

Cross Bayou HUC-8 Watershed, Texas Base Level Engineering (BLE) Results

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Executive Summary

The Texas Water Development Board (TWDB) contracted Halff Associates (Halff) to complete a Base Level Engineering (BLE) analysis for the HUC-08 watershed No. 11140304 – Cross Bayou in Northeast Texas, to support the U.S. Department of Homeland Security’s Federal Emergency Management Agency’s (FEMA) Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory-quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development in support of hydrologic and hydraulic analysis as well as mapping activities were leveraged from various local, State, and Federal partners. Details regarding the different datasets used are provided below in Section 2.1.

Precipitation depths for this study were established using National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall. An average precipitation depth was computed for the study area. The Hydrologic Engineering Center’s (HEC) Hydrologic Modeling System (HMS) was used to develop a simplified hydrologic model to compute excess rainfall which was then used in a rain-on-grid, 2D hydraulic modeling using HEC-RAS. The hydraulic model was used to compute flood depths and peak water surface elevations within the study area.

The stream mile network that was validated for these watersheds was compiled using FEMA’s Community Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risks. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-1.1.1 lists the stream miles associated with this validation analysis.

Table ES-1.1: Summary of Stream Miles

Source	Cross Bayou Stream Miles
CNMS	2,265

The full inventory of Zone A studies in the watershed were classified in CNMS. Total miles validated in CNMS are summarized in Table ES-1.2.

Table ES-1.2: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	290.1
UNVERIFIED	BEING STUDIED	357.1

01 Introduction

Recent innovations and efficiencies in floodplain mapping have allowed FEMA to develop a process called BLE, which can be used to address current program challenges, including the validation of Zone A studies and the availability of flood risk data in the early stages of a flood risk project. The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals. The cost for developing the data and estimates resulting from the BLE process are lower than standard flood production costs. The BLE results may be used for eventual production of regulatory and non-regulatory products.

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every five years, FEMA must evaluate whether the information on Flood Insurance Rate Maps (FIRMs) reflects the current risks in flood-prone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the CNMS Technical Reference. The CNMS Validation Checklist provides a series of critical and secondary checks to determine the validity of flood hazard areas studied by detailed methods (e.g., Zone AE, AH, or AO). While the critical and secondary elements in CNMS provide a comprehensive method of evaluating the validity of Zone AE studies, a cost-effective approach for evaluating Zone A studies has been lacking.

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the early stages of a flood risk project. FEMA Program Standard SID #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses should be shared, and results should be discussed with stakeholders.

An important goal of the BLE process is the scalability of the results. Scalability means that the results of a BLE analysis can not only be used for CNMS evaluations of Zone A studies but can also be leveraged throughout the Risk MAP program. The data resulting from a BLE analysis can be updated as needed and used for the eventual production of regulatory and non-regulatory products, outreach and risk communication, and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

The TWDB contracted Halff to complete a BLE analysis for the Cross Bayou Watershed in Northeast Texas to support FEMA's Discovery process and validation of effective Zone A SFHAs. The study extents include portions of Cass, Harrison, Panola, Miller (AK), and Caddo (LA) Counties, and include the following communities: The Cities of Waskom, Queen City, Shreveport, and Atlanta, the Towns of Bloomburg, Oil City, Blanchard, and Vivian, the Villages of Rodessa, Gilliam, Belcher, and Hosston, and the Communities of Jonesville and Doddridge. The study area consists of five HUC-10 basins: Twelvemile Bayou, Paw Paw Bayou, Cross Bayou, Black Bayou, and Kelly Bayou. Figure 1.1 shows the orientation of the Cross Bayou HUC-8 basin with respect to the counties.

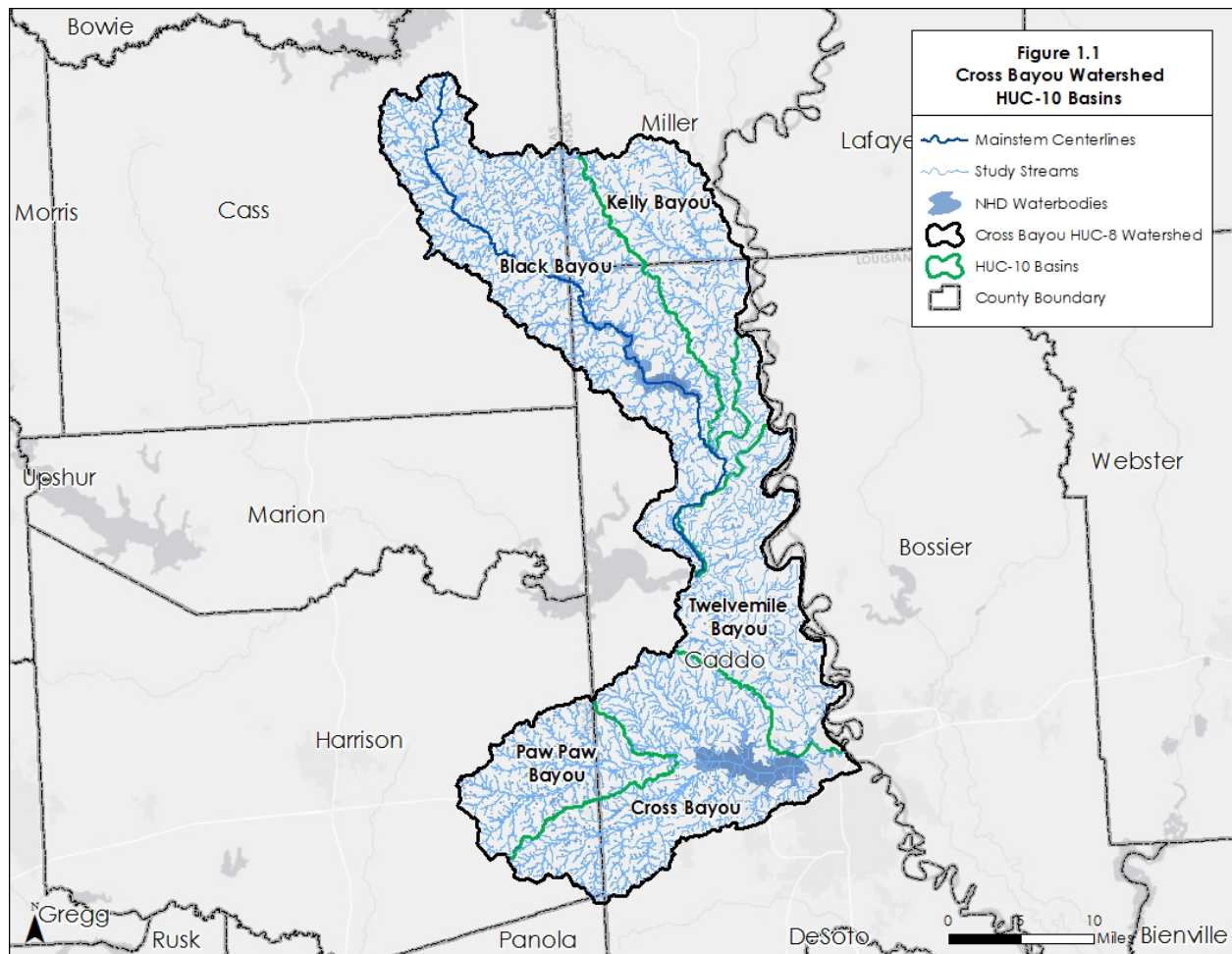


Figure 1.1: Cross Bayou Watershed

02 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2-dimensional (2D) hydraulic engineering analysis for the Cross Bayou Watershed. Inputs such as elevation data, hydrology from rain-on-grid and inflow hydrographs, and hydraulic analyses and variables are defined herein. HEC-RAS 6.1 rain-on-grid utility was applied in the production of these Texas 2D BLE products.

2.1 Topographic Data

A high-resolution Digital Elevation Model (DEM) is a fundamental component for two-dimensional engineering analyses by providing a detailed representation of the surface for hydraulic routing through the model area. As such, DEMs were developed for the Cross Bayou BLE project by leveraging available high-resolution gridded elevation data derived from Light Detection and Ranging (LiDAR) collections throughout the entire State of Texas. The 10-foot DEM developed to support the 2D BLE modeling and analysis, within the Cross Bayou Watershed, was executed using the following steps:

1. Available elevation data for the project area were inventoried and collected.
2. Leveraged elevation data were evaluated and prioritized based on source vertical accuracy, year of collection, and resolution.
3. Seamless DEMs were processed using GIS.
4. Quality was assured using quantitative and qualitative assessment.

Documentation regarding leveraged data including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables and text within Section 2.1. All vertical accuracy specifications were obtained from the metadata or survey reports provided with the leverage datasets. All available metadata, survey reports, and other leverage documentation are included in the FEMA Data Capture Technical Reference compliant submittal content for the Cross Bayou Watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the Cross Bayou BLE project footprint. Figure 2.1 depicts the datasets identified for leveraged across the project area. FEMA, NOAA, USGS, and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

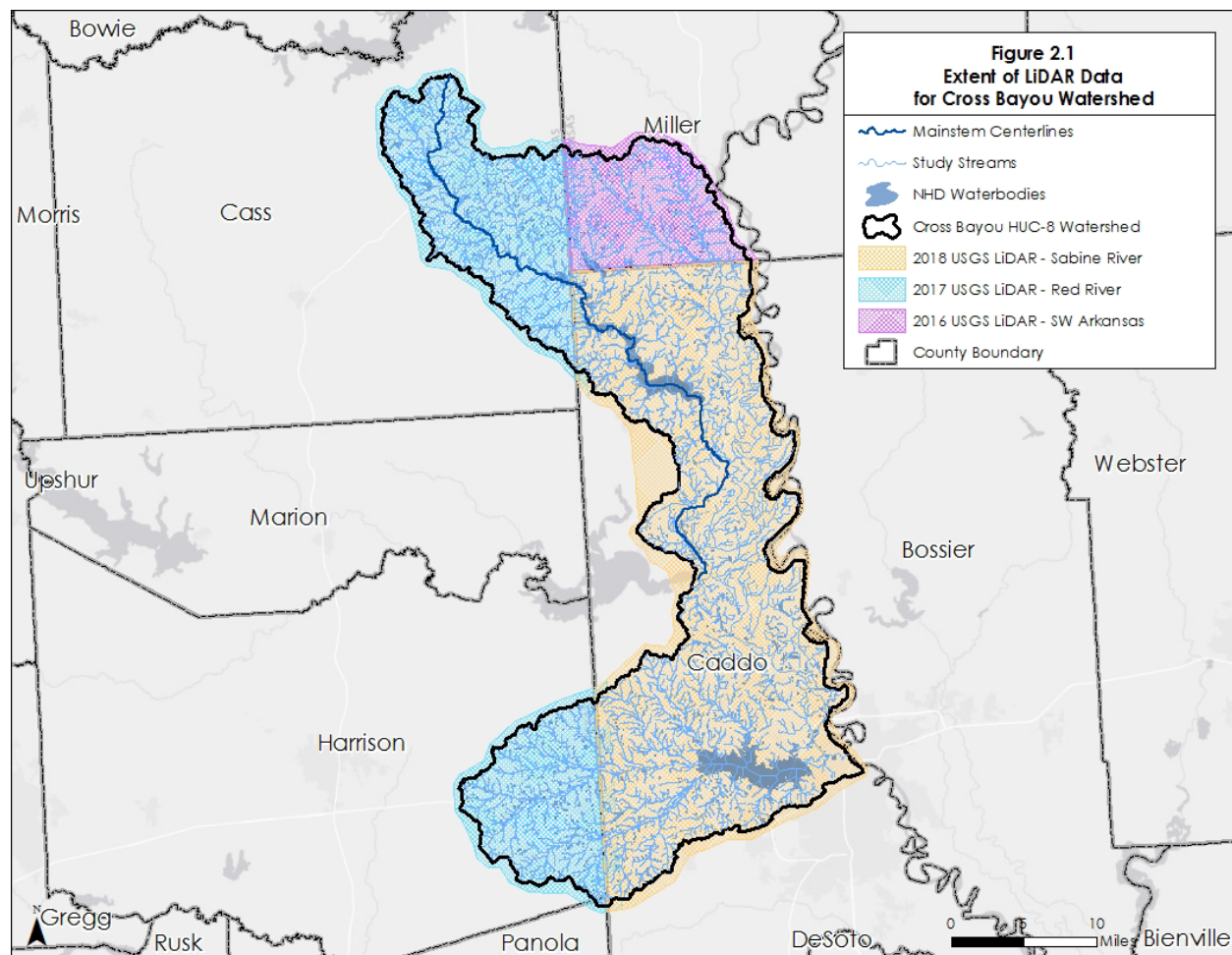


Figure 2.1: Cross Bayou Watershed BLE Source Terrain Data

2017 TNIRIS Red River LiDAR— The 2017 Red River LiDAR was acquired from January 2017 to March 2017. The measured RMSE was documented at 10.9 cm Non-Vegetative Accuracy. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2018 USGS Sabine Louisiana LiDAR— The 2018 USGS Sabine Louisiana LiDAR was acquired from February to March 2018. The measured NVA RMSE was documented as 10.9 cm. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2016 USGS SW Arkansas LiDAR— The 2016 USGS Ouachita Arkansas LiDAR was acquired from January 2016 through March 2016 with some reflights in April 2017. The measured RMSE was documented as less than 19 cm Non-Vegetative Accuracy. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2.1.2 Evaluation

A data coverage assessment was conducted to check for data gaps, extent, accuracy, and completeness. A review of related documentation, reports, indexes, and metadata associated with the leveraged datasets ensured each dataset meets FEMA accuracy requirements for topographic data. Decisions to leverage or exclude a dataset (or portion of it), were based generally on the following criteria coupled with engineering judgment:

- Data meet FEMA vertical accuracy standards (Table 2.1)
- Date of origination
- Data density and coverage

Table 2.1 depicts the Risk Map SID 43 vertical accuracy requirements based on flood risk and terrain slope within the floodplain being mapped.

Table 2.1: FEMA Vertical Accuracy Requirements for Leveraged Data

Level of Flood Risk	Typical Slopes	Specification Level	Vertical Accuracy*	LiDAR Nominal Pulse Spacing (NPS)
High (Deciles 1,2,3)	Flattest	Highest	24.5 cm / 36.3 cm	≤ 2 meters
High (Deciles 1,2,3)	Rolling or Hilly	High	49.0 cm / 72.6 cm	≤ 2 meters
High (Deciles 2,3,4,5)	Hilly	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Flattest	High	49.0 cm / 72.6 cm	≤ 2 meters
Medium (Deciles 3,4,5,6,7)	Rolling	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Hilly	Low	147 cm / 218 cm	≤ 5 meters
Low (Deciles 7,8,9,10)	All	Low	147 cm / 218 cm	≤ 5 meters

*Vertical Accuracy at 95% Confidence Level (FVA or NVA)/(CVA or VVA)

Table 2.2 depicts the complete list of source elevation data and attributes leveraged for the Cross Bayou Watershed BLE project. All datasets used for hydraulic analyses and mapping meet the highest specification level defined in Table 2.1. Further explanation of the Table 2.2 datasets can be referenced in section 2.1.2.1.

Table 2.2: Source Topographic Data Available for the Cross Bayou Watershed

Year	Description	Data Type	RMSE	Source/Owner
2018	2018 Sabine River Lidar	Airborne LiDAR	10.9cm NVA	USGS
2017	2017 Red River Lidar	Airborne LiDAR	10.9cm NVA	USGS
2016	2016 SW Arkansas Lidar	Airborne LiDAR	<19cm NVA	USGS

2.1.2.1 Cross Bayou Watershed Source Terrain Data

The source elevation data for the Cross Bayou Watershed are DEMs derived from USGS, TWDB and FEMA LiDAR data. Preprocessed Bare-earth Hydro-enforced DEMs from the acquiring entity (via TNRIIS) were projected and adjusted as needed into one seamless DEM in Texas State Plane 4204 NAD83, Vertical Feet NAVD88. Bare-earth LiDAR data are typically made by filtering non-ground returns (e.g. buildings, vegetation, etc.) from the processed LiDAR returns. Figure 2.1 depicts the extent of the data defined in

Table 2.2. Please see brief descriptions of the lidar sources below. For more detailed information, please see the attached LiDAR project report for each individual project.

2018 USGS Sabine Louisiana LiDAR– The 2018 USGS Sabine Louisiana LiDAR was acquired from February to March 2018. The measured NVA RMSE was documented as 10.9 cm. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

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2.1.3 Data Development Methodology

The source topographic data were processed for an area covering the Cross Bayou Watershed and contributing drainage areas for the Cross Bayou BLE modeling efforts. The topographic data for Cross Bayou Watershed was projected horizontally, as needed, to North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS) Texas S Central in feet (4204-SPC83). All topographic data were adjusted vertically, as needed, to NAVD88 in feet. Halff used a combination of ArcGIS and other software tools to apply any vertical datum shifts and/or any horizontal projection transformations to the topographic data.

2.1.4 DEM QA/QC

DEMs developed for use in the Cross Bayou Watershed BLE analysis were developed and independent assured to meet quality standards of the project. The data were developed using a controlled process, were evaluated and assured by a topographic data development team and were evaluated and assured by the engineering team. Quality assurance during the data development process includes, but is not limited to the following QC checks:

- Horizontal Projection Check
- Vertical Datum Check
- Resolution Check
- Format Check
- Seamless Data Check to ensure the DEM files are consistent and seamless along source data edges

The quality control after the development process by the DEM development team included visual observations using hillshade, contouring, color rendering, and/or other visual aids to review and identify potential impactful anomalies within the DEM surface. This QC step included, but were not limited to the following QC checks:

- Seamless Data Check to ensure no voids along the edges and between the prioritized datasets
- NoData Value Check to ensure no null values
- Manual Elevation Check using hillshade rasters to find erroneous elevation issues
- Unit Consistency Check
- Legacy Cell Value Anomalies

Quality assurance conducted after the seamless DEM development conducted by the engineering team included visual or automated assessments to identify potentially impactful anomalies or slope changes that may adversely impact hydraulic.

The final DEM data developed for the Cross Bayou Watershed are assured to meet FEMA standards and present a representative surface developed from leveraged elevation data for the purposes of this BLE project.

2.2 2D BLE Methods

The following sections describe the 2D computational mesh and program setting considerations, followed by discussion and tabulation of hydrologic and hydraulic engineering methods and model inputs.

2.2.1 2D Computational Mesh and Settings

The HEC-RAS 2D computational mesh defines the extents of the 2D flow and can affect the accuracy of the 2D calculations. A denser mesh may provide more accurate results, but it can dramatically increase model run times. The original 2D mesh for the model was established as evenly spaced cells at approximately 200 feet. The mesh was further refined by placing breaklines along roads, berms, ridges, and other high ground that can impede flow as well as stream centerlines to allow flow conveyance. To ensure the entire Cross Bayou Watershed, including adjacent inflows, was represented, a 5,000-foot buffer was added to the HUC boundary. This buffer was used to capture inflows and produce mapping through the full extents of the HUC-8 boundary. It should be noted, the buffer was applied to the USGS HUC-8 boundary that was not modified based on topography. A hydro-corrected HUC-8 boundary was not used to meet the FEMA's requirement to provide mapping through the full extent of the USGS HUC-8 watershed.

The HEC-RAS 2D computational mesh was created for the Cross Bayou Watershed based on the USGS HUC boundaries using ArcGIS toolsets, such as smoothing and simplification routines; ultimately, significantly reducing the need for manual edits to mesh cells within HEC-RAS that happen to generate errors. The 2D mesh consists of 686,016 cells with a 200-foot nominal mesh cell size. Factors that result in either larger or smaller cell sizes included:

- Proximity to the edge of the 2D mesh
- Presence of breaklines
- Refinement of mesh for significant flood control features (levees, dams, etc.)

A 1-minute time step was used in the HEC-RAS model, applying the Diffusion Wave (simplified Full Momentum) equations.

2.2.1 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires establishing a 2D computational mesh boundary, and often requires defining inflow boundary conditions in addition to excess precipitation applied to the mesh. For the Cross Bayou basin, an inflow hydrograph from Caddo Lake was used, along with excess precipitation applied to the mesh. Figure 2.2 shows the 2D computational mesh for the Cross Bayou basin, along with USGS peak streamflow gages pertinent to the study. Figure 2.3 shows the inflow boundary condition location for the Caddo Lake basin.

The development of the inflow hydrographs, and excess precipitation hyetographs for the 2D mesh, is described in the following Section 2.2.2.

Outflow boundary conditions (from the computational 2D mesh) were utilized along basin boundaries. Unique outflow boundaries were established for obvious riverine outflows, while the remaining boundaries were defined as continuous boundaries to allow drainage from adjacent basins to leave the model area freely. Normal depth was used for non-unique outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain data.

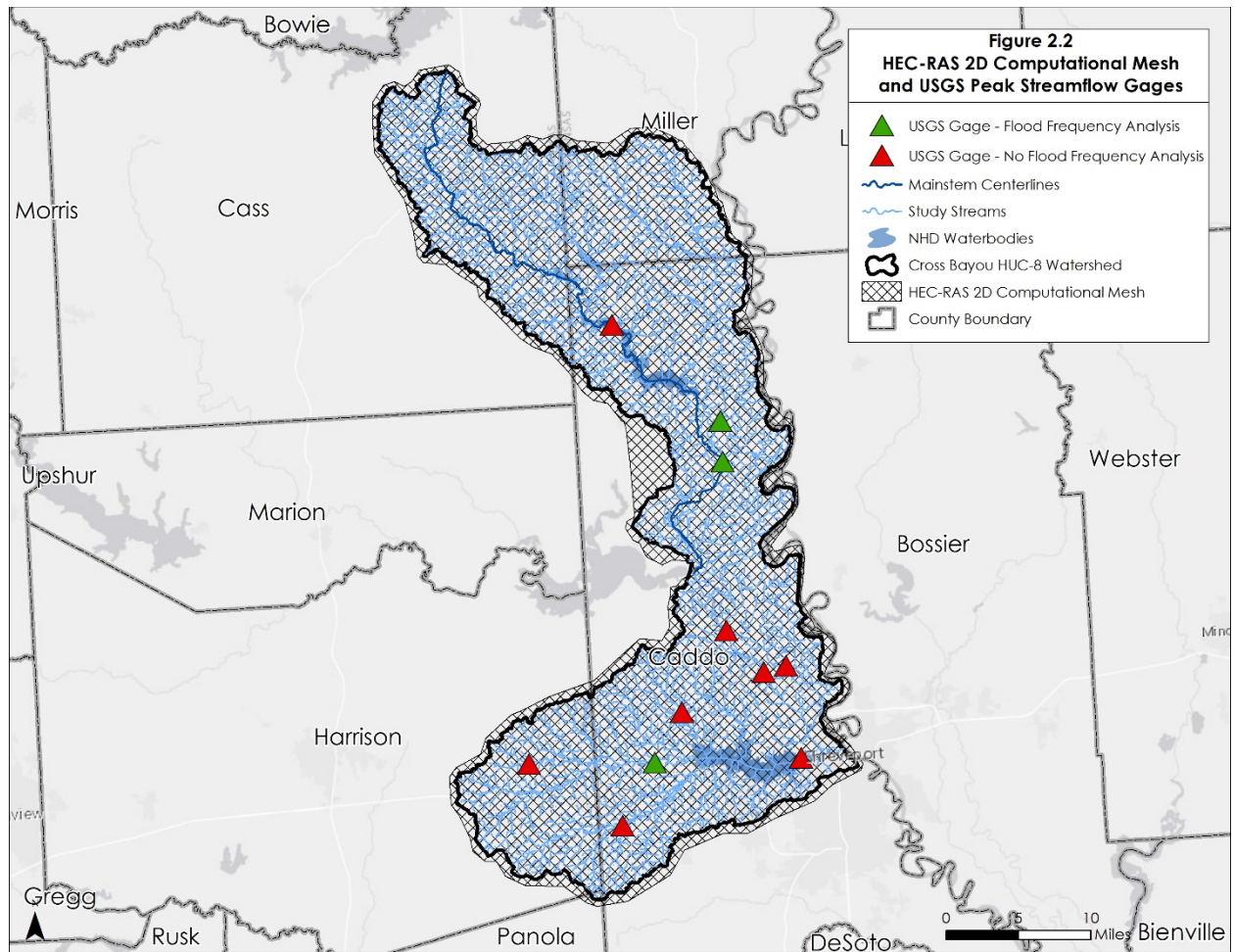


Figure 2.2: HEC-RAS 2D Computational Mesh and USGS Peak Streamflow Gages

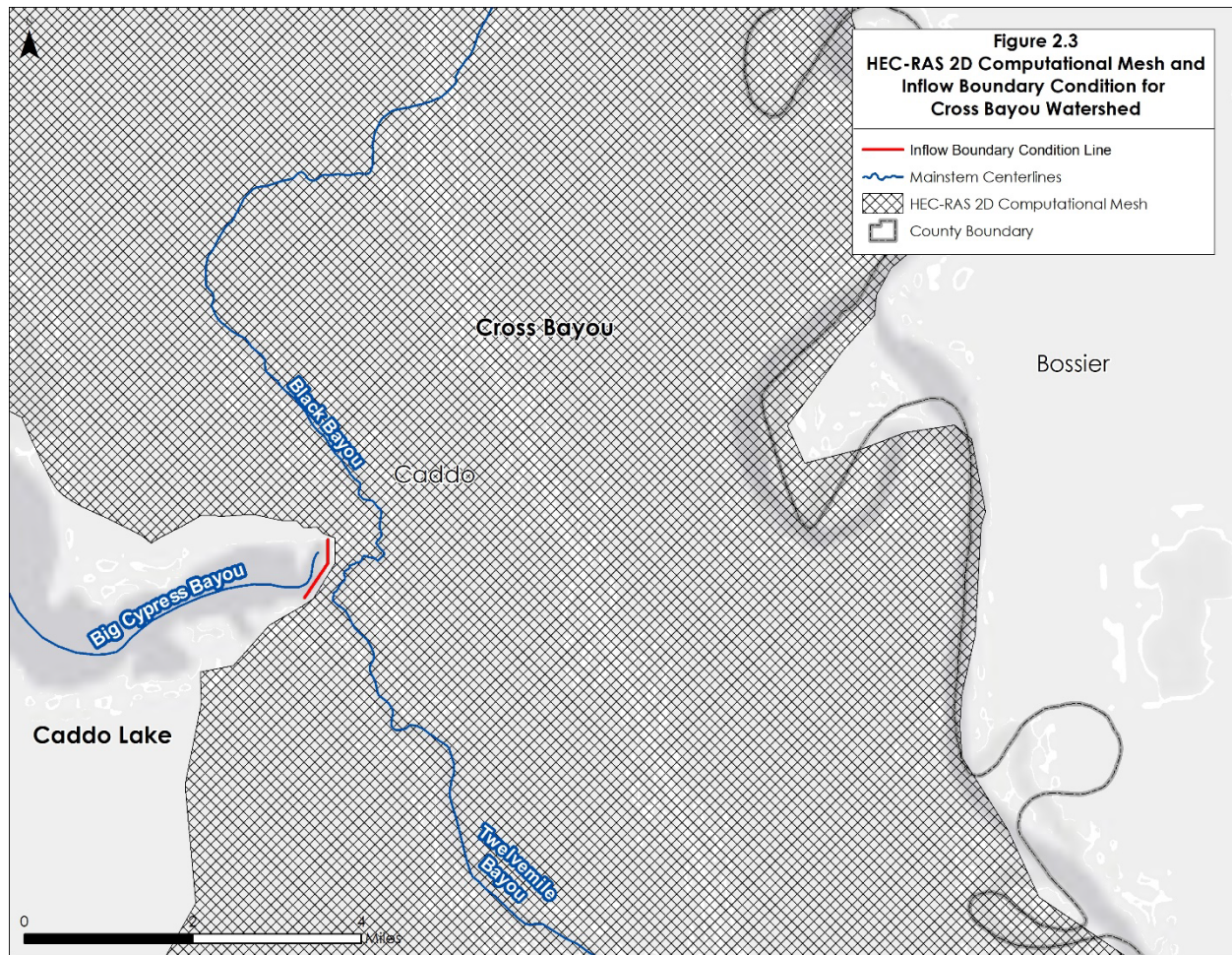


Figure 2.3: HEC-RAS 2D Computational Mesh and Inflow Boundary Conditions for Caddo Lake HUC

2.2.2 Hydrology

HEC-HMS, Version 4.8, was used solely for the development of excess precipitation hyetographs which were applied to the 2D mesh. Precipitation frequency data published in NOAA Atlas 14; Volume 11 Version 2.0 (NOAA, 2018) were used for this study. These data were obtained from NOAA's Precipitation Frequency Data Server (PFDS) (<http://hdsc.nws.noaa.gov/hdsc/pfds/index.html>). The 10-, 4-, 2-, 1-, and 0.2-percent annual chance 24-hour precipitation depths for the watershed were determined by area-weighted intersection of gridded PFDS data within the study area. Excess precipitation for the 2D mesh was developed as described in Section 2.2.2.1. Inflow hydrographs were developed for Cross Bayou from Caddo Lake.

A total of 11 USGS gages are found within the Cross Bayou Watershed. Six of these gages had only recorded water surface elevation and no peak flow data so these gages were not included in the analysis. The USGS Gage No. 07346450 – Black Bayou at Rodessa, LA had only 17 points of record and was thus excluded from the analysis due to insufficient data. The USGS Gage No. 07348000 – Twelvemile Bayou near Dixie, LA experienced multiple changes in datum with more recent flow and depth data unavailable, therefore, this gage was also excluded from the analysis. The remaining three (3) USGS gages found within the Cross Bayou Watershed were leveraged to estimate peak flows for model validation purposes, as discussed in Section 2.3.1. The gages utilized for this study are presented in Table 2.3.

Table 2.3: USGS Peak Streamflow Gages

Gage ID	Flooding Source and Location	Published Drainage Area (mi ²)	Period of Record
07344450	Paw Paw Bayou nr Greenwood, LA	81	1956-2020
07347000	Kelly BYU nr Hosston, LA	116	1945-1969
07347500	Black BYU nr Gilliam, LA	364	1943-1971

Annual chance peak flows were calculated at each gage using USGS Bulletin 17B and 17C (EMA) methodology. The peak flows were computed using both methodologies and evaluated based on confidence of the gage analysis. Calculated discharges for the 1%, 1% plus, and 1% minus events were used for comparison of flow validation within the upper (1% plus) and lower (1% minus) confidence intervals, are presented in Table 2.4 for the gage utilized in this study.

Table 2.4: USGS Peak Streamflow Gage Analysis Results

Gage ID	Flooding Source and Location	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
07344450	Paw Paw Bayou nr Greenwood, LA	17,410	13,750	23,440
07347000	Kelly BYU nr Hosston, LA	2,854	2,561	3,282
07347500	Black BYU nr Gilliam, LA	9,589	7,786	12,680

2.2.2.1 Excess Precipitation for 2D Computational Mesh

HEC-HMS, Version 4.8, was used to apply the SCS Curve Number method to calculate losses and define excess precipitation for each watershed. Temporal distributions of point rainfall totals were defined using frequency distributions. The plus and minus standard error for the 1-percent annual chance precipitation

depths were determined as the upper and lower 84% confidence limits on the nominal 1-percent depth, assuming a normal distribution of the logarithms for the precipitation depths.

In addition to recurrence interval precipitation estimates, NOAA Atlas 14 provides 90% confidence intervals of reported precipitation values. On a normal distribution curve, 90% confidence intervals (i.e. the upper and lower 95% confidence limits) correspond to ± 1.645 standard deviations. The 1% plus and minus events are defined to be one standard deviation above and below the 1% event

Curve Numbers were computed by intersecting the National Land Cover Dataset (NLCD) 2019 coverage and NRCS soils data based on the matrix presented in Table 2.5.

Table 2.5: Land Use-Soils-CN Matrix for Computing Initial Curve Numbers

LU_GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	99	99	99	99
21	Developed Open Space	49	69	79	84
22	Developed Low Intensity	61	75	83	87
23	Developed Medium Intensity	81	88	91	93
24	Developed High Intensity	89	92	94	95
31	Barren Land	39	61	74	80
41	Deciduous Forest	30	55	70	77
42	Evergreen Forest	30	55	70	77
43	Mixed Forest	30	55	70	77
52	Shrub Scrub	30	48	65	73
71	Herbaceous	49	62	74	85
81	Hay Pasture	39	61	74	84
82	Cultivated Crops	51	67	76	80
90	Woody Wetlands	72	80	87	93
95	Emergent Herbaceous Wetlands	72	80	87	93

The time of concentration for the study area was approximated as the square root of the drainage area, then multiplied by 0.6 to compute the lag time. The lag time does not impact the excess rainfall hyetograph, so it was not necessary to compute a more accurate basin travel time. The table below shows the curve number and lag time values used in this study.

Table 2.6: Rainfall-Runoff Parameters (Curve Number, Lag Time)

Sub-basin Description	CN	Tlag (min)
Cross Bayou	74	1,004

NRCS rainfall-runoff methods were used to define excess precipitation applied to the 2D mesh, including curve numbers for defining rainfall losses and lag time for transforming the runoff temporally. No routing was considered in the rainfall-runoff modeling. Frequency storm distributions were used for defining temporal distributions of point rainfall totals. Weighted average rainfall depths were calculated for the 10-, 4, 2, 1, 0.2-percent ACEs. The weighted average rainfall depths for 1-percent plus and 1-percent minus rasters were also calculated using the upper and lower confidence intervals for the 1-percent event. These steps were performed for durations of 5-min, 15-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr and 24-hr. The weighted average rainfall depths were used to determine the excess precipitation in the HEC-HMS model.

Areal reduction was applied using TP40 curves and an assumption of storm area equivalent to approximately one half of the total study area. Table 2.7 provides the precipitation totals used for determining excess precipitation.

Table 2.7: Precipitation Totals for HEC-RAS 2D Computational Mesh (post ARF)

Sub-basin Description	Percent Annual Chance Precipitation Total (in)	Rainfall Duration (in)							
		5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
Cross Bayou	10yr	0.70	1.29	2.54	3.20	3.62	4.40	5.25	6.18
	25yr	0.82	1.52	3.01	3.82	4.36	5.35	6.43	7.58
	50yr	0.92	1.69	3.38	4.32	5.33	6.12	7.41	8.76
	100yr	1.01	1.87	3.76	4.83	5.58	6.95	8.47	10.04
	100yr minus	0.81	1.49	3.01	3.89	4.51	5.66	6.93	8.26
	100yr plus	1.21	2.24	4.50	5.76	6.64	8.25	10.00	11.81
	500yr	1.25	2.29	4.70	6.12	7.18	9.13	11.27	13.44

Figure 2.4 shows the hyetographs applied to the 2D computational mesh.

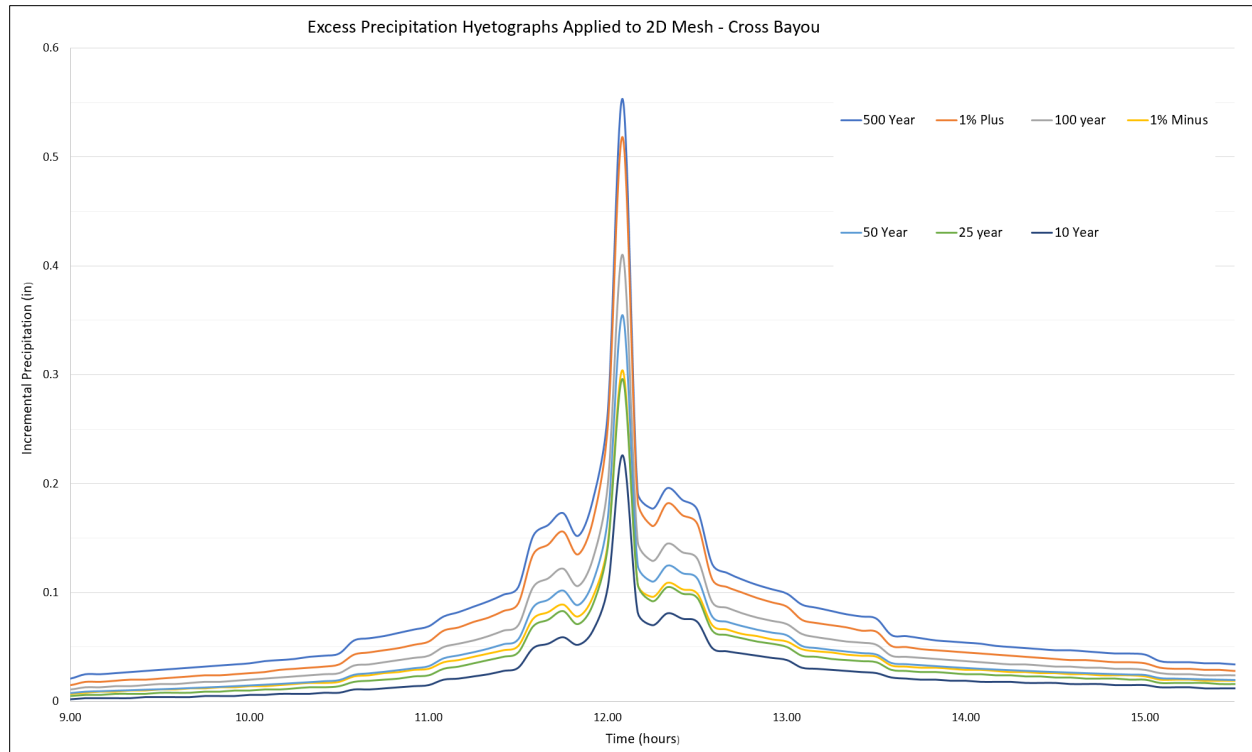


Figure 2.4: Excess Precipitation Hyetographs Applied to the Computational Mesh

2.2.2.2 Rainfall-Runoff Hydrograph Boundary Conditions

This section discusses the drainage areas for which inflow hydrographs, developed from rainfall-runoff modeling, were used as boundary conditions to the 2D computational mesh. Figure 2.5 shows the inflow hydrographs from Caddo Lake applied to the 2D computational mesh. Minor instability in the lower portion of the rising limb was noted but does not impact the peak model results for flow or water surface elevation.

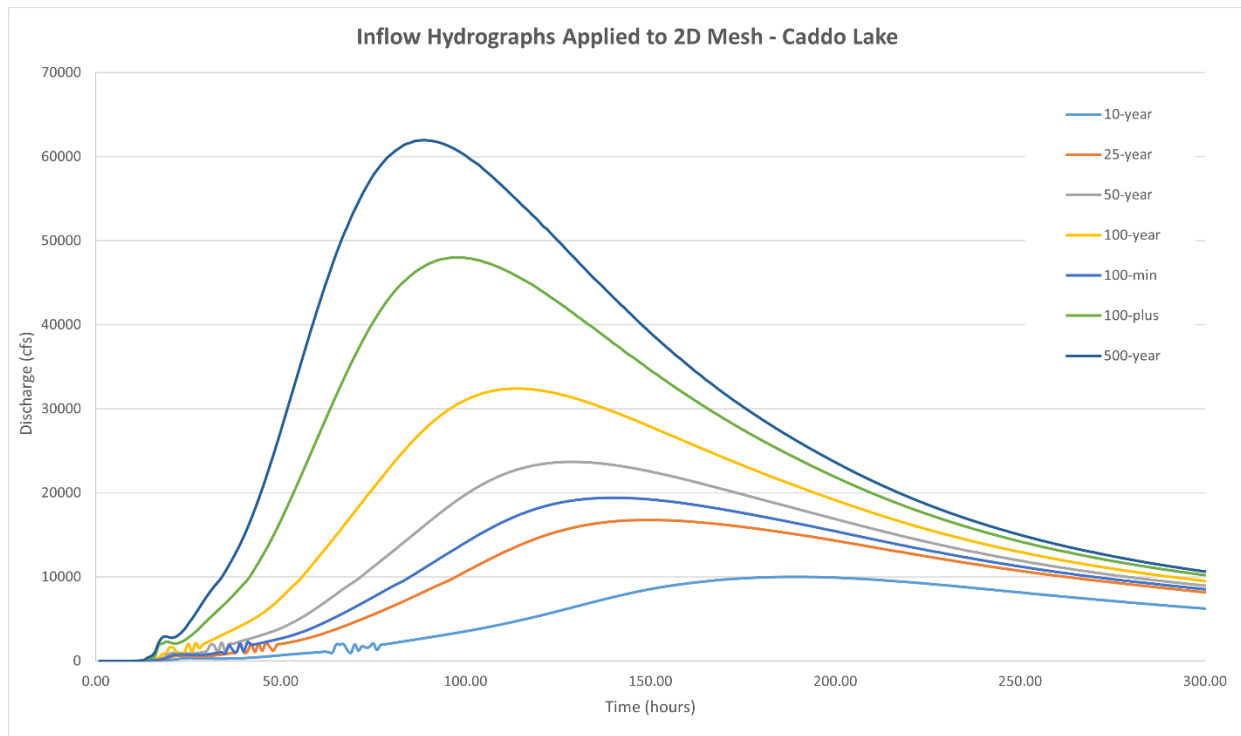


Figure 2.5: Caddo Lake Basin Contributing Drainage Area Inflow Hydrographs

2.2.3 Hydraulics

This section describes the remaining hydraulic modeling considerations, including implementation of Manning's roughness, breaklines, and hydraulic structures within the 2D computational mesh.

2.2.3.1 Roughness Coefficients

A Manning's n roughness coverage was developed for the 2D computational mesh using typical values for roughness for given NLCD land classifications. In several areas, the channel section land use indicated a Manning's n -value inappropriate for channel conveyance. A 30-foot buffer zone was created around each stream centerline to create a main channel roughness zone. The channel roughness zone was given a Manning's n value of 0.045 to ensure the channel 2D cells have appropriate conveyance with the value being taken from the HEC-RAS User's Manual. A higher roughness coefficient was utilized for barren land based on regionally appropriate values. The table below shows a typical land use-roughness matrix used in defining the roughness coverage for the study area.

Table 2.8: NLCD 2019-Manning's N Roughness Matrix

NLCD Classification	Manning's N	Minimum	Normal	Maximum
Open Water	0.030	0.025	0.038	0.050
Developed, Open Space	0.050	0.030	0.040	0.050
Developed, Low Intensity	0.070	0.060	0.090	0.120
Developed, Medium Intensity	0.100	0.080	0.120	0.160
Developed, High Intensity	0.120	0.120	0.160	0.200
Barren Land	0.050	0.023	0.025	0.030
Deciduous Forest	0.100	0.100	0.150	0.200
Evergreen Forest	0.100	0.080	0.120	0.160
Mixed Forest	0.100	0.080	0.140	0.200
Scrub/Shrub	0.070	0.070	0.115	0.160
Grassland/Herbaceous	0.050	0.025	0.038	0.050
Pasture/Hay	0.050	0.025	0.038	0.050
Cultivated Crops	0.050	0.020	0.035	0.050
Woody Wetlands	0.100	0.045	0.098	0.150
Emergent Herbaceous Wetland	0.100	0.050	0.068	0.085
Main Channel ¹	0.045			

Source: HEC-RAS 2D Modeling User's Manual

¹ Clean, winding, some pools and shoals, some weeds and stones, lower stages, more ineffective slopes and sections

2.2.3.2 Breaklines

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including, road embankments and hydraulic structures as well as stream centerlines. Road embankments were identified in ArcGIS and imported into HEC-RAS as breaklines to ensure that water was not routed past roads until it was deep enough to overtop the road. County, interstate, state recognized, and U.S. roads were incorporated for road breaklines from the ESRI North America Detailed Streets layer. The stream centerlines were input as breaklines to ensure cells lined up perpendicular to the stream and to capture stream conveyance. Stream centerlines were simplified to speed up editing and run times in HEC-RAS. Levees from the National Levee Inventory, and railroads from the TIGER Railroads layer were also incorporated. Additionally, several private dams and embankments were added as breaklines to better represent flow patterns through and around these structures.

2.2.3.2.1 Roads

Culvert crossings specifically were identified by intersections of the stream centerlines and road lines by automated processes and were modeled by burning channels through the embankment in the DEM to prevent unnecessary impoundment of water. This approach was used for most hydraulic structures because it could be implemented in ArcGIS on a large scale with much less effort than alternative methods. Since this an automated process, it was not possible to isolate specific culverts to burn through the DEM, thus conservative assumptions on width of opening were applied to not overestimate the release of water through the crossing.

Bridge/culvert crossings that were not processed out of the terrain data were modeled by inserting v-notches into the road breaklines at the points of intersection with the bridge/culvert crossings. The v-notches cause the grid cells to realign around the embankment and allow water to be routed across the embankment without creating artificial backwater. An example of the v-notch breakline approach is shown below.

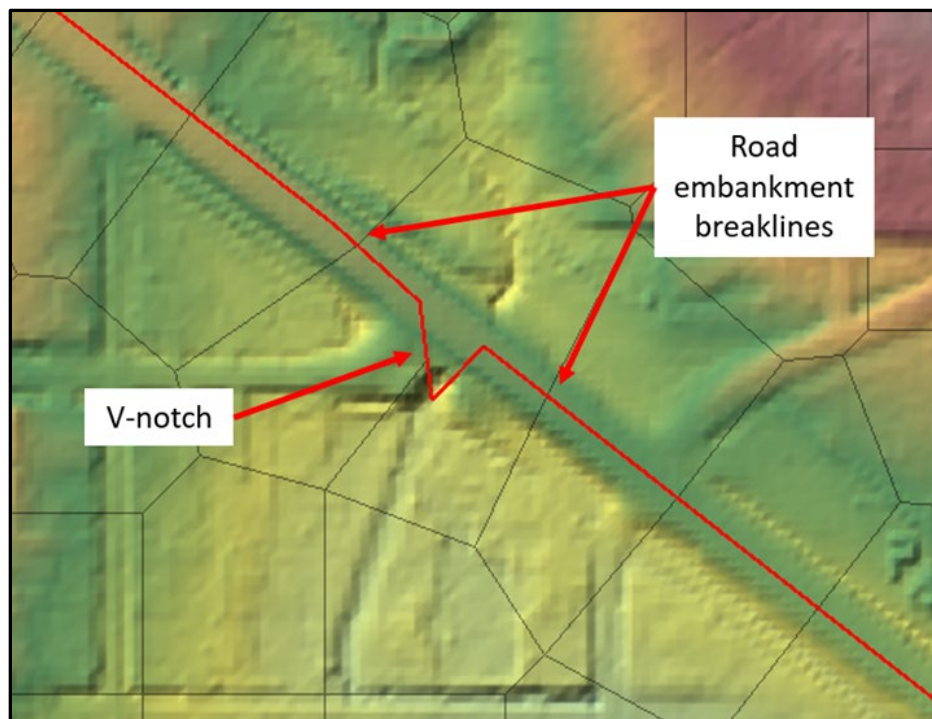


Figure 2.6 : V-Notch Breakline Approach at Bridge Crossing

2.2.3.3 Initial Conditions

Initial conditions were not used in the Cross Bayou 2D BLE model.

2.2.4 Special Assumptions

Within the Cross Bayou watershed is Cross Lake Dam. This dam, regulated by the United States Army Corp of Engineers (USACE), and reservoir provide significant flood protection within the watershed and thus required a more detailed modeling approach than typically used in BLE. Data for the dam was obtained from the USACE National Inventory of Dams (NID).

Cross Lake Dam consists of 189-foot-wide gate-controlled concrete ogee-crested principal/service spillway at crest elevation 171.2 ft-msl. The top of dam is at elevation 189.2 ft-msl. To model this structure in HEC-RAS, 2D connector lines were used. The principal/service spillway was modeled using a discharge rating curve developed using the weir equation outside of HEC-RAS with a weir coefficient of 3.1 representative of an ogee-crested spillway crest. Table 2.9 provides the summary information for the dam. Figure 2.7 shows the discharge rating curve applied for the spillway within the model.

Due to limited information and the high-level modeling approached used for BLE, additional information was not acquired for the gate operations of this structure. Future detailed studies in this area may consider coordination with USACE and the dam owner to represent the spillway discharges more accurately.

Table 2.9: Dam Information

Dam Name	ID Number	Source of Information	Owner	County	Outfall Structure Type	Top of Dam Elevation (ft)
Cross Lake	LA00346	USACE	City of Shreveport	Caddo	Gated service spillway	189.2

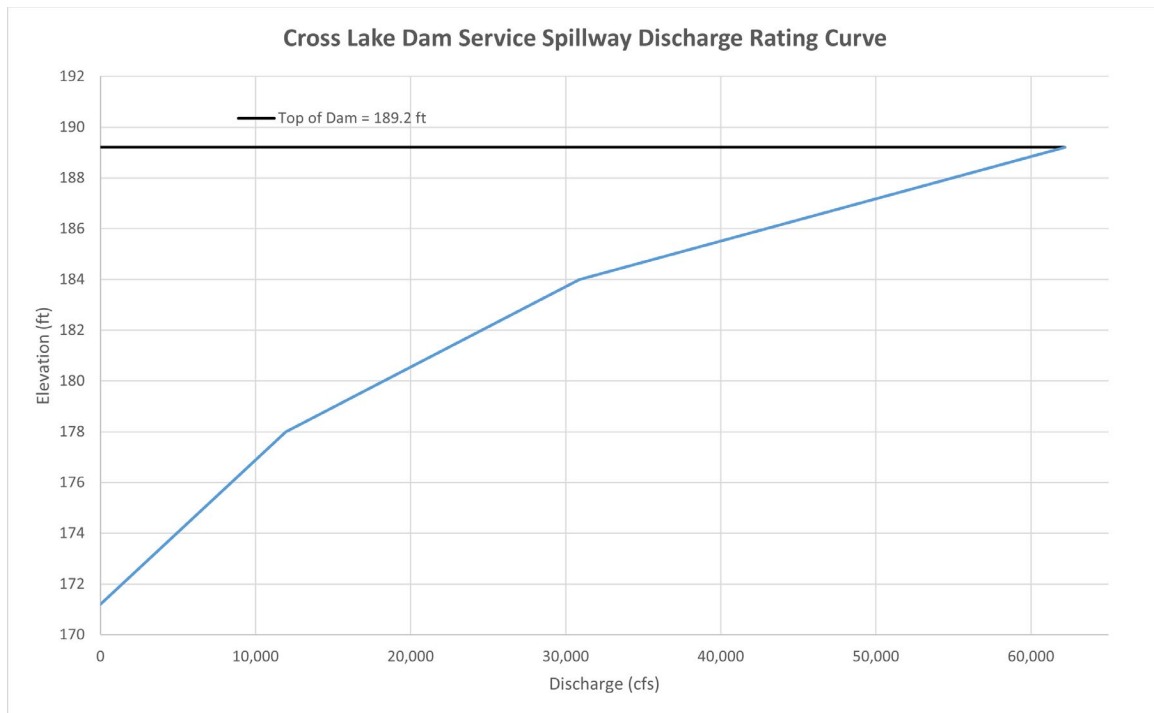


Figure 2.7 : Cross Lake Dam Service Spillway Discharge Rating Curve

2.3 Model Results

The 2D BLE results for the study produced an SFHA that compared reasonably well with the effective SFHA in most cases and provides additional estimated SFHA in areas that do not currently have an SFHA mapped. Table 2.10 shows a comparison of some the effective BFE data with the model results. The differences from the effective BFEs is largely due land use changes, topographic differences, and the change of rainfall data. While the results provide context for flood risk communication as part of the Discovery process, and are scalable, the results require further analysis to be used for regulatory purposes. The validity of the 2D BLE results should be verified through community work map meetings before being applied to a regulatory product.

Table 2.10: Effective and Model BFE Comparison

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
Audrey Lane Lateral	10,465	186	185.4	-0.6
Bickham Bayou	11,228	202	202.5	0.5
Black Bayou	9,600	227	229.0	2.0
Choctaw Bayou	22,046	208	205.9	-2.1
Country Club Lateral	4,229	192	189.0	-3.0
Cross Bayou	14,041	166	172.0	6.0
Cross Bayou Lateral	4,632	180	177.7	-2.3
Cross Bayou Tributary 1	2,300	210	212.8	2.8
Cross Bayou Tributary 2	4,502	217	221.0	4.0
Cross Bayou Tributary 3	5,500	246	249.2	3.2
Ford Park Lateral	3,520	191	192.3	1.3
Galaxy Lateral	6,550	187	177.2	-9.8
Green Oaks Lateral	400	176	176.8	0.8
Haw Creek	9,246	252	256.0	4.0
Hurricane Creek	4,160	255	251.3	-3.7
Logan Bayou	30,249	238	230.0	-8.0
McCain Creek	25,723	185	186.6	1.6
North Tributary to Black Bayou	4,070	245	244.0	-1.0
Page Bayou	25,300	207	206.4	-0.6
Page Bayou Tributary A	1,326	215	215.6	0.6
Rose Park Lateral	1,947	195	196.0	1.0
South Tributary to Black Bayou	2,090	238	231.0	-7.0
Twelve Mile Bayou	17,162	166	174.6	8.6

2.3.1 Calibration & Sensitivity Analysis

Known USGS gages within the model area with more than 10 years of flow record were used for calibration and validation of the 1-percent ACE. Peak flows within the model were compared with Bulletin 17B

Analyses and EMA (Bulletin 17C) analyses of the gage data using PeakFQ, Version 7.3. Results of the flow comparisons are presented in Table 2.11.

Table 2.11: 1% Annual Chance Reasonability Comparisons

Flooding Source	USGS Gage Used for Verification	HEC-RAS 6.1 (2D)		Reference	
		WSEL (ft)	Discharge (cfs)	WSEL (ft) ¹	Discharge (cfs)
Paw Paw Bayou	07344450	185.89	17,925	186.32	17,410
Kelly Bayou	07347000	186.73	2,304	186.47	2,854
Black Bayou	07347500	183.48	10,412	183.10	9,589

¹ Water surface elevation is approximate based on PeakFQ input data and adjusted to NVGD 29 Datum.

To determine which factors were significantly impacting the model results, a sensitivity analysis was run to evaluate the impact of five parameters including Manning's roughness values, breaklines, hydrologic losses, initial conditions, and boundary conditions. Further discussion of the roughness coefficients can be found in Section 2.2.3.1. It was determined that enforced breaklines at major roads and centerlines were needed and are discussed further in Section 2.2.3.2. No changes were made to the precipitation. Table 2.12 - 15 summarize the results of each run at each of the USGS gages.

Table 2.12: Sensitivity Analysis Results at USGS Gage 07344450

Run	Manning's N Zones	Breaklines ¹	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	19,312	185.8
2	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	17,909	185.6
3	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	17,909	185.9
4 ²	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	17,925	185.9
					Gage Analysis:	17,410	186.32 ¹

¹ Water surface elevation is approximate based on PeakFQ input data.

² Parameters from Iteration 4 were used for the final model.

Table 2.13: Sensitivity Analysis Results at USGS Gage 07347000

Run	Manning's N Zones	Breaklines ¹	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	2,324	186.9
2	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	2,304	186.7

Run	Manning's N Zones	Breaklines ¹	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
3	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	2,306	186.7
4 ²	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	2,304	186.7
					Gage Analysis:	2,854	186.47 ¹

¹ Water surface elevation is approximate based on PeakFQ input data.

² Parameters from Iteration 4 were used for the final model.

Table 2.14: Sensitivity Analysis Results at USGS Gage 07347500

Run	Manning's N Zones	Breaklines ¹	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	10,736	184.2
2	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	10,287	183.4
3	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	10,346	183.3
4 ²	Original Land Use	Original Breaklines	Excess Precipitation	Dry / 1min	Normal Depth	10,412	183.5
					Gage Analysis:	9,589	183.10 ¹

¹ Water surface elevation is approximate based on PeakFQ input data.

² Parameters from Iteration 4 were used for the final model.

2.4 Challenges

Major challenges included a lack of peak streamflow records within the watershed. There were only three gages with significant data to validate, though sufficient data was available to provide confidence in the results. Within the watershed, there are two distinct terrain types: high ground with distinct channels mainly in the northern half of the watershed and low, flat ground (mostly lakes) at the southern portion of the watershed. The difference in terrain caused the time step used to be a factor in model stability. It was determined that a smaller time step (1 minute) would be needed.

Additionally, Cross Bayou Watershed discharges into the Red River which has recently been studied by the USACE. This study, which has not been finalized by the USACE, provided revised terrain data within the model that incorporated survey and 1D cross sections which did not align with the best available LiDAR

data for this study. Due to the differences in terrain and this study not being released with final floodplain mapping along the Red River, it was not possible to cleanly tie-in the Cross Bayou Watershed BLE mapping to the Red River USACE study. This tie-in should be reviewed in future BLE maintenance cycles once the USACE study has been finalized with final mapping for the Red River.

The Caddo Levee System, a FEMA accredited levee system designated on the Caddo Parish effective FIRM dated May 19, 2014, separates the Cross Bayou Watershed from the Red River along the majority of the eastern watershed boundary. This BLE study provides flood risk analysis due to interior drainage to the west of the levee system and does not account for additional flood risk associated with flooding along the Red River. There may be additional flood risk in this area and should be reviewed with the completion of the USACE study.

Structures have not been added to the BLE model despite evidence of cross structures which allow the streams to convey water through numerous structures. In these locations, the model may be overestimating the water surface elevation upstream of the road until the road is overtopped and underestimating the water surface elevation downstream of the road.

HEC-RAS, Version 6.1, has an apparent bug that was identified in reviewing isolated areas of flooding. In these areas, the lower frequency events (ex. 10-percent) showed higher water surface elevations than the higher frequency events (ex. 0.2-percent). This was reviewed in multiple versions of HEC-RAS and was confirmed to occur in Version 5.7, 6.1 and 6.2. It is unknown why this may occur; however, the model does not experience instabilities and the mainstem floodplains have not shown this occurring when reviewing profile lines. In review of the model setup, stability and results, the flood extent results appear appropriate and impacts due to the bug are likely negligible.

HEC-RAS, Version 6.1 has a known error in the rain on mesh interpolation of flood depths between adjacent cells in the overbank area. This error produces artificially higher depths of flooding on the flood fringe referred to as cupping. Since this is a known issue in HEC-RAS and HEC is working on a solution, effort to remove these errors from the flood extents was not performed. Figure 2.12 below provides an example of cupping for reference. Once a solution is provided by HEC, it may be possible to update mapping to reduce and/or remove the cupping effects on the fringe of the floodplains.

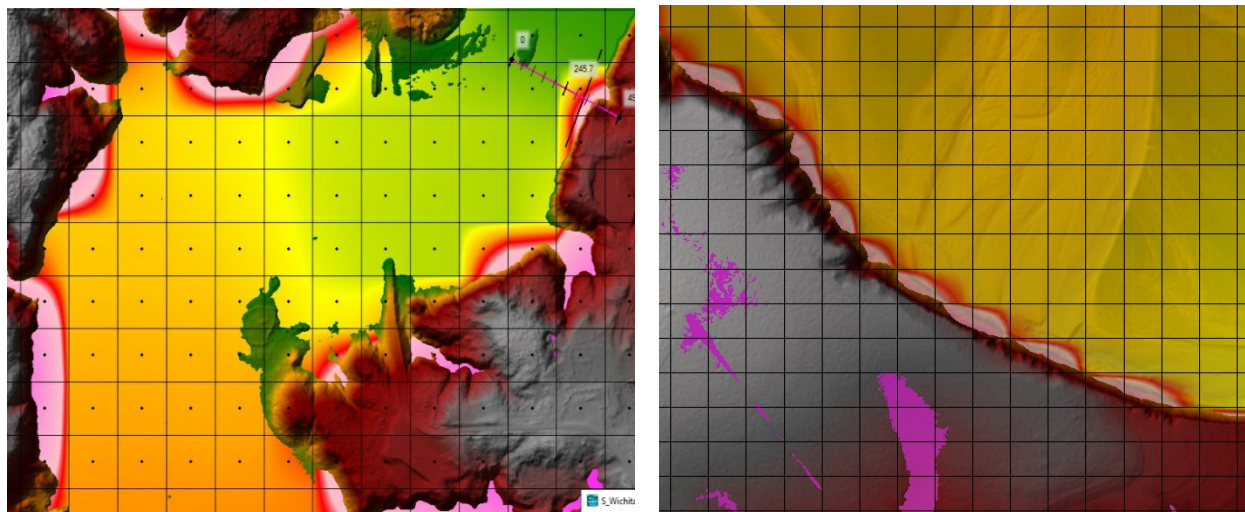


Figure 2.8: Cupping Example

2.5 Recommendations

This study provides significant information useful for flood identification and communication among those affected. The study is highly scalable, and stakeholder input and further analysis would enhance the product and inform implementation of regulatory flood hazard areas. In addition, the validity of the 2D BLE results should be verified through community work map meetings before being applied as a regulatory product.

03 Floodplain Mapping and Effective Zone A Validation

The following sections provide a synopsis of how raw modeled depths were translated into SFHAs. In addition to developing a new SFHA, the BLE model data was leveraged to validate the effective zone A studies within the project footprint. The results of the validation effort can be found below in Section 3.2.

3.1 Special Flood Hazard Area

3.1.1 Model Outputs

The floodplains are derived from the raw modeled depth grids using the maximum value. These depth grids are exported from HEC-RAS as TIFF format rasters with an interpolated rendering that slope values at the center and along the faces/edges of the computational mesh cells. Using GIS, the TIFF rasters are post processed into a 10-percent non-regulatory feature class, 1-percent ACE SFHAs and 0.2-percent shaded X polygons.

3.1.2 Methodology

The use of 2D modeling methods results in water surface elevation values at every cell in the model's computational mesh. In order to represent the desired model results and eliminate extraneous disconnected cells, post processing of the depth grids is required. For the purposes of the Cross Bayou BLE study, floodplain mapping delineation was completed using connected raster cells at the extent of the CNMS mapped and unmapped features in the project footprint. Converting the raster data to polygon features enabled an intersection of modeled results to the CNMS and effective zones to create the SFHA and 0.2-percent shaded X features. Because the new mapping, based on gridded engineering, retains the blocky shape of a raster, a simplification process was applied using GIS to smooth the boundaries using a 10-foot smoothing threshold. These processes remove unnecessary points, bends, and angles while preserving the natural shape of the polygon. Furthermore, small voids, or "holes" inside of the floodplain were aggregated with the larger surrounding polygons to merge them and make the floodplain complete. In alignment with the TWDB's 2D BLE Guidelines (May 2022) floodplain polygons were cleaned against the criteria provided below in Table 3.1 which provides thresholds for mapping removal based on depth and area of flood risk.

Table 3.1: Mapping Threshold Matrix

Area (ac)	Depth (ft)
< 0.33	-
0.33 - 0.5	< 0.33
0.5 - 1.0	< 0.25
1.0 - 2.0	<0.1

For example, if flooding polygons were disconnected from a flooding source and less than two acres in area and 0.1 feet of depth, the polygon was removed from the SFHA. These edits align to the mapping standards adopted by the TWDB and those required by FEMA.

In addition to the SFHA, all other flooding associated with the 1- and 0.2-percent raw results were retained as "on the shelf" data that may be leveraged for future needs and analysis. This information is available in the included Supplemental Data associated with this study.

3.1.3 Flood Hazard Area Layer

Special Flood Hazard Areas (SFHA), as noted above, were developed to at least the extent of the CNMS features and up to 0.1 square mile drainage area and effective zone A study locations. The Regional CNMS database, National Flood Hazard Layer, and paper inventory were used as reference data to ensure extent of the BLE results represents appropriate current flooding extent coverage, at a minimum.

The 0.2-percent flood areas were produced using the same methods as the 1% SFHA. After both layers were developed, a union of the two products was performed to develop the deliverable format EBF_E_FLD_HAZ_AR.

3.1.4 Mapping Considerations

3.1.4.1 Ponds

Numerous ponds exist through the Cross Bayou Watershed. Due to the nature of 2D BLE and the large mesh cells used for modeling, the entire extent of smaller, isolated ponding areas is not always fully mapped in the raw model output. To identify flood risk in these areas, the pond footprints were merged in by automated processes using the best available National Hydrography Dataset. This dataset has its own limitations in that it is not current to current topography or LiDAR and may not align completely to the present-day pond footprints. However, it was used as the best available at the time of the study. A nominal depth of 0.1-foot was used for any areas merged into the floodplain that were not in the raw model results and the water surface elevation was interpolated. The water surface elevations in these areas should not be considered correct and would require further study to refine the correct water surface elevation based on detailed modeling.

3.1.4.2 Mapping Tie-Ins

Watershed tie-ins required manual review and coordination between HUCs to ensure tie-ins could be met within the required 0.5-foot FEMA requirement. For Cross Bayou, a significant tie-in occurs downstream of the Caddo Lake watershed, on the downstream side of the Caddo Lake Dam. This portion of the Caddo Lake Watershed was modeled in both the Caddo Lake 2D HEC-RAS model and the Cross Bayou 2D model using an overlapping mesh to determine the appropriate tie-in location. The Caddo Lake results replaced mapping in a portion of the Cross Bayou HUC.

As discussed in Section 2.4, Cross Bayou Watershed discharges into the Red River which has recently been studied by the USACE. Due to the differences in terrain and this study not being released with final floodplain mapping along the Red River, it was not possible to cleanly tie-in the Cross Bayou Watershed BLE mapping to the Red River USACE study. This tie-in should be reviewed in future BLE maintenance cycles once the USACE study has been finalized with final mapping for the Red River.

Minor fringe watershed tie-ins to adjacent HUCs were checked to ensure they met the 0.5-foot tie-in requirement. Mapping changes to the floodplain extents and grids were not made to the minor fringe tie-ins if within the 0.5-foot mapping tolerance.

3.1.4.3 Centerline Alignment

After completion of the FLD_HAZ_AR, the S_WTR_LNs (centerlines) were reviewed for containment within the 1-percent ACE floodplain. Any centerlines that were 50-feet or greater in length outside of the 1-percent floodplain extent were realigned for containment.

3.2 Validation of Effective Zone A SFHA

The following summarizes the results of the CNMS validation assessments for the effective Zone A studies in the Cross Bayou Watershed.

3.2.1 Initial Assessment A1 – Significant Topography Update Check

The significant topography update check determines whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. If the effective studies were based on topographic data derived from LiDAR then A1 is set to PASS. If the effective studies were not based on LiDAR then A1 is set to FAIL. If the topographic data source was not provided, then an assumption of studies with effective dates prior to 2000 were assumed to be non-LiDAR based studies and studies completed after 2000 were assumed to have used LiDAR.

3.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

The significant hydrology changes check determines whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent ACE flow. New regression equations were made available for Texas in 2009. Thus, effective studies completed prior to 2009 are assumed to FAIL the A2 assessment while studies completed after 2009 are assumed to PASS the A2 assessment. If already attributed as PASS in the CNMS database, then A2 classification was maintained as such.

3.2.3 Initial Assessment A3 – Check for Significant Development

The significant development check, using the National Urban Change Indicator (NUCI) dataset, assesses increased urbanization in the study watershed. If the percentage of urban area within a HUC-12 watershed containing the effective Zone A study is 15 percent or more and has increased by 50 percent or more since the effective analysis, the study would fail this check. The check for significant development in the Cross Bayou Watershed was completed by evaluating percentage of urban change at the HUC-12 level. The entire watershed is classified as rural, and all reaches were set to PASS for this assessment.

Table 3.2 presents the summarized results of checks A1 through A3.

Table 3.2: A1-A3 Validation Results

Assessment Checks	Pass / Fail	Notes
A1 – Topography	Pass/Fail	LiDAR significantly better than effective USGS topo source/Effective mapping leveraged LiDAR data.
A2 – Hydrology	Pass/Fail	Effective hydrology methods are unknown
A3- Development	Pass/Fail	Less than 15% of study area is under urban cover/>50% increase in urban area in an urban HUC-12

3.2.4 Validation Check A4 – Check of Studies Backed by Technical Data

Zone A studies that pass all initial assessment checks described above may be categorized as “Valid” in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If the effective Zone A study passes all initial assessment checks, but is not supported by modeling, or if the original engineering method used is unsupported or undocumented, a comparison of the BLE results and effective Zone A’s is performed.

If the effective study was model backed, then A4 is set to PASS. If the effective study was not model backed, then A4 is set to FAIL. If it was unknown if the study was model backed or not, then it was assumed it was not model backed and the A4 assessment was set to FAIL.

Due to lack of documentation of the original engineering methods in the Cross Bayou Watershed, check A4 has been marked as FAIL for most parts of this study and left as PASS if it was already identified as such in previous CNMS.

3.2.5 Validation Check A5 – Comparison of BLE and Effective Zone A

The effective Zone A comparison was performed at the full extent of the Cross Bayou Watershed. The validation of the effective Zone A boundaries using 2D flood hazard products differ from the standard 1D methods due to the lack of cross sections and their use with standard FBS methodology. For this 2D study, the effective A zone boundaries were compiled using the National Flood Hazard Layer and Core Logic effective digital uplift product. These data were dissolved to one continuous A-zone layer, which then had test points placed along its perimeter at least every 200 feet.

For each test point, a 75-foot buffer polygon was created. Using this buffer, the minimum and maximum values of the DEM were extracted, as a proxy for the effective base flood elevation. The minimum value of the 1% minus raster, and the maximum value of the 1% plus raster are also extracted. These 1% plus maximum and 1% minus minimum values are products of the new 2D BLE study and act as the vertical tolerance. The test point passes if the DEM maximum value is less than or equal to the 1% plus maximum value and the DEM minimum value is greater than or equal to the 1% minus minimum value. This can be visualized as a short 75-foot radius cylinder, with a height of 1% plus maximum – 1% minus minimum. This test verifies that at least one point from the ground surface (i.e. proxy BFE) falls both vertically and horizontally within this range.

3.2.6 Validation Results

All 647.2 total miles of available CNMS features representing the effective Zone A studies were categorized as shown in Table 3.3 and illustrated in Figure 3.1. Table 3.4 summarizes the validation results based on the individual HUC 12 watersheds within Cross Bayou Watershed.

Table 3.3: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	290.1
UNVERIFIED	BEING STUDIED	357.1

Table 3.4: HUC 12 Zone A Validation Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)
Watershed Name	Watershed Number					
West Fork Kelly Bayou	111403040101	1,180	561	619	52.5	FAIL
East Fork Kelly Bayou	111403040102	1,057	348	709	67.1	FAIL
Outlet Kelly Bayou	111403040103	6,336	498	5,838	92.1	PASS
Butler Creek-Black Bayou	111403040201	2,197	449	1,748	79.6	FAIL
Hurricane Creek-Black Bayou	111403040202	1,819	475	1,344	73.9	FAIL
Upper State Line Creek	111403040203	1,724	576	1,148	66.6	FAIL
Lower State Line Creek	111403040204	1,478	357	1,121	75.8	FAIL
Clear Creek-Black Bayou	111403040205	3,107	813	2,294	73.8	FAIL
Black Bayou Lake	111403040206	3,603	257	3,346	92.9	PASS
Outlet Black Bayou	111403040207	7,787	2,392	5,395	69.3	FAIL
Swift Bayou	111403040301	11,203	1,396	9,807	87.5	PASS
Cottonwood Bayou	111403040302	9,264	581	8,683	93.7	PASS
Twelvemile Bayou Outlet	111403040303	2,866	1,393	1,473	51.4	FAIL
Bullard Creek	111403040401	1,017	288	729	71.7	FAIL
Upper Paw Paw Bayou	111403040402	1,711	639	1,072	62.7	FAIL
Lower Paw Paw Bayou	111403040403	2,124	275	1,849	87.1	PASS
Piney Bayou	111403040501	1,543	43	1,500	97.2	PASS
Upper Cross Bayou	111403040502	1,188	379	809	68.1	FAIL
Lower Cross Bayou	111403040503	2953	241	2712	91.8	PASS
Upper Cross Lake	111403040504	2021	80	1941	96.0	PASS
Choctaw Bayou	111403040505	327	25	302	92.4	PASS
Lower Cross Lake-Outlet Cross Bayou	111403040506	163	17	146	89.6	PASS

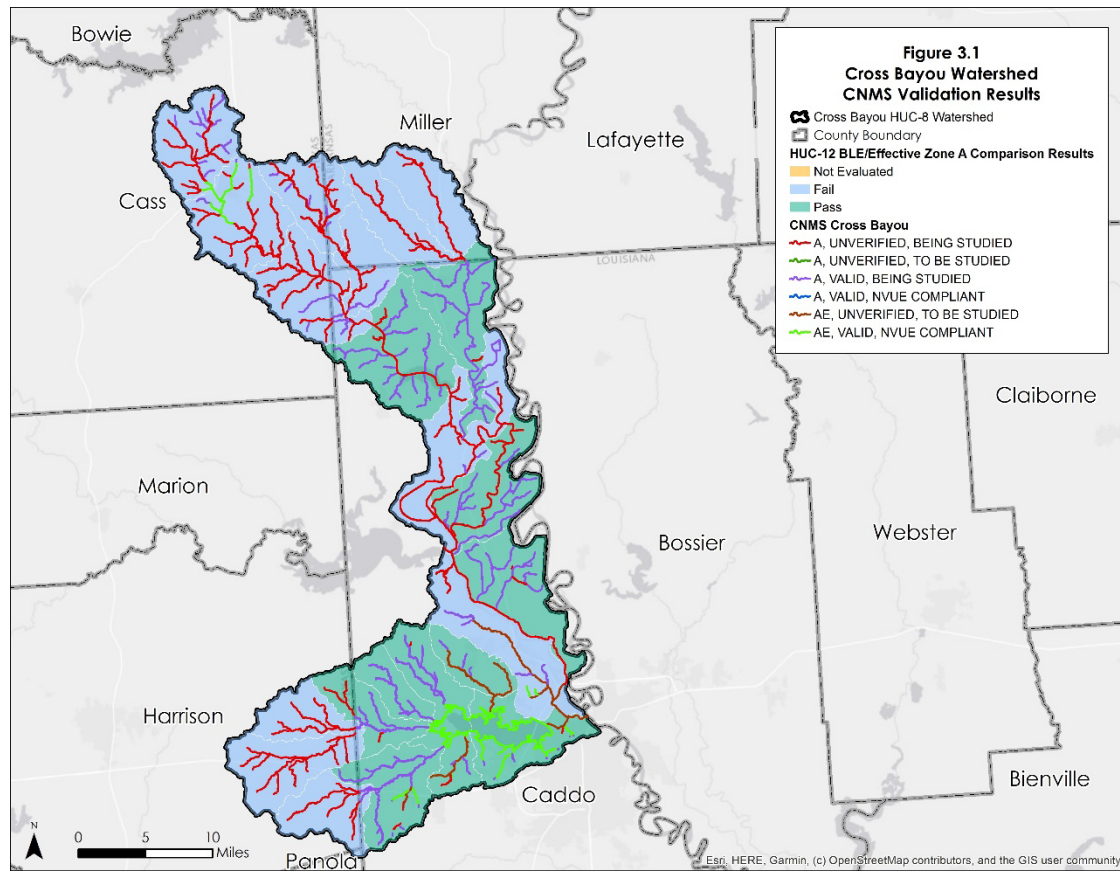


Figure 3.1: Cross Bayou Watershed CNMS Validation Results

3.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent ACE depth grid was used to calculate the potential flood losses. The loss results are stored in the S_FRAC_AR spatial file within the FRD geodatabase. All results are reported in whole dollar values.

Hazus Version 5.1 (SP02) was used for the basic and refined loss analysis.

The losses are reported via census blocks. It is important to note that Hazus Version 5.1 (SP02) uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by bodies of water, wetlands, or forests) from the census blocks, changing their shape and reducing their size in these areas. For more information on dasymetric data visit FEMA's Media Library for the Hazus-MH Data Inventories: Dasymetric vs. Homogenous, or Hazus 3.0 Dasymetric Data Overview.

Hazus analysis was performed by county within the project watershed extents for the 1-percent return period to ensure proper model processing. A summary of results per county for the 1-percent ACE scenario is shown in Table 3.5.

Table 3.5: Hazus 5.1 (SP02) Results for 1-percent-annual-chance (100 year) scenario for Cross Bayou Watershed, Texas

County/Parish	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Arkansas			
Miller	\$6,909,000.00	\$104,251,000.00	\$61,869,000.00
Louisiana			
Caddo	\$914,906,000.00	\$6,712,279,000.00	\$4,600,543,000.00
Texas			
Cass	\$137,878,000.00	\$1,251,564,000.00	\$807,961,000.00
Harrison	\$18,940,000.00	\$431,307,000.00	\$255,901,000.00
Panola	\$22,000.00	\$4,276,000.00	\$2,137,000.00
Total	\$1,078,655,000.00	\$8,503,677,000.00	\$5,728,411,000.00

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