Aranssas Bay HUC-8 Watershed, Texas
Base Level Engineering (BLE) Results

MAS No. FY20-CTP-FRP-MAST#2 T.O. No. 8

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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-8 watershed No. 12100405 – Aransas Bay in South Central 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 standard 2D model development procedures to produce 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 1.1.

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 model using HEC-RAS. This 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 this watershed 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 lists the stream miles associated with this validation analysis.

Table ES-1.1: Summary of Stream Miles

Source	Aransas Bay Stream Miles
CNMS	116

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
Unverified	To be Studied	110.8
Valid	NVUE Compliant	5.2

01 Introduction

Recent innovations and efficiencies in floodplain mapping have allowed the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA)to develop a process called formerly known as First Order Approximation (FOA), now called Base Level Engineering (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 standard 2D model development procedures to produce 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 Mapping, Assessment and Planning (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 Aransas Bay HUC-8 Watershed (12100405) in South Central Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Goliad, Refugio, Aransas, and San Patricio Counties, and include the following communities: The Cities of Rockport, Aransas Pass, Gregory, Ingleside, and Ingleside on the Bay, and the Towns of Fulton and Bayside. The study area consists of five HUC-10 basins: San Antonio River-Guadalupe River, Copano Creek, Saint Charles Bay, Copano Bay, and Aransas Bay. Figure 1.1 shows the location and extent of the Aransas Bay HUC-8 watershed.

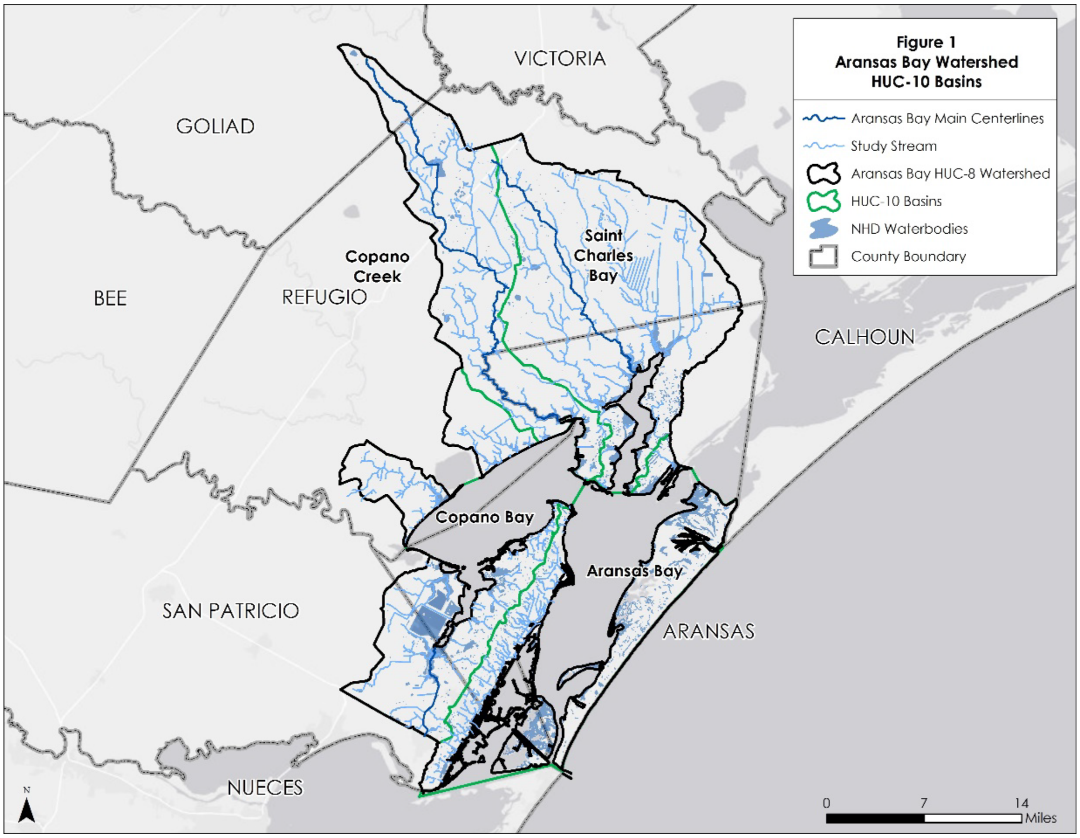

Figure 1.1: Aransas Bay Watershed

02 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2-dimensional (2D) hydraulic engineering analysis for the Aransas Bay Watershed. Inputs such as elevation data, hydrology for rain-on-grid and inflow hydrographs, and hydraulic analyses and variables are defined herein. HEC-RAS 5.0.7 rain-on-grid utility was applied in the production of the 2D BLE products produced for this watershed.

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 Aransas Bay 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 Aransas Bay 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 below. 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 Aransas Bay Watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the Aransas Bay BLE project footprint. Figure 2.1 depicts the datasets identified for leverage across the project area. FEMA, NOAA, U.S. Geological Survey (USGS), and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

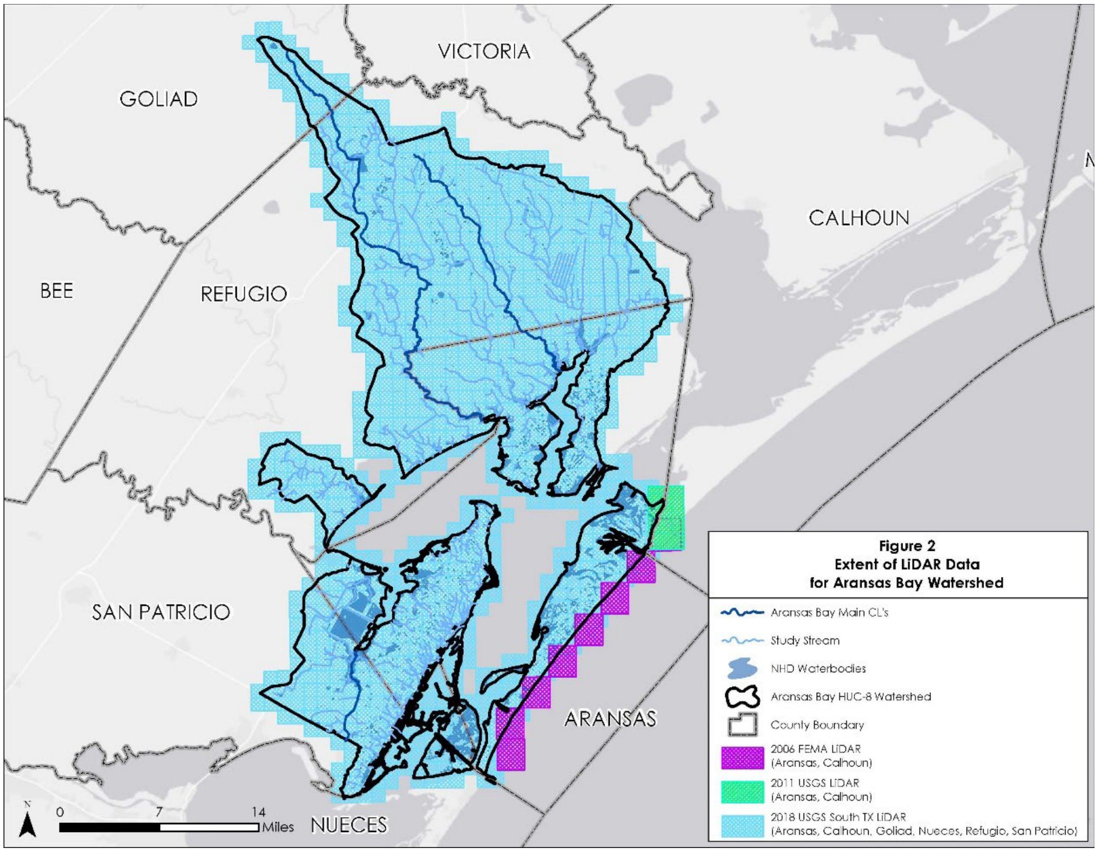

Figure 2.1: Aransas Bay Watershed BLE Source Terrain Data

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 Aransas Bay 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 Aransas Bay Watershed

Year	Description	Data Type	RMSE	Source/Owner
2018	2018 USGS South TX LiDAR (Aransas, Calhoun, Goliad, Nueces, Refugio, San Patricio)	Airborne LiDAR	0.089	USGS
2011	2011 USGS LiDAR (Aransas, Calhoun)	Airborne LiDAR	0.057 m	USGS
2006	2006 FEMA LiDAR (Aransas)	Airborne LiDAR	13.88 cm	FEMA

2.1.2.1 Aransas Bay Watershed Source Terrain Data

The source elevation data for the Aransas Bay Watershed are DEMs derived from 2018 and 2011 USGS and 2006 FEMA LiDAR data. Preprocessed Bare-earth, hydro-enforced DEMs from the acquiring entity (via TNRIS) 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. Please see brief descriptions of the LiDAR sources below.

2018 USGS South TX LiDAR, Aransas, Calhoun, Goliad, Nueces, Refugio, San Patricio – The 2018 USGS LiDAR was acquired from January 2018 to February 2019 and was collected with a point spacing of 70 cm. The measured RMSE was documented at 0.089 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) x 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.

2011 USGS LiDAR, Aransas, Calhoun, TX – The 2011 USGS LiDAR was acquired between December 2010 and February 2011 and collected with a point spacing of 150 cm. The Fundamental Vertical Accuracy (FVA) of the Classified Bare Earth files for the project area achieved an RMSE of 0.057 meters.

2006 FEMA LiDAR, Aransas, TX– The data for the 2006 FEMA LiDAR in Aransas County was collected with a point spacing of 140 cm. The accuracy assessment yielded a RMSE of 13.88 cm, well within the 18.5 cm RMSE requirement in open areas.

2.1.3 Data Development Methodology

The source topographic data were processed for an area covering the Aransas Bay Watershed and contributing drainage areas for the Aransas Bay BLE modeling efforts. The topographic data for Aransas Bay 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 Aransas Bay Watershed BLE analysis were developed and independently assured to meet quality standards of the project. The data were developed using a controlled process, 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 computations.

The final DEM data developed for the Aransas Bay 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 2D mesh for the model was set as evenly spaced cells at approximately 200 feet. The mesh was 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 all adjacent inflows to the Aransas Bay Watershed were represented, a buffer was added to the HUC boundary.

The HEC-RAS 2D computational mesh was created for the Aransas Bay Watershed based on 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 437,609 cells and a 200-foot nominal mesh cell size; there are factors that could result in either larger or smaller cell sizes including proximity to the edge of the 2D mesh or the presence of breaklines. A 1-minute time step was used in the HEC-RAS model, applying the Diffusion Wave (simplified Full Momentum) equations.

2.2.2 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires establishing a 2D computational mesh boundary. For the Aransas Bay basin, excess precipitation was applied to the mesh. Figure 2.2 shows the 2D computational mesh for the Aransas Bay basin, along with USGS peak streamflow gage pertinent to the study. North Corpus Christi (HUC 12110201) to the south contributes flow into Aransas Bay which was accounted for using an inflow hydrograph. This location is shown in Figure 2.3. The development of the inflow hydrograph, and excess precipitation hyetograph for the 2D mesh, is described in Section 2.2.3.

Outflow boundary conditions (from the computational 2D mesh) were utilized along basin boundaries. A stage hydrograph representing a known water surface elevation was used for the boundary conditions along St. Charles Bay, Carlos Bay, Mesquite Bay, Port Bay, Copano Bay, Mission Bay, Corpus Christi Bay, Aransas Bay, and the Gulf of Mexico. This was established using NOAA tidal datums for the Texas coast and applying the mean higher high water elevation. 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.

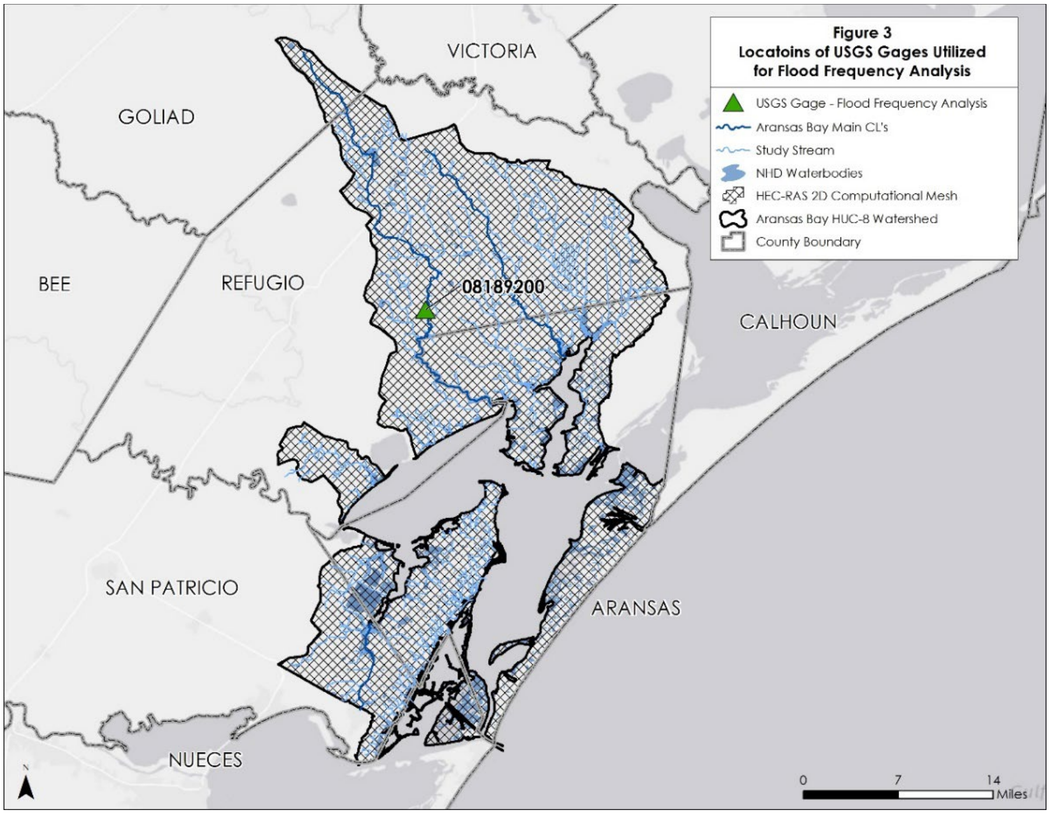

Figure 2.2: HEC-RAS 2D Computational Mesh and USGS Peak Streamflow Gage

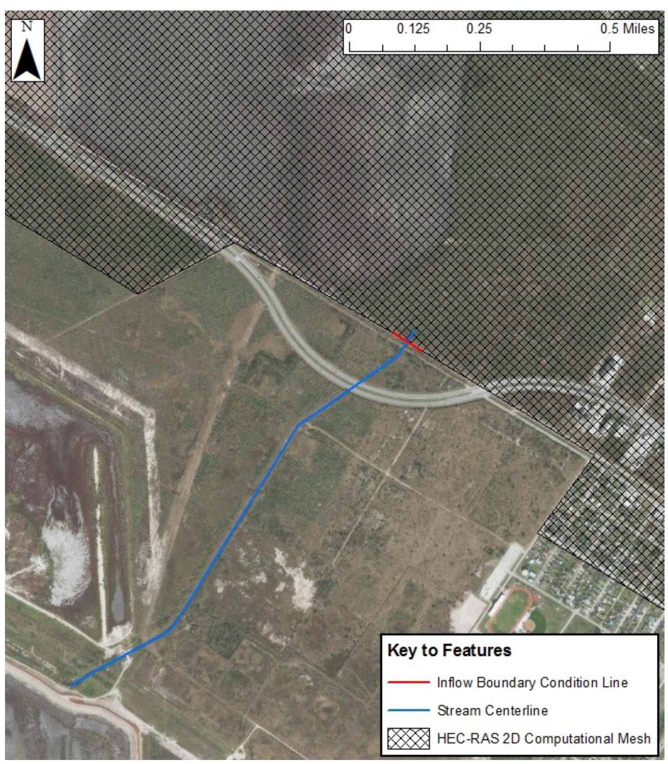

Figure 2.3: HEC-RAS 2D Computational Mesh and Inflow Boundary Conditions for North Corpus Christi HUC

2.2.3 Hydrology

The HEC-HMS, Version 4.3, 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.

USGS streamflow gage data were leveraged to estimate peak flows for downstream gages within each work area for calibration purposes, as discussed in Section 2.3.1.1. 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
08189200	Copano Ck nr Refugio, TX	61	1971 – 2018

Annual chance peak flows were calculated at each gage using USGS Bulletin 17B methodology. Calculated discharges for the 1%, 1% plus, and 1% minus events used for comparison of flow validation within the upper and lower confidence intervals are presented in Table 2.4 for each 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)
08189200	Copano Ck nr Refugio, TX	6,604	4,337	14,910

2.2.3.1 Excess Precipitation for 2D Computational Mesh

HEC-HMS, Version 4.3, was used to apply the SCS Curve Number method to calculate losses and define excess precipitation for the study watershed. Temporal distributions of point rainfall totals were defined using frequency storm 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) 2016 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 numbers and lag time values used in this study.

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

Sub-basin Description	CN	Tlag (min)
Aransas Bay	76	866

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. 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)						
	10	4	2	1	0.2	1% Minus	1% Plus
Aransas Bay	7.23	9.29	11.03	12.94	18.04	10.21	15.67

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

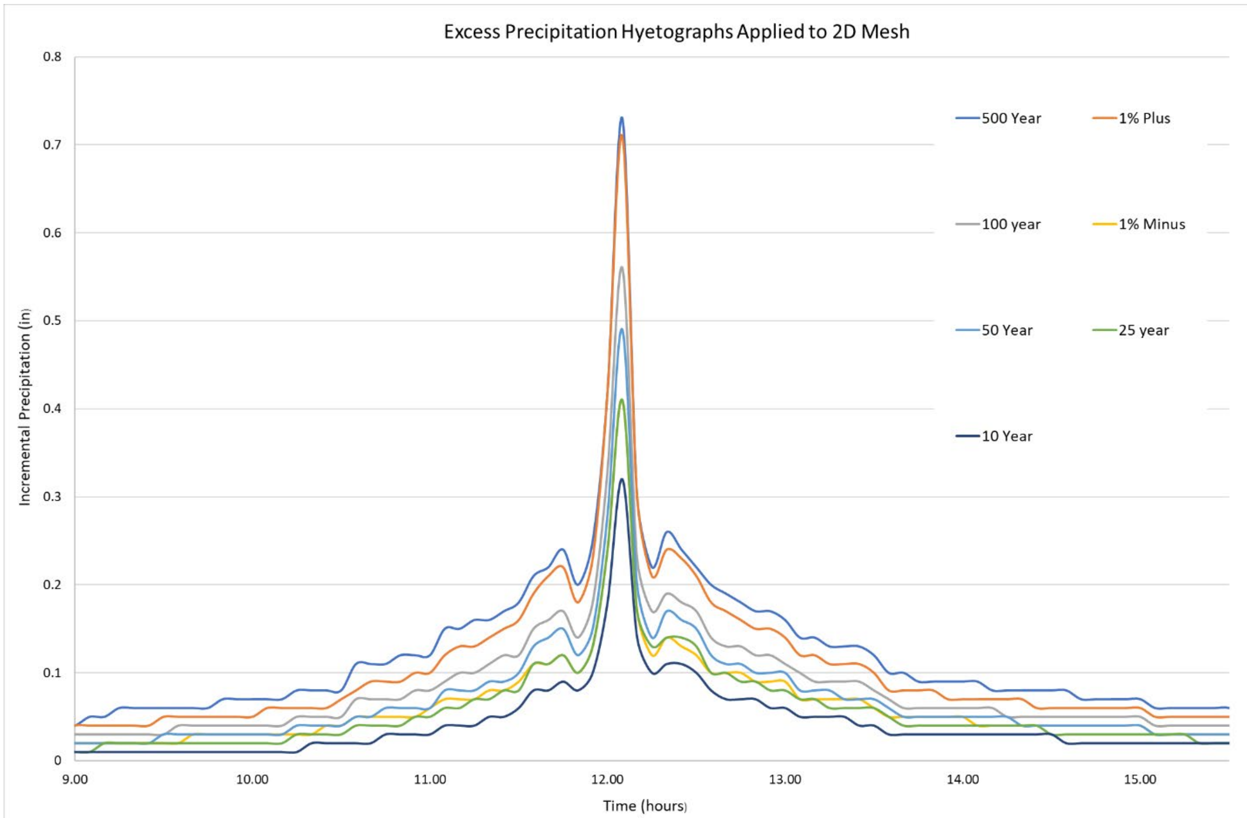

Figure 2.4: Precipitation Hyetographs (post ARF) applied to the Computational Mesh

2.2.3.2 Rainfall-Runoff Hydrograph Boundary Conditions

Aransas Bay has additional contributing drainage area that was accounted for with the addition of an inflow hydrograph, used as a boundary condition to the 2D computational mesh. Figure 2.5 shows the contributing inflow hydrograph from North Corpus Christi to Aransas Bay as applied to the 2D computational mesh.

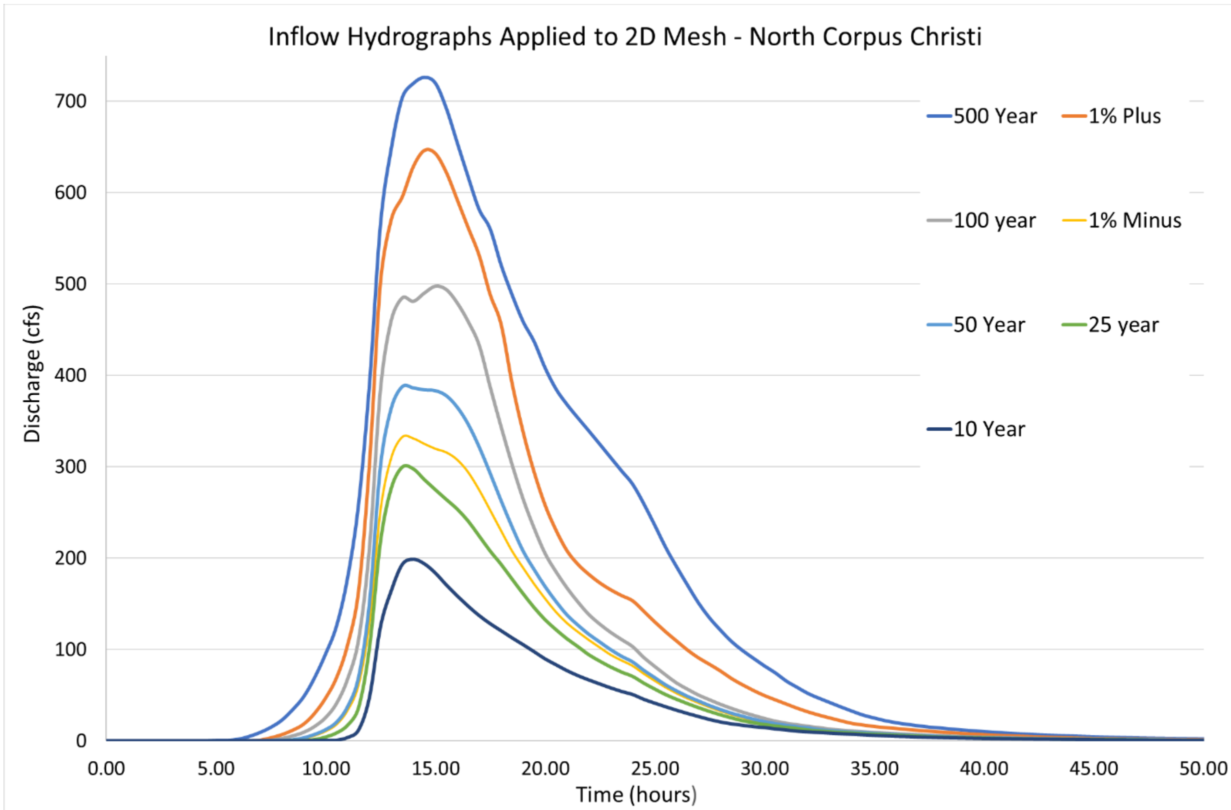

Figure 2.5: North Corpus Christi Basin Contributing Drainage Area Inflow Hydrographs

2.2.4 Hydraulics

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

2.2.4.1 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 . A 20-foot buffer zone was created by automated processes around each stream centerline (mainstem and tributaries) to create a main channel roughness zone. The channel roughness zone was given a Manning's n value of 0.045, obtained from the HEC-RAS User's Manual, to ensure the channel 2D cells have appropriate conveyance. The table below shows a typical land use-roughness matrix used in defining the roughness coverage for the study area.

Table 2.8: NLCD 2016-Manning's N Roughness Matrix

NLCD Classification	Manning's N	Minimum	Normal	Maximum	Source
Open Water	0.030	0.025	0.030	0.033	Chow 1959
Developed, Open Space	0.050	0.010	0.013	0.016	Calenda, et al. 2005
Developed, Low Intensity	0.070	0.038	0.050	0.063	Calenda, et al. 2005
Developed, Medium Intensity	0.100	0.056	0.075	0.094	Calenda, et al. 2005
Developed, High Intensity	0.120	0.075	0.100	0.125	Calenda, et al. 2005
Barren Land	0.050	0.025	0.030	0.035	Chow 1959
Deciduous Forest	0.100	0.100	0.120	0.160	Chow 1959
Evergreen Forest	0.100	0.100	0.120	0.160	Chow 1959
Mixed Forest	0.100	0.100	0.120	0.160	Chow 1959
Scrub/Shrub	0.070	0.035	0.050	0.070	Chow 1959
Grassland/Herbaceous	0.050	0.025	0.030	0.035	Chow 1959
Pasture/Hay	0.050	0.030	0.040	0.050	Chow 1959
Cultivated Crops	0.050	0.025	0.035	0.045	Chow 1959
Woody Wetlands	0.100	0.080	0.100	0.120	Chow 1959
Emergent Herbaceous Wetland	0.100	0.075	0.100	0.150	Chow 1959
Main Channel[1]	0.045				HEC-RAS User's Manual

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

2.2.4.2 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. Similarly, bridge/culvert crossings 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.

Bridge/culvert crossings that were not processed out of the terrain data using ArcGIS were modeled by adding v-notches, u-notches, or offset breaklines adjacent to the road embankment to align grid cells around the embankment and allow water to be routed across the embankment without creating artificial backwater. An example of the offset breakline approach is shown below.

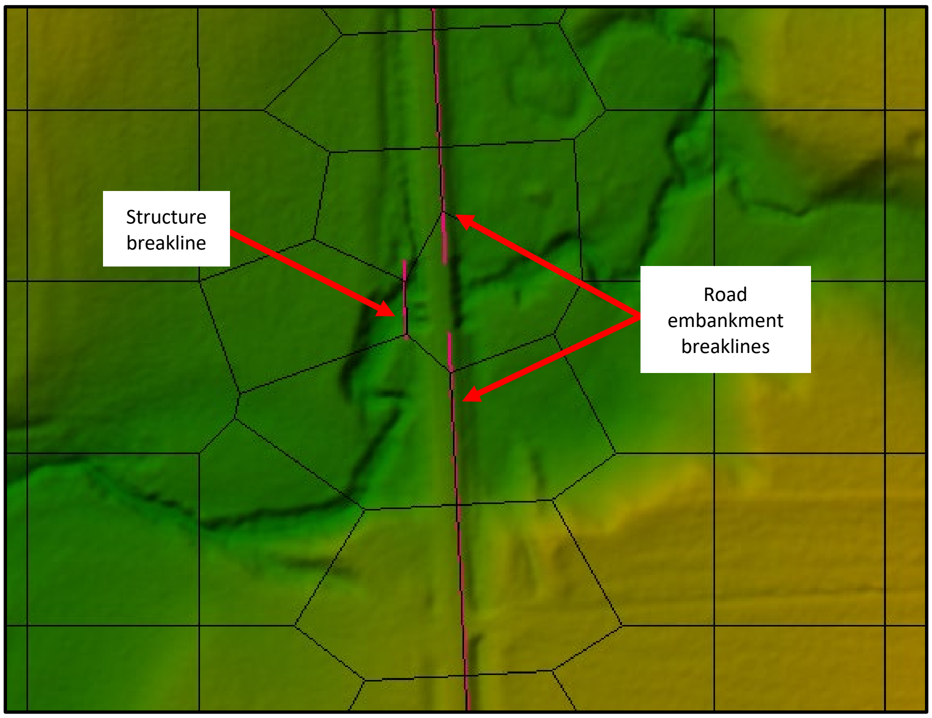

Figure 2.6: Offset Breakline Approach at Bridge Crossing

County, interstate, common name, 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. Levees from the National Levee Inventory and railroads from the TIGER Railroads layer were also incorporated.

2.2.4.3 Initial Conditions

Initial conditions were not used in the Aransas Bay 2D BLE model.

2.2.5 Special Assumptions

After cell and breakline edits, an area near the City of Ingleside in the southwest section of the HUC was found to have flow entering from the North Corpus Christi Watershed. The buffer added to the mesh in this area was cut back and a boundary condition line was added to allow inflow into the HUC using a flow hydrograph from the North Corpus Christi 2D BLE HEC-RAS Model. Figure 2.6 below shows the edited mesh and new flow hydrograph boundary condition (middle), along with existing normal depth boundary conditions.

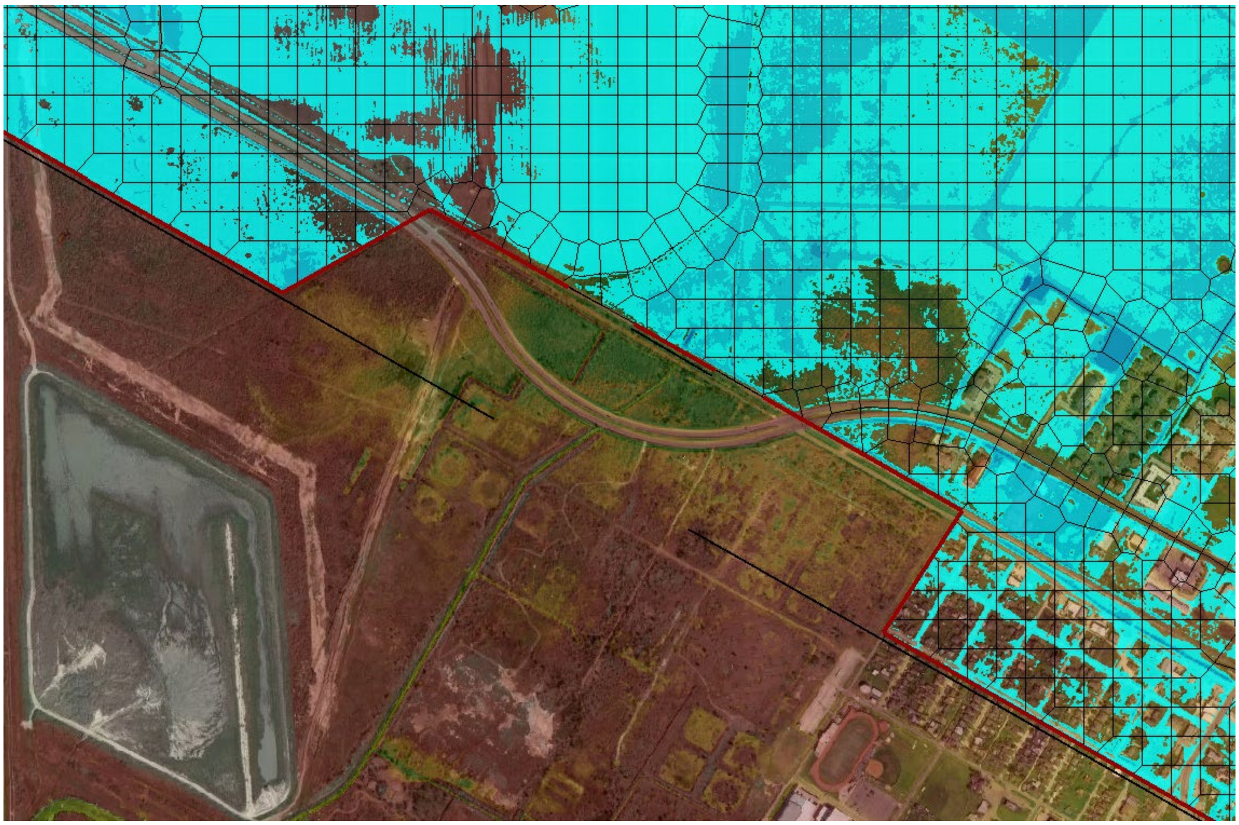

Figure 2.6: Edited Mesh and Inflow from North Corpus Christ Watershed

An area on the west side of the HUC was also found to have some overflow entering from the adjacent Mission HUC. It was determined that the best course of action was to edit the Mission HEC-RAS mesh to overlap farther into Aransas Bay to help the water surface elevations tie-in between HUCs. The water surface elevations from Mission and Aransas Bay lie within 0.5 ft near the boundary. The model will require further refinement, including surveys and structures, to estimate the inter-basin flow.

The barrier islands on the south end of the HUC were not included in the modeling extents. These areas were determined to be protected by the Coastal Barrier Resources Act, and therefore further development is not allowed on the islands.

2.3 Model Results

The 2D BLE results for the study produced flood risk mapping which compared reasonably well with the effective SFHA in most cases. The 2D BLE flood risk mapping extends the traditional SFHA due to the nature of the watershed wide approach of rain-on-mesh methodology. Additionally, the application of rain-on-mesh modeling allowed for the identification of localized flood risk beyond the extents of the traditional SFHA. Table 2.9 shows a comparison of the effective BFE data with the model results. 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 as a regulatory product.

Table 2.9: Effective and Model BFE Comparison

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
McCampbell Slough	-231	10.3	7.8	-2.5
McCampbell Slough	306	10.3	8.3	-2.0
McCampbell Slough	1535	10.3	8.4	-1.9
McCampbell Slough	4311	10.3	8.8	-1.5
McCampbell Slough	7798	10.6	9.1	-1.5
McCampbell Slough	11057	10.9	9.5	-1.4
McCampbell Slough	14352	11.1	9.7	-1.4
McCampbell Slough	15205	11.2	9.7	-1.5
McCampbell Slough	16704	11.2	9.9	-1.3
McCampbell Slough	17091	11.2	10.2	-1.0
McCampbell Slough	17386	11.5	11.2	-0.3
McCampbell Slough	18508	11.7	11.4	-0.3
McCampbell Slough	18834	11.8	11.4	-0.4
McCampbell Slough	19456	11.9	11.4	-0.5
McCampbell Slough	19963	11.9	11.5	-0.4
McCampbell Slough	20405	11.9	11.5	-0.4
McCampbell Slough	21014	12.3	11.8	-0.5
McCampbell Slough	21331	12.3	11.8	-0.5
McCampbell Slough	21533	12.3	11.8	-0.5

2.3.1.1 Calibration & Sensitivity Analysis

Known USGS gages within the model area with more than 20-years of flow record were used for calibration and validation of the 1% annual chance event. Peak flows within the model were compared with Bulletin 17B Analyses and EMA Analyses of the gage data using PeakFQ 7.2. Results of the flow comparisons are presented in Table 2.10.

Table 2.10: 1% Annual Chance Reasonability Comparisons

Flooding Source	USGS Gage Used for Verification	**HEC-RAS 5.0.7** (2D)		Reference	
		WSEL (ft)	**Discharge (cfs)**	**WSEL (ft)** [1]	**Discharge (cfs)**
Copano Creek	08189200	35.96	6,965	35.77	6,604

[1] Water surface elevation is approximate based on PeakFQ input data and adjusted to NAVD 88 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 2.2.4.1. It was determined that enforced breaklines at major roads and centerlines were needed and are discussed further in Section 2.2.4.2. No changes were made to the precipitation values. Table 2.11 summarizes the results of each run at the USGS gage.

Table 2.11: Sensitivity Analysis Results at USGS Gage 08189200

Iteration	Manning's N Zones	Breaklines	Hydrologic Losses	Initial Conditions / Computational Interval	Boundary Conditions[1]	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	None	Excess Precipitation	Dry / 1 min	Stage Hydrograph and Normal Depth	5,619	36.24
2[2]	Original Land Use	Major Roads w/Centerlines Enforced	Excess Precipitation	Dry / 1 min	Stage Hydrograph and Normal Depth	6,965	35.96
3	Land Use with Woody Wetland 0.12	Major Roads w/Centerlines Enforced	Excess Precipitation	Dry / 1 min	Stage Hydrograph and Normal Depth	6,988	35.93
4	Land Use with Woody Wetland 0.12 and Deciduous, Evergreen, Mixed Forest 0.16	Major Roads w/Centerlines Enforced	Excess Precipitation	Dry / 1 min	Stage Hydrograph and Normal Depth	6,751	35.76
5	Land Use with Woody Wetland 0.12, Emergent Herbaceous Wetland 0.15 and Deciduous, Evergreen, Mixed Forest 0.16	Major Roads w/Centerlines Enforced	Excess Precipitation	Dry / 1 min	Stage Hydrograph and Normal Depth	6,712	35.74
					Gage Analysis:	6,604	35.77[3]

[1] Normal depth boundary conditions used except at outfalls to bays where stage hydrographs representing known water surface elevations were used.
[2] Parameters from Iteration 2 were used for the final model, however additional computational mesh was implemented following the results of the sensitivity analysis.
[3] Water surface elevation is approximate based on PeakFQ input data.

2.4 Challenges

A major challenge was due to the lack of peak streamflow records at the study area outlet. However, sufficient data was available within the study area to provide confidence in the final model results.

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 5.0.7 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 2.7 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.

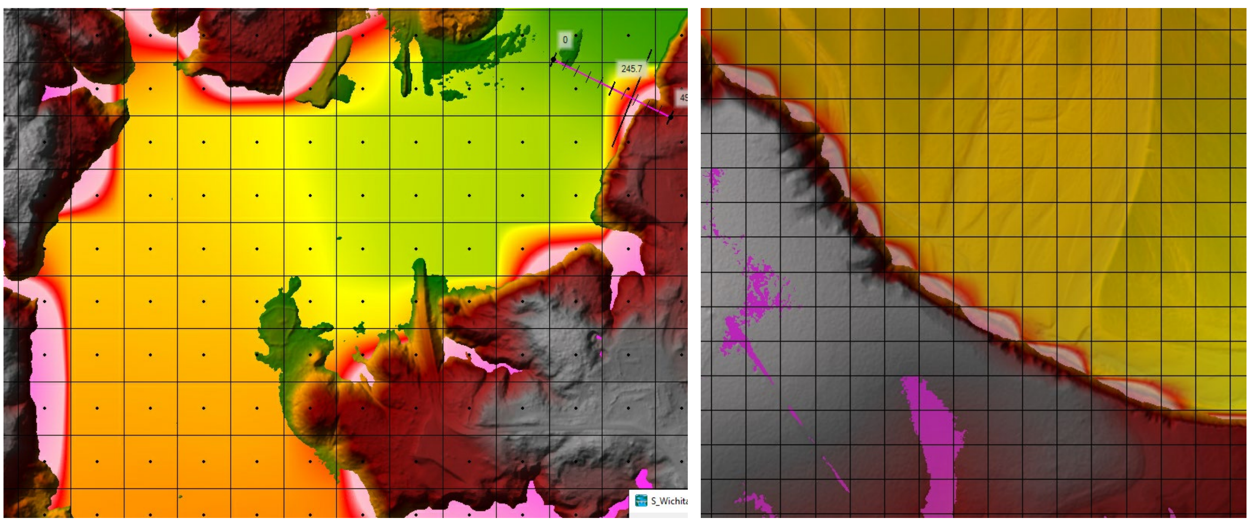

Figure 2.7: Cupping Examples

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 1% SFHA and 0.2% 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 Aransas Bay 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 with raster depths greater than 0.33 feet. 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% 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. 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. Mapping polygons were cleaned against the criteria of being larger than 0.33 acres. For example, if flooding polygons were disconnected from a flooding source and less than 0.33 acres, the polygon was removed from the SFHA. Flood polygon less than 0.33 acres that intersected a flooding source were assessed individually. These edits adhere to traditional and approved floodplain mapping approaches.

In addition to the SFHA, all other flooding associated with the 1% and 0.2% raw results were retained as "on the shelf" data that may be leveraged for future needs and analysis.

3.1.3 Flood Hazard Area Layer

Special Flood Hazard Areas, as noted above, were developed to the extent of the CNMS features or up to 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 flooding extent.

The 0.2% 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 EBFE_FLD_HAZ_AR.

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 Aransas Bay 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. For this study area, the best available lidar data was used. Recent quality lidar provided coverage for the entire study area, therefore this check is set to PASS.

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-annual-chance flow. This element was set to PASS for all reaches within the study area.

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 watershed of the BLE. If the percentage of urban area within the 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 Aransas Bay 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 this assessment. Table 3.1 presents the summarized results of checks A1 through A3.

Table 3.1: A1-A3 Validation Results

Assessment Checks	Pass / Fail	Notes
A1 – Topography	Pass	LiDAR significantly better than effective USGS topo source/Effective mapping leveraged LiDAR data.
A2 – Hydrology	Pass	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. Due to lack of documentation of the original engineering methods in the Aransas Bay Watershed, check A4 has been marked as PASS for all HUC 12s.

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 Aransas Bay 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. A test point was created around the perimeter of the floodplain area every 100’.

For each test point, a 75-foot buffer 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 704 total miles of available CNMS features representing the effective Zone A studies were categorized as shown in Table 3.2, 3.3 and illustrated in Figure 3.1 below. Table 3.3 summarizes the validation results based on the individual HUC 12 watersheds within Aransas Bay Watershed.

Table 3.2: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
ASSESSED	BEING STUDIED	602
UNVERIFIED	N/A	97
VALID	N/A	5

Table 3.3: HUC 12 Zone A Validation Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>90%)
Watershed Name	Watershed Number					
Aransas Bay	All Streams	**880,419**	**13,156**	**867,263**	**99%**	**Pass**
Aransas Bay	121004050400	102,044	4,702	97,342	**95%**	**Pass**
Artesian Creek	121004050301	57,201	349	56,852	**99%**	**Pass**
Big Devil Bayou	121004050307	36,724	934	35,790	**97%**	**Pass**
Burgentine Creek	121004050303	57,616	1,479	56,137	**97%**	**Pass**
Fresh Water Lake-Copano Bay	121004050203	52,245	661	51,584	**99%**	**Pass**
Lower Cavasso Creek	121004050306	46,649	357	46,292	**99%**	**Pass**
Lower Copano Creek	121004050103	65,960	648	65,312	**99%**	**Pass**
Middle Copano Creek	121004050102	76,599	557	76,042	**99%**	**Pass**
Mud Flats-Aransas River	121004070404	3,318	26	3,292	**99%**	**Pass**
Mullens Bayou-Copano Bay	121004050202	30,327	334	29,993	**99%**	**Pass**
Plumbers Slough-Copano Bay	121004050201	37,264	156	37,108	**100%**	**Pass**
Salt Lake-Copano Bay	121004050204	87,011	1,537	85,474	**98%**	**Pass**
Twin Creek-Willow Creek	121004050302	34,026	285	33,741	**99%**	**Pass**
Upper Cavasso Creek	121004050305	45,657	200	45,457	**100%**	**Pass**
Upper Copano Creek	121004050101	79,516	468	79,048	**99%**	**Pass**
Willow Creek-Salt Creek	121004050304	68,262	463	67,799	**99%**	**Pass**

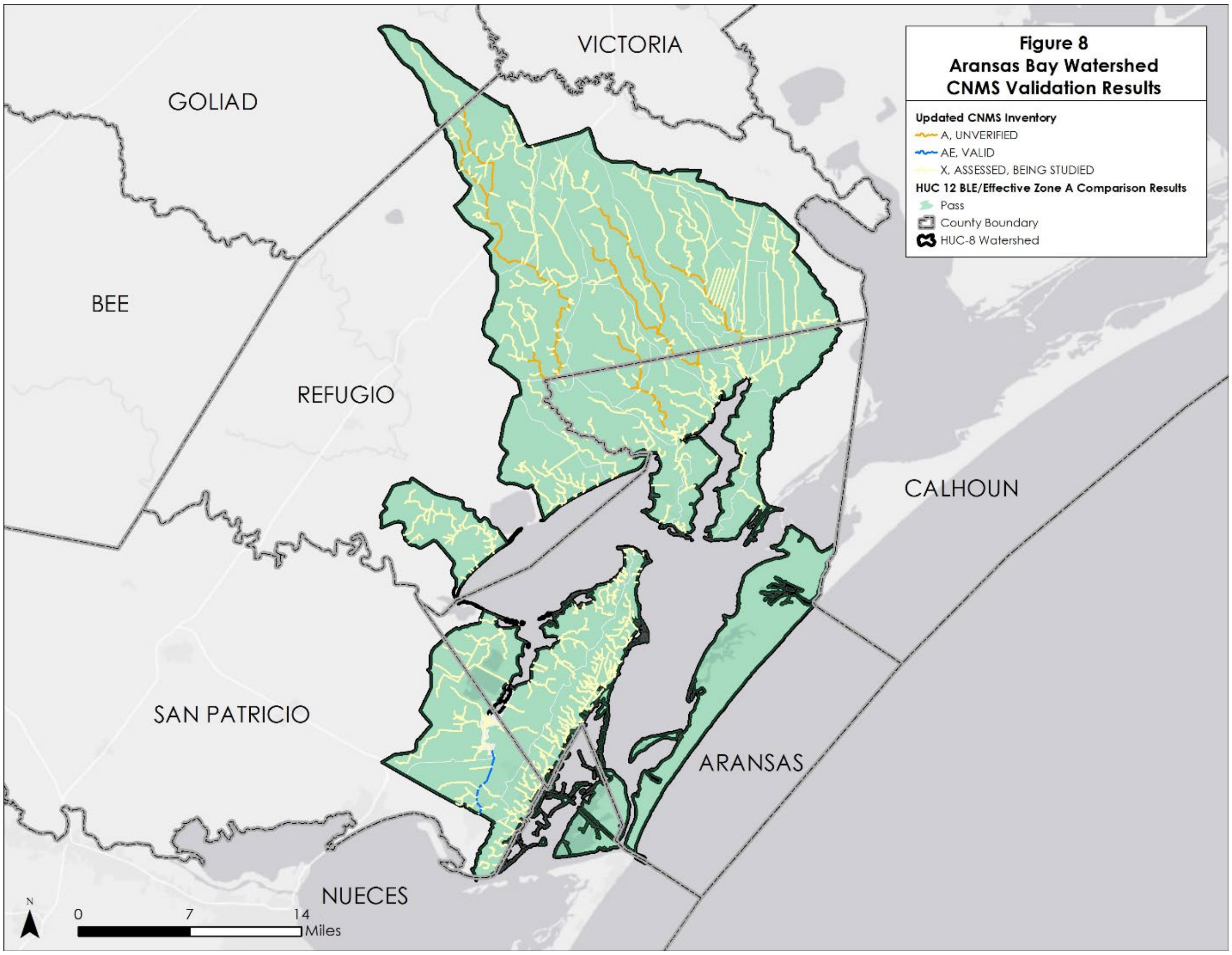

Figure 3.1: Aransas Bay Watershed CNMS Validation Results

3.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent annual chance 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 4.2 (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 4.2 (SP02) uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by other 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 extends for each return period to ensure proper model processing. A summary of results per county for the 100-year scenarios are shown in Table 3.4. through Table 3.6.

Table 3.4: Hazus 4.2 (SP02) Results for 1-percent-annual-chance (100 year) riverine scenario for Aransas Bay Watershed, Texas

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Aransas	283,928	2,957,082	1,698,082
Goliad	257	3,244	1,965
Nueces	<1	707	499
Refugio	8,278	85,726	46,391
San Patricio	160,918	1,368,821	898,012
Total	**453,381**	**4,415,580**	**2,644,949**

Table 3.5: Hazus 4.2 (SP02) Results for 1-percent-annual-chance (100 year) coastal scenario for Aransas Bay Watershed, Texas

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Aransas	125,463	1,266,533	701,614
Nueces	<1	293	293
Total	**125,463**	**1,266,826**	**701,907**

Table 3.6: Hazus 4.2 (SP02) Results for 1-percent-annual-chance (100 year) coastal and riverine scenarios for Aransas Bay Watershed, Texas

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Aransas	409,391	4,223,615	2,399,696
Goliad	257	3,244	1,965
Nueces	<1	1,000	792
Refugio	8,278	85,726	46,391
Nueces	160,918	1,368,821	898,012
Total	**579,101**	**5,685,650**	**3,348,821**

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