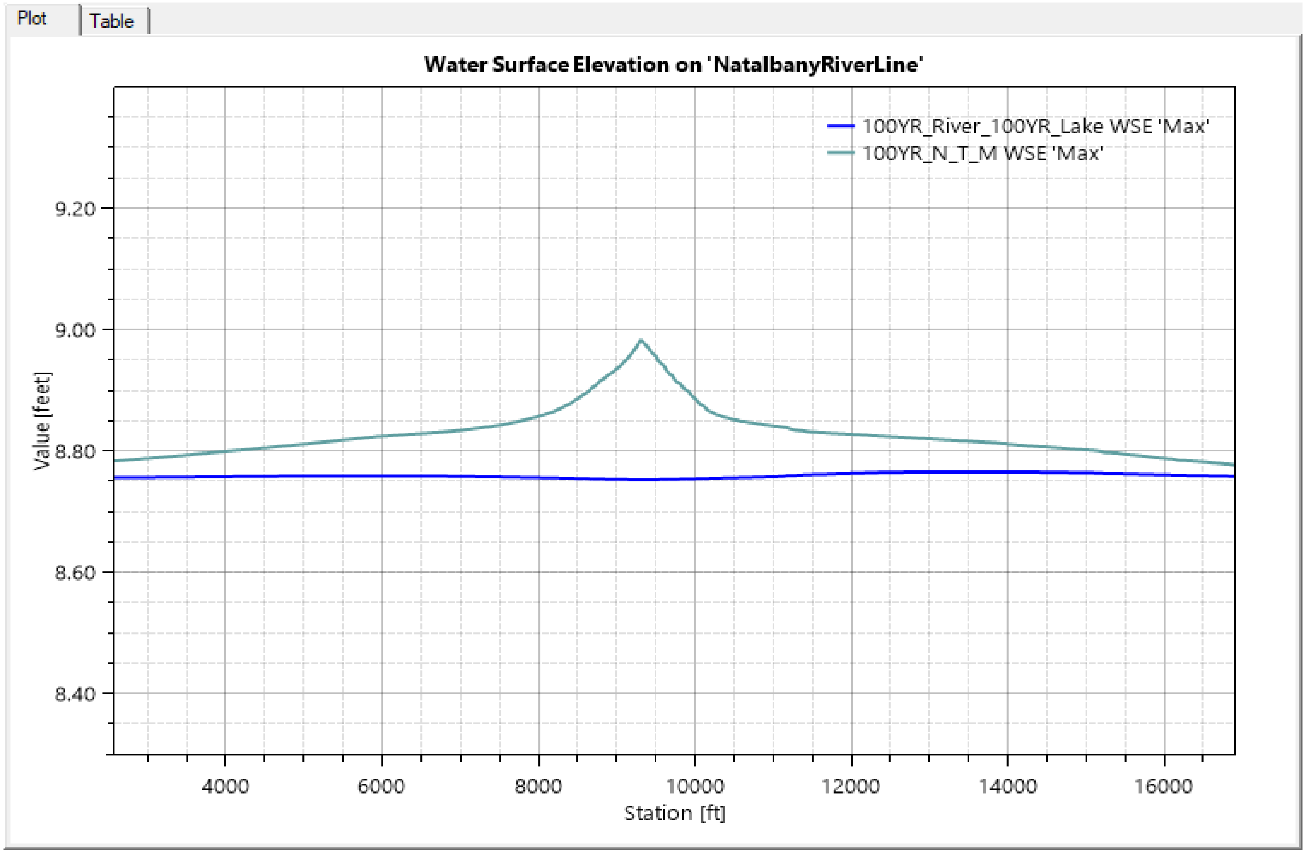
Annex E: Tickfaw River Effect on the Natalbany River and Selser's Creek Model

TICKFAW INFLUENCE ON COSTAL SURGE ZONE

It was decided to do a sensitivity analysis to see if flow from the Tickfaw River had an influence in flood stages for the Natalbany River upstream of the Natalbany junction with the Tickfaw. A ratio of 1% AEP flow and drainage area was done to estimate the 100yr flow for the Tickfaw River, and it was estimated to be 88,000 cfs. A new 2D interior boundary condition was created and a constant flow of 88,000 cfs was added to the model. The plan chosen to add this flow to was with the 1% AEP flow on the Natalbany River and 100yr stage for Lake Maurepas.

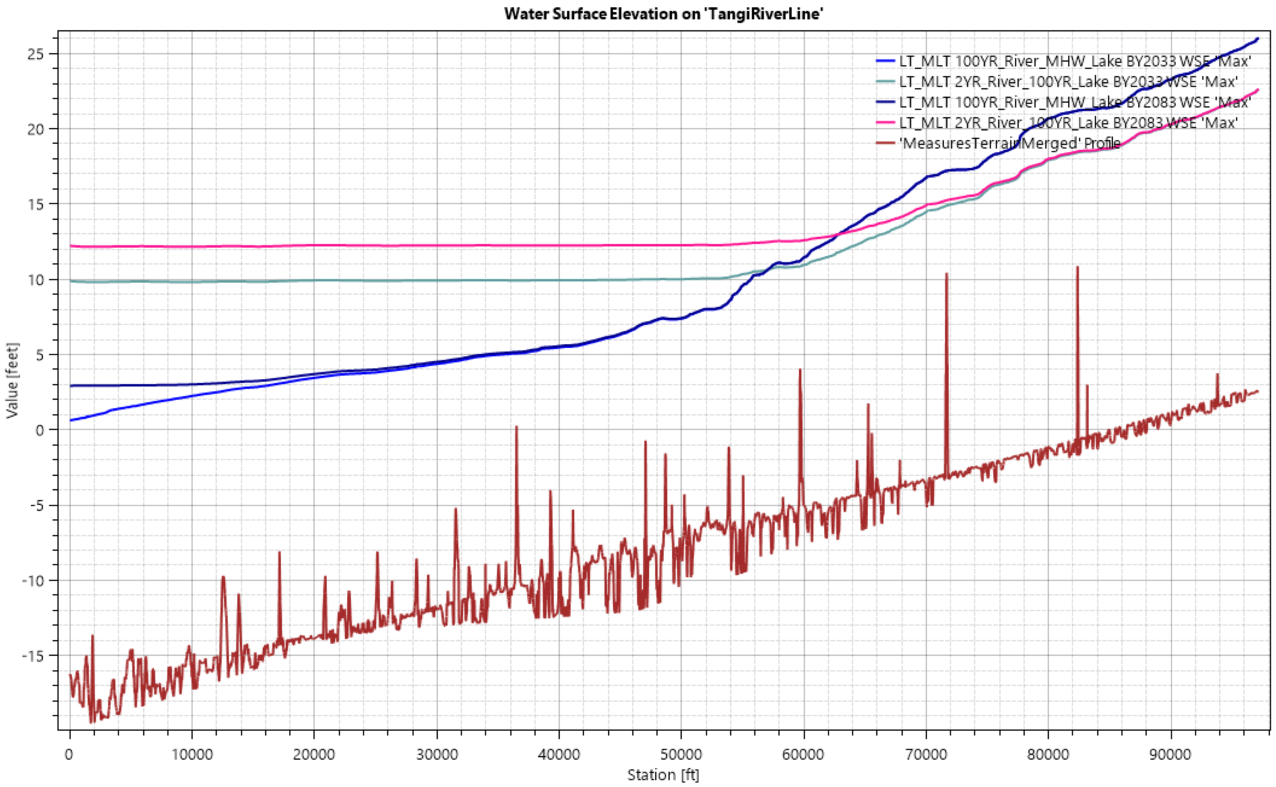
Adding the Tickfaw 1% AEP flow did not have an impact on flood stages in the Natalbany River. The following figures show water surface elevation along the Natalbany River from Lake Maurepas to the upstream gage at Baptist. A small increase in stage can be seen right around where the Tickfaw flow comes into the profile line. The extents are within 2,000 feet of the Tickfaw and there is not impacted structures in the vicinity of the stage increase. Coastal surge is the main influence of flooding in this area. This means flow from the Tickfaw River can be disregarded for the purposes of this study.


Water Surface Elevation on 'NatalbanyRiverLine'
100YR_River_100YR_Lake WSE 'Max'
100YR_N_T_M WSE 'Max'
Station [ft]
Value [feet]
Plot
Table


Plot
Table
Water Surface Elevation on 'NatalbanyRiverLine'
100YR_River_100YR_Lake WSE 'Max'
100YR_N_T_M WSE 'Max'
Value [feet]
9.20
9.00
8.80
8.60
8.40
4000
6000
8000
10000
12000
14000
16000
Station [ft]

Annex F: Sea Level Change Effects on Tangipahoa and Natalbany River Profiles (1% AEP)

Tangipahoa River Profiles – Base Year 2033 Versus Year 2083



Natalbany River Profiles – Base Year 2033 Versus Year 2083