South Laguna Madre Watershed, Texas 2D Base Level Engineering Methods and Results

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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 formerly known as First Order Approximation (FOA), now labeled Base Level Engineering (BLE), which can be used to address program challenges such as the validation of previous Zone A studies and provide flood risk data in the early stages of a Flood Risk Project. The BLE process involves using best available data and automated techniques to produce estimates of flood hazard boundaries for multiple rainfall recurrence intervals. The South Laguna Madre Watershed BLE documented here was enhanced using 2-dimensional (2D) modeling techniques and validation to develop products intended to be transitioned into regulatory data development workflows.

Per 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 determines flood hazard data validity by examining watershed attributes and change characteristics, as specified in the Validation Checklist of the Coordinated Needs Management Strategy (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, BLE is intended to be a cost-effective approach for evaluating Zone A studies.

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 Identification (SID) #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping which may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an anal+ysis 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 should 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 large volume of data resulting from a BLE 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 stakeholders.

FEMA Region VI (Region) contracted Compass to perform a BLE analysis for the South Laguna Madre HUC-8 Watershed (12110208) in South Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study area is primarily Hidalgo, Cameron, and Willacy counties, but does include portions of Kenedy, and Starr counties as well. **Figure 1** depicts the South Laguna Madre Watershed footprint.

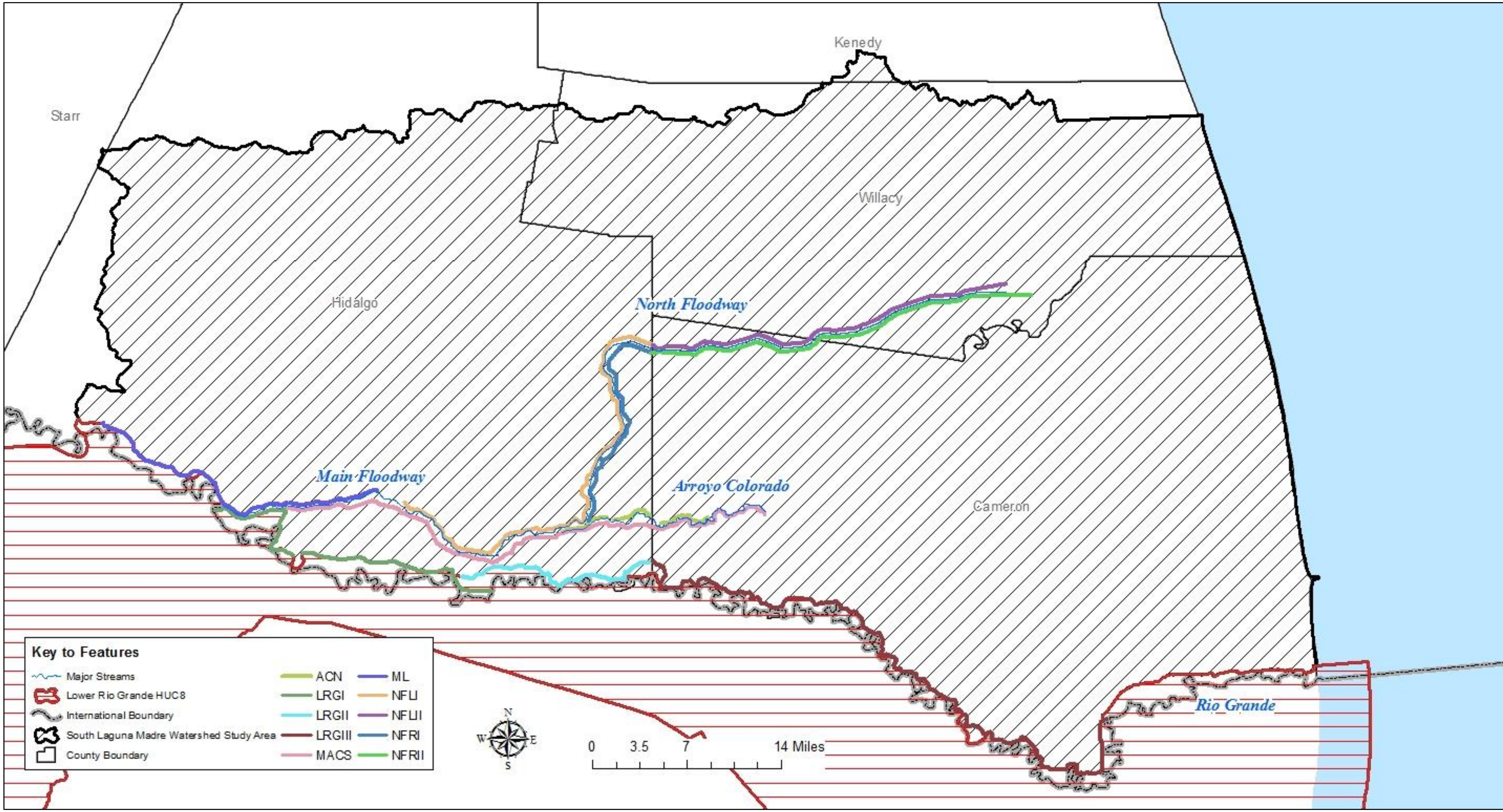

Figure 1: South Laguna Madre Watershed

The South Laguna Madre HUC-8 has a controlled contributing flow coming in through a regulated diversion structure located at the Anzalduas Dam near Mission, TX. The flow can be directed out of the Rio Grande River and into the South Laguna Madre HUC-8, bounded by a reach of levees that currently are not accredited by FEMA. There are no additional watersheds contributing to the project area.

In addition to the BLE study, this project includes a natural valley procedure (NVP) of those unaccredited levees within the project extents. For each of the NVP scenarios, the terrain was adjusted to remove the levees and allow flow to leave the levee reach, which can establish potential inundation locations outside the SFHAs. Details of the separate NVP, are mentioned in this report and further explained in **Appendix A**. This report documents the BLE process, products, and results for this 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 South Laguna Madre Watershed. Inputs such as elevation data, hydrology from 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 South Laguna Madre BLE project by leveraging available high-resolution gridded elevation data derived from Light Detection and Ranging (LiDAR) collections throughout the state of Texas. The 10-foot DEM developed to support the 2D BLE modeling and analysis, within the South Laguna Madre Watershed, was developed using the following steps:

1. Available elevation data for the project area were inventoried, collected, and listed in **Table 2**.
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 assessments detailed in 2.1.4.

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 each dataset. All available metadata, survey reports, and other leverage documentation are included in the FEMA Data Capture Technical Reference compliant submittal content for the South Laguna Madre Watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the South Laguna Madre BLE project footprint.

Figure 2 depicts the datasets identified and leveraged across the project area. FEMA, National Oceanic and Atmospheric Administration (NOAA), United States Geological Survey (USGS),3D Elevation Program (3DEP) (obtained in 2020), and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

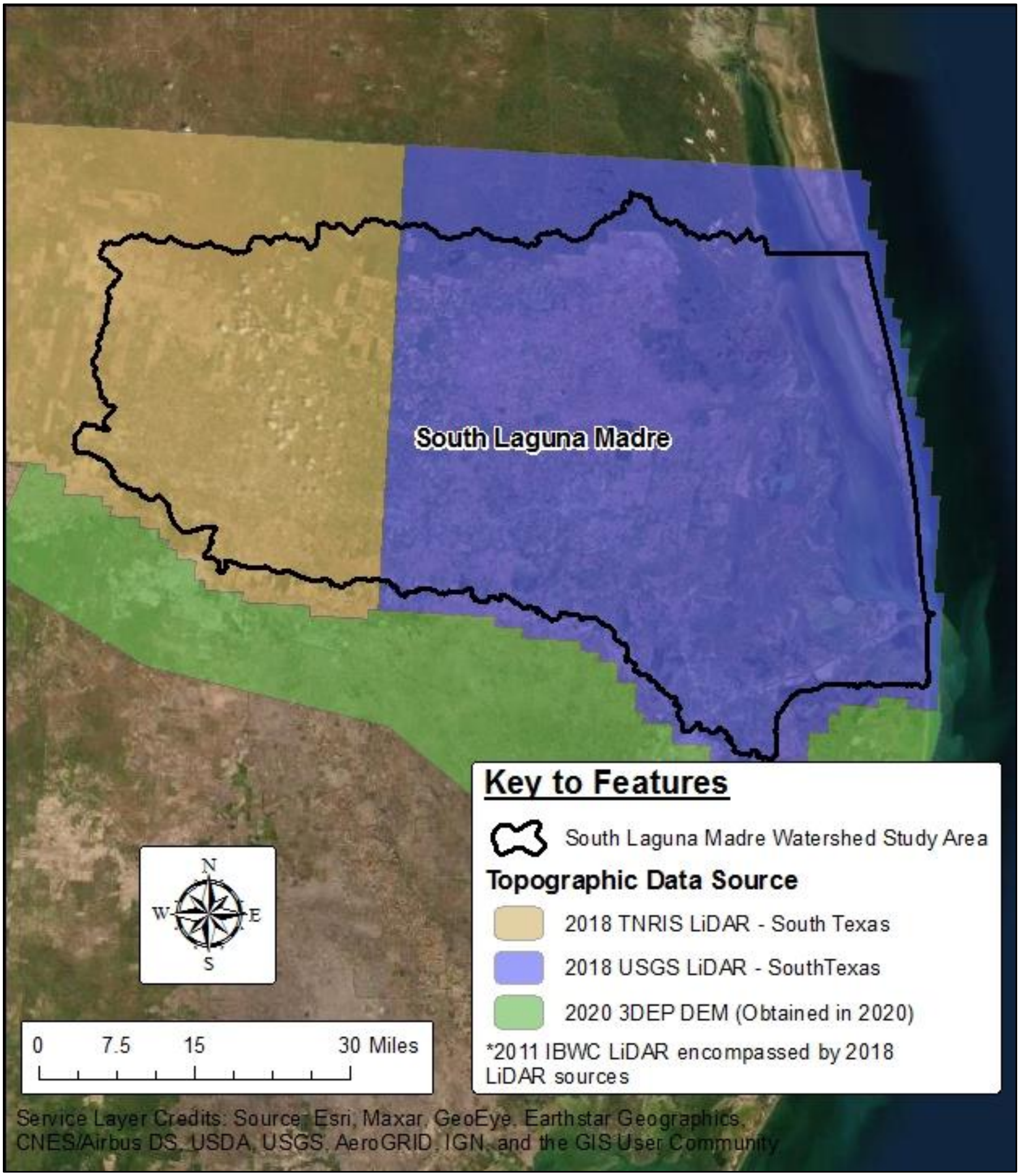

Figure 2: South Laguna Madre Watershed BLE Source Terrain Data

2.1.2 Evaluation

A data coverage assessment was conducted to check for data gaps, extent, accuracy, and completeness. The review of related documentation, reports, indices, and metadata associated with the leveraged datasets confirmed 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 1**)
- Date of origination
- Data density and coverage

Table 1 depicts the Risk MAP SID #43 vertical accuracy requirements based on flood risk and terrain slope within the floodplain being mapped.

Table 1: FEMA Vertical Accuracy Requirements for Leveraged Data

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

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

Table 2 depicts the complete list of source elevation data and attributes leveraged for the South Laguna Madre Watershed project. All datasets used for hydraulic analyses and mapping meet the highest specification level defined in **Table 1**. Further explanation of the **Table 2** datasets can be referenced in section 2.1.2.1.

Table 2: Source Topographic Data Available for the South Laguna Madre Watershed

Year	Description	Data Type	RMSE	Source/Owner
2018	USGS South Texas LiDAR	Airborne LiDAR	19.6 cm	USGS
2011	USIBWC LiDAR	Airborne LiDAR	3 cm	USIBWC
2020*	3DEP Elevation Program (3DEP)	Airborne LiDAR	*	USGS
*3DEP data was obtained in 2020 and accuracy not provided				

2.1.2.1 South Laguna Madre Watershed Source Terrain Data

The source elevation data for the South Laguna Madre Watershed are DEMs derived from the 2018 South Texas USGS LiDAR, the 2011 USIBWC LiDAR Project and the 3D Elevation Program (3DEP). Only points classified as "ground" points (i.e., bare earth) were imported from the LiDAR and used for development of the project DEMs. Bare-earth LiDAR data are typically made by filtering non-ground returns (e.g., buildings, vegetation, etc.) from the raw laser returns.

3DEP terrain data was used to supplement LiDAR data in areas without coverage including areas south of the Rio Grande River.

2.1.3 Data Development Methodology

The source topographic data were processed for an area covering the South Laguna Madre Watershed BLE modeling efforts. The topographic data for South Laguna Madre Watershed was projected horizontally, as needed, to North American Datum of 1983 (NAD83), State Plane Lambert Conformal Conic Texas South in feet (4205). All topographic data were adjusted vertically, as needed, to North American Vertical Datum of 1988 (NAVD88) in feet. Compass 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 South Laguna Madre 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 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 (checks DEM files along source data edges)

Quality control procedures implemented after the DEM development 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
- No Data 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 control checks 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 impact hydraulic computations.

After reviewing the 3DEP DEM, terrain discrepancies were found alongside the Rio Grande with some topography increasing more than 20 feet when compared to the neighboring 2018 USGS DEMs. When reviewing recent imagery of the areas, these terrain differences are not present. An example of terrain discrepancies is shown in Error! Reference source not found. below. The black line in the figure represents a cross section cut north to south across the seamless DEM in that area with the 2018 TNRIS LiDAR in the North and 3DEP to the south. As seen, once the line crosses into the 3DEP section of the terrain the elevations drop from 125 ft to 105 ft.

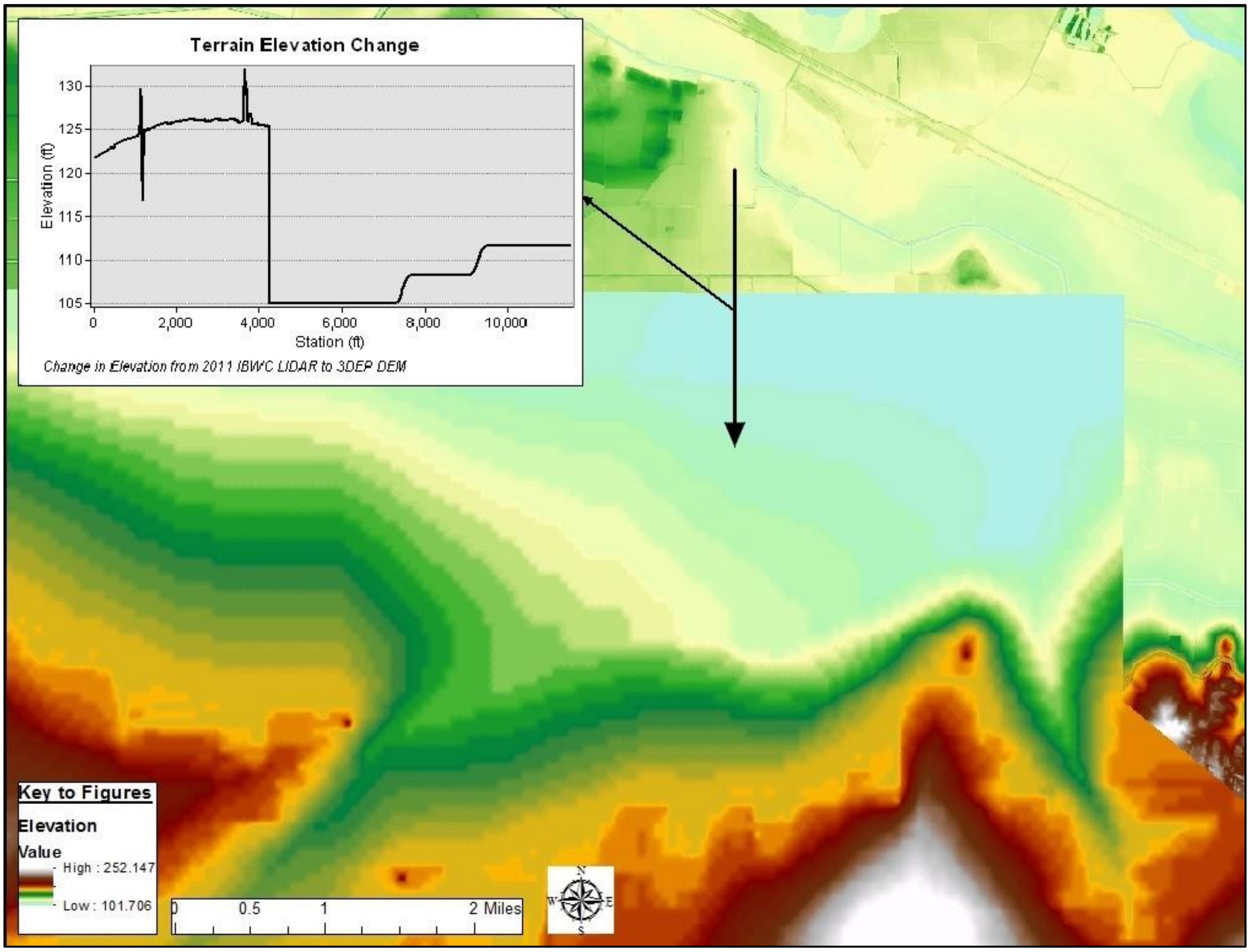

Figure 3: Discrepancy between LiDAR and NED 3DEP BLE Source Terrain Data

Due to the discrepancies of the 3DEP terrain compared to the surrounding datasets, model adjustments were made to exclude or adjust areas with major differences. Model adjustments made to overcome the discrepancies are explained in section 2.3.1.1 Validation & Sensitivity Analysis. The final DEM data developed for the South Laguna Madre Watershed is developed to meet FEMA standards and present a representative surface created from leveraged elevation data for the purposes of this BLE project.

2.2 2D BLE Methods

The following sections describe the model approach and considerations, followed by discussion and tabulation of hydrologic and hydraulic engineering methods and model inputs.

2.2.1 Model Approach

Two model variations were developed for the South Laguna Madre watershed: the South Laguna Madre Interior Drainage model and the Rio Grande Inflow Model. The South Laguna Madre Interior Drainage model was developed by applying precipitation to the entire 2D area with no inflows from the Rio Grande. The purpose of this model is to capture all the 2D flows occurring within the South Laguna Madre HUC-8 without any influence from the Rio Grande River levee system. All levees were assumed to provide protection as mapped on the effective FIRMs and modeled as significant topographic features in the 2D mesh.

The Rio Grande Inflow Model used an inflow hydrograph based on peak discharge values obtained from the US Section of the International Boundary Water Commission (USIBWC). No precipitation data was applied to the Rio Grande Inflow Model. The HEC-RAS geometry associated with this model represents baseline conditions for the NVP, from which each independent natural valley scenario is developed. See **Appendix A** for more information on the Natural Valley Procedure.

Running the models separately allowed for improved model stability and ease of validation. In addition, each model can be run independently to reflect the difference in timing of storm events in the two separate watersheds, Lower Rio Grande and South Laguna Madre. This allows for flexibility of use for future mapping partners.

The Main Floodway, North Floodway, and the Arroyo Colorado (also referred to as the floodway systems) typically provide flooding relief to the localized interior drainage areas. However, during major events with rainfall in the Rio Grande watershed, the floodway systems are assumed to be at capacity and can no longer provide relief. During these major events, the gates allowing conveyance from the interior drainage areas into the floodways are closed, creating more flow accumulation on the landside of the floodway system levees. The gates are closed to prevent high flow volumes from the Rio Grande watershed to exit the floodway system and flow into the interior protected areas.

For the purposes of this analysis, the team assumed that the gates that control flow into and out of the floodway systems will be closed during major events impacting the Rio Grande watershed, preventing flow from entering or leaving the floodway system. Flow shown within the floodways of the Interior Drainage Model is due to the rain-on-grid approach and represents rainfall accumulation within the floodways themselves. Conversely flow shown outside the levees of the Rio Grande Inflow Model is due to flow overtopping the levees.

An additional benefit from analyzing the Rio Grande Inflow model separately from the South Laguna Madre Interior Drainage Model, is to accurately identify areas where the Rio Grande overtops the levee and controls over the South Laguna Madre Interior Drainage Model. Performing the modeling analyses separately enabled the identification of the source of risk in the area and allowed the validation efforts to be applied separately between the Rio Grande Inflow Model and the South Laguna Madre Interior Drainage Model. The remainder of Section 2.2 further outlines the modeling decisions for both model approaches, unless otherwise specified.

2.2.2 Hydrology

Precipitation data for this study were referenced from NOAA's Precipitation Frequency Data Server, and appropriate values for all sub-basin elements were determined considering spatial variation and a representative total for South Laguna Madre. Excess precipitation for the 2D mesh was developed as described in Section 2.2.2.1. There were no known USGS gages available for validation within the interior drainage model area that were not influenced by discharges from the Rio Grande. Other validation efforts are discussed in Section **Error! Reference source not found.**.

The HEC-HMS version 4.2 model was used solely for the development of excess precipitation (i.e., runoff) hyetographs which were applied to the 2D mesh of the interior drainage model.

Precipitation frequency data published in NOAA Atlas 14; Volume 9 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% annual chance 24-hour precipitation depths (per FEMA BLE requirement) for all sub-basin elements were determined by area-weighted intersection of gridded PFDS data with sub-basins. Excess precipitation for the 2D mesh was computed as described in Section 2.2.2.1. The USGS gages in the study area are presented in **Table 3** and **Figure 4**. These gages are within the floodway systems and were not utilized for validation efforts for either model, as discussed in Section 2.3.1.1.

Table 3: USGS Peak Streamflow Gages

Gage ID	Flooding Source and Location	Published Drainage Area (mi^2)	Period of Record
USGS 08469200	Rio Grande bl Anzald Dam nr Mission, TX	176,112	180 day rolling record
USGS 08470050	Arroyo Colorado bl Siphon nr Donna, TX	129	180 day rolling record
USGS 08470400	Arroyo Colorado at Harlingen, TX	381	180 day rolling record
USGS 08473700	Rio Grande nr San Benito, TX & Ramirez, MX	176,304	180 day rolling record
USGS 08475000	Rio Grande nr Brownsville, TX	176,333	180 day rolling record
*Gages with periods of record less than 20 years are insufficient for validation; Influence caused by inflows from the Rio Grande removed both Arroyo Colorado gages from being able to validate to for the 2D BLE study; Gages were not utilized for validation purposes. Further discussed in Model Sensitivity and Validation section.			

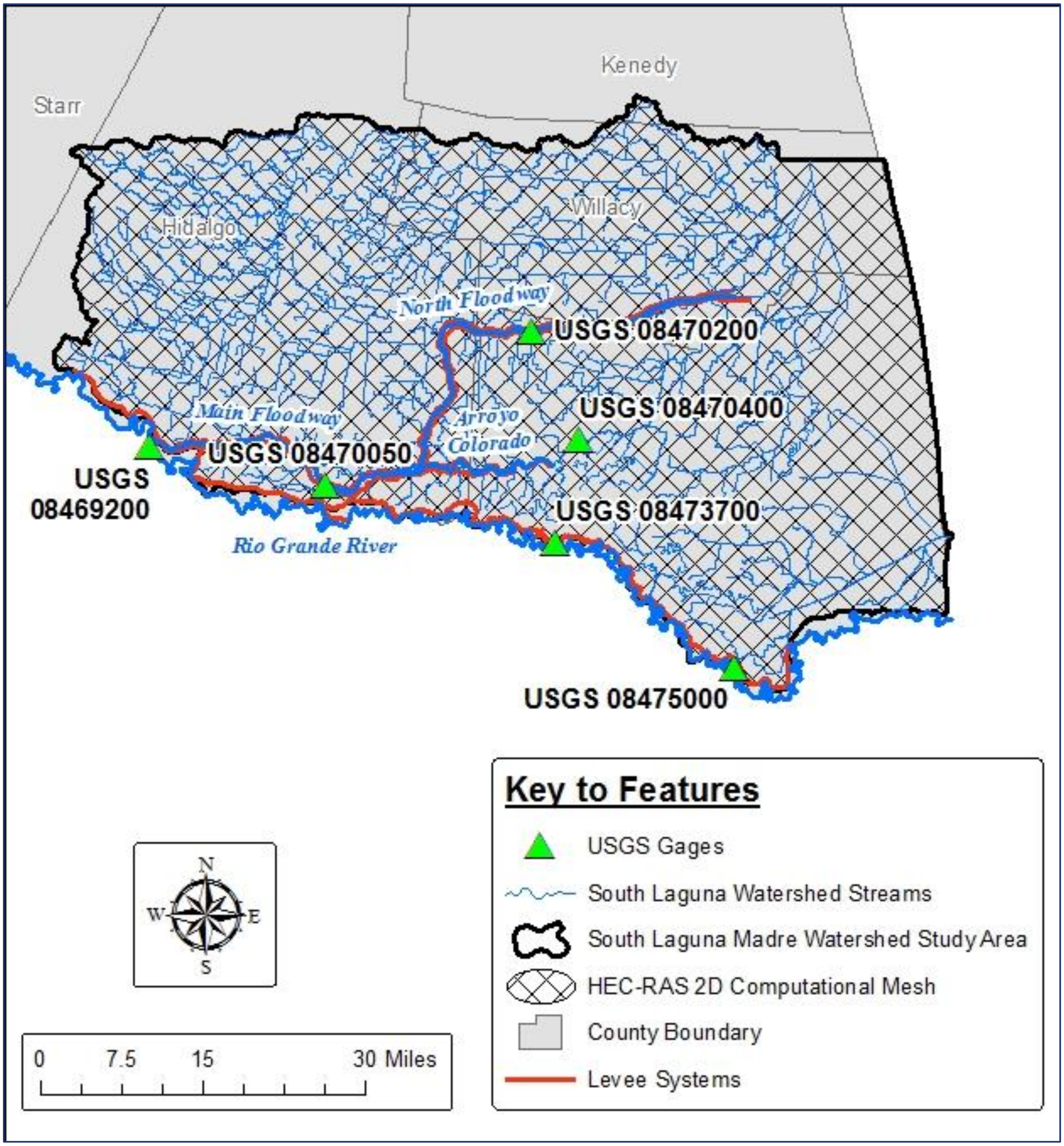

Figure 4: HEC-RAS 2D Computational Mesh and USGS Peak Streamflow Gages

2.2.2.1 Excess Precipitation for 2D Computational Mesh

HEC-HMS version 4.2 was used to apply the Soil Conservation Service (SCS) Curve Number method to calculate losses and define excess precipitation for this watershed. Temporal distributions of point rainfall totals were defined using 24-hour, SCS Type III storm distributions. The plus and minus standard error for the 1% annual chance precipitation depths were determined as the upper and lower 84% confidence limits on the nominal 1% 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. It should be noted that the standard errors for the 1% rainfall depth were based on the depth used post-areal reduction.

Default areal reduction factor (ARF) values for BLE studies were obtained through Area-Depth curves for the 24-hour storm, from *Technical Paper No. 40, Rainfall Frequency Atlas of the United States*. For South Laguna Madre, the original ARF value was 0.91. For further refinement, Areal Reduction equations were obtained from *Areal-Reduction Factors for the Precipitation of the 1-Day Design Storm in Texas*, with the assumption that Houston would be most like the Valley. Due to South Laguna Madre being more oval than circular, the ARF value was calculated over four radial distances and averaged, calculating 0.56. For validation purposes, discussed in **Section 2.3.1.1**, the ARF was adjusted to better represent precipitation and discharges in the region, finalized at 0.80.

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 4.**

Table 4: Land Use-Soils-CN Matrix for Computing Initial Curve Numbers (Compass Region 6)

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

A Curve Number (CN) can be considered a parameter, exhibiting variability that follows some frequency distribution. While Antecedent Runoff Condition (ARC) II CNs were used for a 1% event, the range between ARC I and ARC III for the ARC II CN was assumed to correspond to an 80% confidence interval of the ARC II CN. The CN loss method assumes a maximum potential retention parameter, S, is inversely related to a CN by S = 1000 / CN – 10; this relationship is based on a median value of S determined from plotting many observations.

Chapter 5 of the NRCS National Engineering Handbook (NEH) Part 630 provides an example of computing an initial CN for a watershed based on annual peak gage observations. The example involves computing a CN and corresponding S value for each event, then taking the logarithms of the S values. Further, the logarithm of S is assumed to vary normally, and the mean of the logarithms corresponds to the arithmetic median. Therefore, 10% (S10) and 90% (S90) extremes of lognormally distributed S values can be assumed to correspond to ARC III and ARC I condition CN values, respectively. This range represents an 80% confidence interval, corresponding to +/- 1.282 standard deviations from the mean. The following procedure was used to estimate one standard deviation of a given CN (in fact, one standard deviation of the logarithm of S) for the purposes of modeling 1% plus and minus events. First, ARC III (corresponding to S10) and ARC I (corresponding to S90) CN values can be estimated from a 1% CN (ARC II) by:

$$\mathrm{CNI} = 4.2 * \mathrm{CNII} \,/\, (10 - 0.058 * \mathrm{CNII})$$
$$\mathrm{CNIII} = 23 * \mathrm{CNII} \,/\, (10 + 0.13 * \mathrm{CNII})$$

Next, S90 and S10 can be computed by:

$$S10 = 1000 / CNIII - 10$$
$$S90 = 1000 / CNI - 10$$

The following relationship can then be used to compute one standard deviation of the logarithm of S:

$$\log(S10) = \text{mean}(\log S) + 1.282 \text{ std. dev.} (\log S)$$
$$\log(S90) = \text{mean}(\log S) - 1.282 \text{ std. dev.} (\log S)$$
$$1 \text{ std. dev.} (\log S) = (\log S10 - \log S90) / 1.282$$

Therefore, 1% plus and minus S values can be estimated by:

$$\log SPlus = \log S + [1 \text{ std. dev.} (\log S)]$$
$$\log SMinus = \log S - [1 \text{ std. dev.} (\log S)]$$

Finally, 1% plus and minus CNs can be computed by:

$$CNPlus = 1000 / (SPlus + 10)$$
$$CNMinus = 1000 / (SMinus + 10)$$

Since the 1% plus and minus events represent plus and minus one standard deviation of a 1% event, CNs used in a rainfall-runoff simulation for modeling 1% plus and minus events were developed, as described above.

Lag times for sub-basins were determined using the SCS lag method, as well as engineering judgment based on prior experience and studies in the Rio Grande Valley.

During the validation of the model, it was determined that a decrease in the curve number would be required to calibrate the model. The validation is discussed in further detail below in 2.3.1.1. **Table 5** below shows the adjusted curve numbers and lag time values used in this study.

Table 5: Rainfall-Runoff Parameters (Calibrated Curve Number, Lag Time)

Sub-basin Description	Initial CN	Validated CN	Validated CN 1% Minus	Validated CN 1% Plus	Tlag (min)
South Laguna Madre	**75.3**	**72***	57	83.3	4,108

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. NRCS Type III storm distributions were used for defining temporal distributions of point rainfall totals. **Table 6** provides the precipitation totals used for determining excess precipitation.

Table 6: 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
South Laguna Madre	5.23	6.71	7.94	9.34	13.28	7.43	11.24

Figure 5 shows the hyetographs applied to the 2D computational mesh for the interior drainage model.

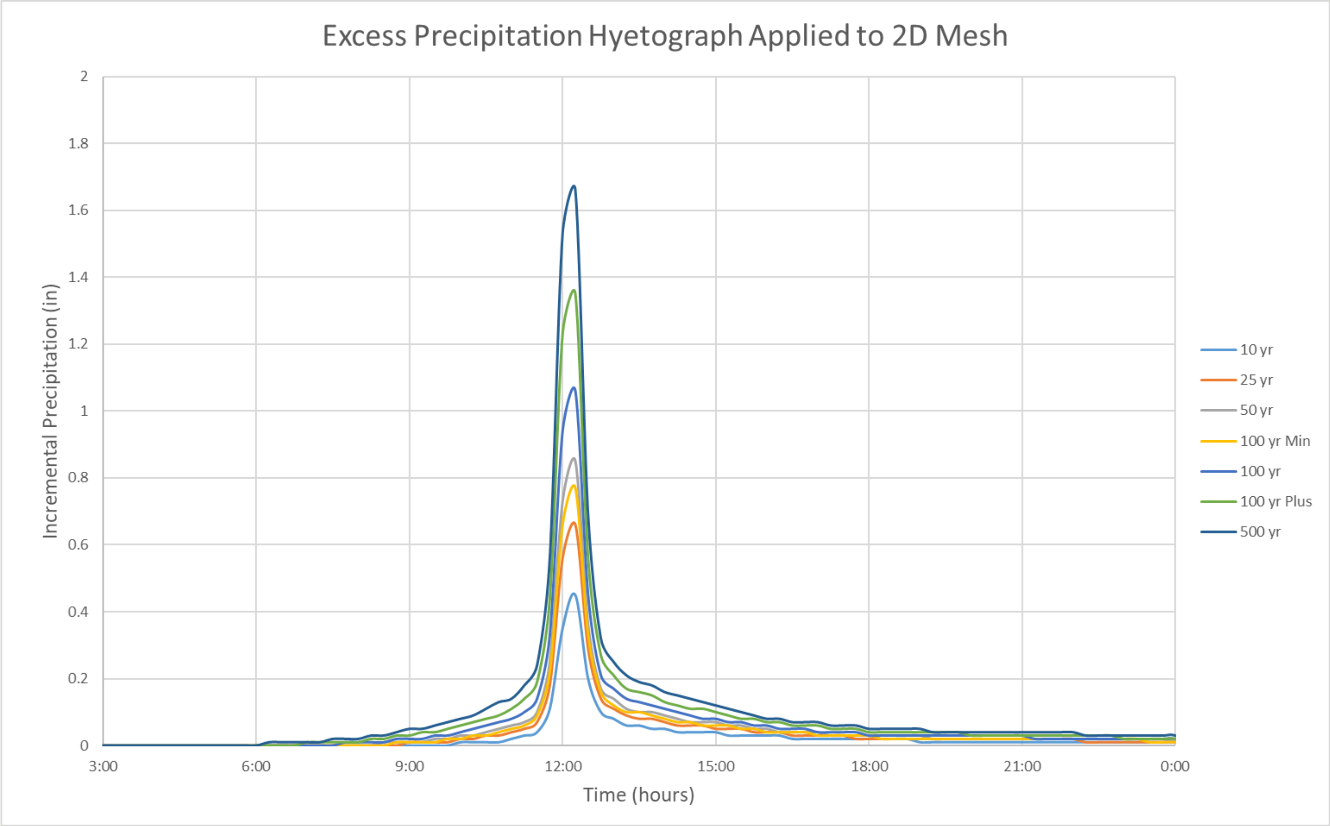

Figure 5: Precipitation Hyetographs (post ARF) applied to the Computational Mesh

2.2.2.2 Rio Grande Inflow Incorporation

Inflow data for the Rio Grande Inflow Model were obtained from the peak design capacity for the interior floodways designated and approved by USIBWC in Minute No. 238 in September 1970. The design flows were provided by the USIBWC, sourced in **Appendix B**, and are based on the Hurricane Beulah flood event in 1967, which reached a maximum flow of 220,000 cubic feet per second (cfs) at Rio Grande City, around 34 miles upstream of the Main Floodway. It was determined the precipitation from Hurricane Beulah was 60 to 80 percent of the maximum probable precipitation, subsequently resulting in the adoption of a design flow of the Lower Rio Grande of 250,000 cfs at Rio Grande City.

According to Minute No. 238, the design flow for the Rio Grande at Rio Grande City is 250,000 cfs. There is then a reduction of 15,000 cfs due to channel storage between Rio Grande City and the Anzalduas Dam. At the Anzalduas Dam, there is a structure that diverts 105,000 cfs into the Main Floodway. The remaining flow in the Rio Grande continues downstream, with an additional 5,000 cfs lost to storage, and another 105,000 cfs diversion to the Rio Grande into the Mexico Floodway. The remaining 20,000 cfs in the Rio Grande continues downstream to Brownsville. The 105,000 cfs that enters the US Main Floodway is diverted near Weslaco, TX, with 84,000 cfs continuing in the North Floodway and 21,000 cfs continuing in the Arroyo Colorado. The diversions and flow values are shown below in **Figure** 6**6** provided by the USIBWC.

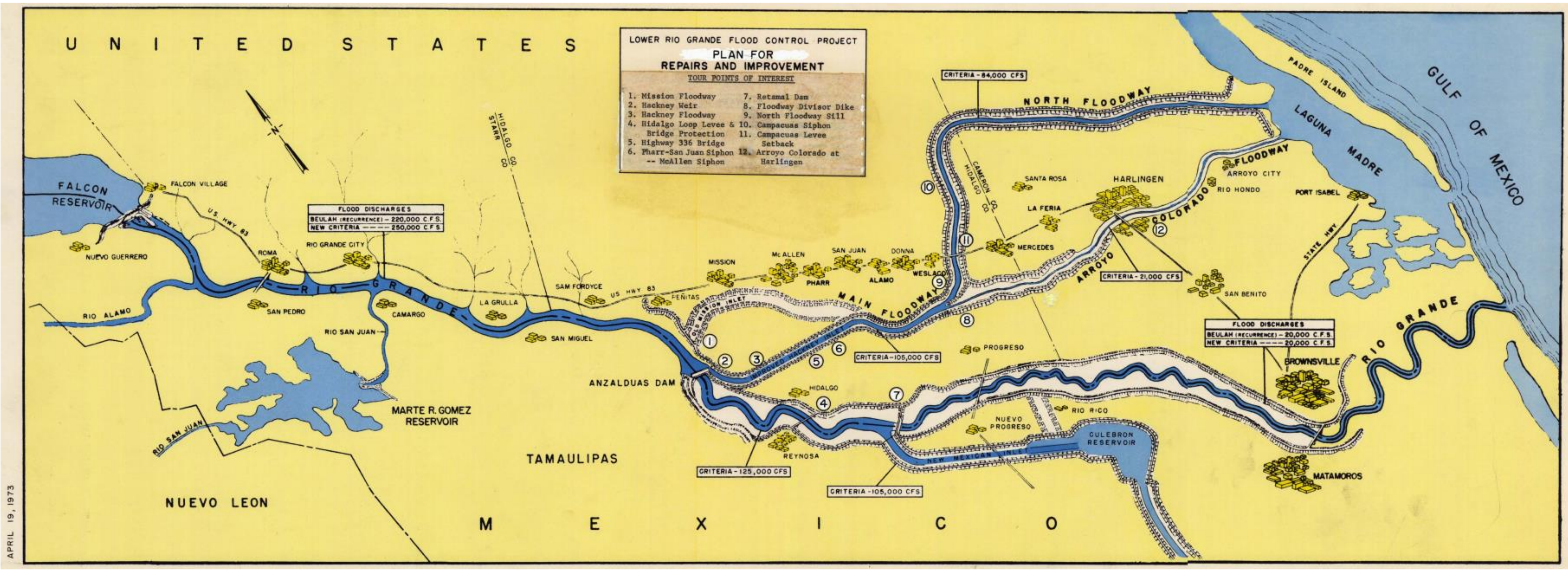

Figure 6: USIBWC Provided Figure of Lower Rio Grande Flows and Diversions

Flood frequency analysis of extreme peak flows for the Rio Grande below Anzalduas Dam were limited to the Flood Operations Criteria and diversions into the U.S. floodway system. General flood operations allocate equal allotments of flood flows into the United States and Mexican interior floodways to limit flows below Retamal dam to 15,000 cfs. In the 2003 Flood Frequency Study for the Rio Grande, analysis initially determined peak flows at Rio Grande City for the 100-, 50-, 20-, 10-, 5-, and 2-year recurrence intervals. From those, conveyance losses were removed throughout the reach and diversion flows were calculated. **Table 7** reflects the applied data provided in “Table 1 Peak Flows According to the Flood Operations Criteria” from Appendix 28 Flood Frequency Analysis for Rio Grande below Anzalduas Dam near Reynosa, Tamaulipas and Mission, Texas.

Table 7: Peak Flows According to Flood Operations Criteria

Return Interval	Units in 1,000 cfs	
	Peak Flow Rio Grande City	Divert to U.S. Interior Floodway
100	220	92.5
50	206	86.5
20	158	64
10	105	39
5	72	23.5
2	20	0

Inflow hydrographs for the Rio Grande Inflow Model were developed from the peak diversion flows for the design storm and the calculated recurrence intervals. A tabulated Beulah Hydrograph was developed for the 2008 Lower Rio Grande Flood Control Project report and input into an associated hydraulic model. **Figure 7** shows the plot provided in the 2008 USIBWC Report.

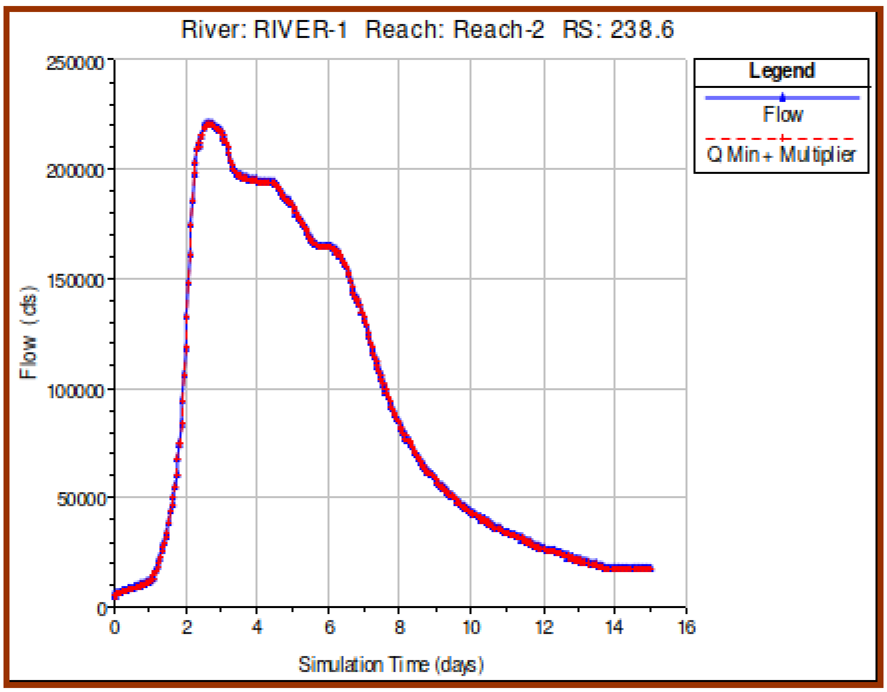

Figure 7: 2008 Lower Rio Grande Flood Control Project HEC-RAS Plot of 1967 Beulah Hydrograph at Rio Grande City

The hydrograph data was extracted from the hydraulic model provided by the USIBWC. The hydrograph was then converted into a unit hydrograph based on the design flow of 250,000 cfs. All frequencies modeled for the Rio Grande River Inflow Model include, 10-, 25-, 50-, and 100-year events. The extrapolated 1% plus and 500-year events were not modeled as these values exceeded the design flow (297,524 and 320,000 cfs, respectively). The flows within the US floodway system are regulated to not exceed the design flow, so these storm events were not modeled. The inflow hydrograph boundary condition was incorporated into the Rio Grande Inflow Model at Penitas, Texas.

2.2.3 Hydraulics

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

A 1D/2D model was developed to identify levee overtops and gaps for the Rio Grande Inflow and established as the basis for the natural valley procedure. Modeling of NVP scenarios produced notable model instabilities and these discrepancies would likely hinder stakeholder confidence, accessibility, and reuse, preventing further model refinement – a primary goal of the FEMA BLE program. To properly capture the interactions, both pluvial and fluvial, the study area was run as a complete 2D model in RAS with updated terrain data and improved hydraulic modeling methods. The processes described below apply to both the interior drainage and the Rio Grande River Inflow Model, and NVP models unless specified otherwise.

2.2.3.1 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 computation times and program file size. The 2D mesh for the models were set as evenly spaced cells at 300 feet. Typical cell size is 200 feet, but to accomplish model run times less than 24 hours, a larger cell size was used. The mesh was further refined by placing breaklines along roads, railroads, levees, stream centerlines, irrigation canals, and additional locations for incorporating key topographic features that can influence the flow. The addition of breaklines will create smaller localized cell sizes for model refinement.

Because the USGS HUC-8 boundaries are typically done on older, lower resolution topography a 1,000-foot buffer was added to the DEM to confirm the entire South Laguna Madre Watershed was represented in the study. The buffer identified additional areas that needed to be included in the South Laguna Madre Interior Drainage model for a more accurate representation of the entire watershed. This means very small portions on the Central Laguna Madre HUC-8 were included to capture interactions of flow between the two watersheds. This additional area is often due to the comparison of current HUC-8 boundaries to watershed delineations developed on newer, more detailed topography and is not considered as significant watershed inflow as explained in the Introduction. Future HUC-8 boundary refinement may be considered based on the resulting maps and flow directions. **Figure 8** shows the 2D computational mesh for the South Laguna Madre Interior Drainage model. In areas of coastal influence, established by effective VE, V, and coastal AE zones, computational mesh was reduced. See **Section 2.2.3.4** and **Figure 10** for further explanation on coastal influence.

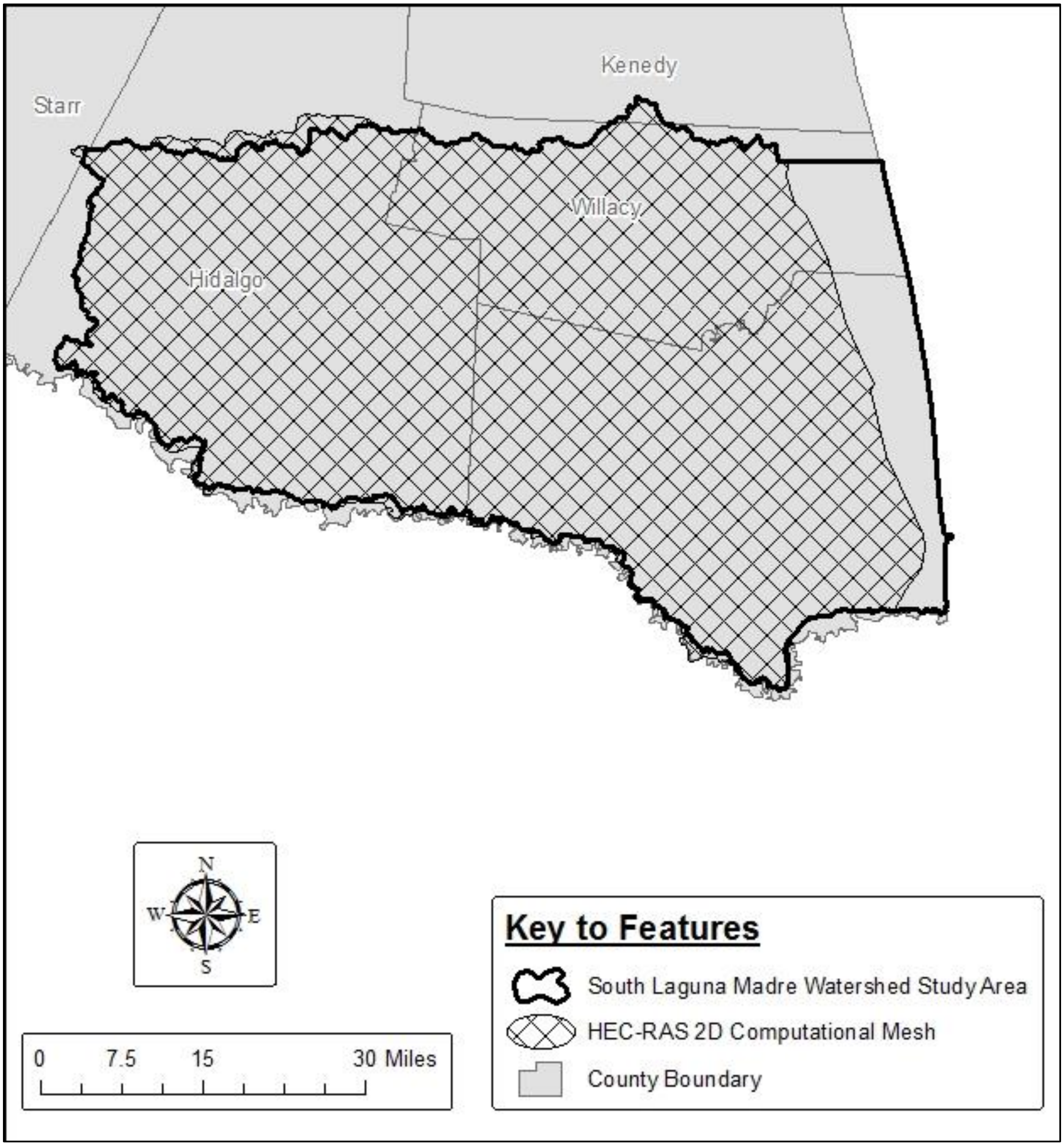

Figure 8: HEC-RAS 2D Computational Mesh

The HEC-RAS 2D computational mesh was created using ArcGIS refinement toolsets, such as smoothing and simplification routines. This significantly reduced the need for manual edits to cells within HEC-RAS that often create more opportunity to generate errors. The 2D mesh consists of over 800,000 cells and a 300-foot nominal mesh cell size. Cells with breakline edits or in proximity to the edge of the mesh do have variable sizes. A 1-minute time step was used in the HEC-RAS model, applying the Diffusion Wave (simplified Full Momentum) equations.

The Rio Grande Inflow Model is a condensed mesh based on the approximate impact zone of the floodways. This area includes the Rio Grande River, which is outside the South Laguna Madre HUC-8 boundary. Extra consideration and detail have been given to the location of the 300-foot cell faces along the high grounds of the levees. Since levees are meant to provide flood protection, it was imperative to identify any areas of cell leakage and edit those cells or break lines to prevent artificial overtopping and flooding. Cell leakage occurs when a cell straddles high elevation and flow is allowed to balance on either side of that high point instead of the high point acting as an obstacle. In this case if cell leakage occurred across the high points of the levees, the resulting mapping and flow would represent the levee being overtopped. Overtopping locations can be found in **Appendix C.**

2.2.3.2 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires establishing a 2D computational mesh boundary. For the South Laguna Madre Interior Drainage Model, an excess precipitation was applied to the mesh. All identified USGS gages are within the floodway systems and were not utilized for calibration efforts for either model, as discussed in Section 2.3.1.1. The Interior Drainage model does not include the floodway reach validation, so gages within the system are not applicable.

The development of the excess precipitation hyetographs for the 2D mesh are described in Section 2.2.2.

Outflow boundary conditions (from the computational 2D mesh) were utilized along basin boundaries using normal depth. 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 all non-unique outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain data. Coastal boundary conditions were placed using a Stage Hydrograph with a High-High Water Mark of 1 ft.

2.2.3.3 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; because of this, a 70-foot buffer zone was created around each stream centerline to create a main channel roughness zone. The initial channel roughness zone was given a Manning’s n value of 0.045, taken from the HEC-RAS User’s Manual. Typical of channels in the area, the channel Manning’s value was selected based on vegetated channels throughout the HUC8, and validation efforts further refined values. All initial roughness coefficients were lowered iteratively for validation after initial adjustments. **Table 8** below shows a typical land use-roughness matrix used to define the roughness coverage for the study area.

Table 8: NLCD 2016-Manning's N Roughness Matrix

NLCD Classification	Validated[2]	Initial Classification Range			Source
		Minimum	Normal	Maximum	
Open Water	**0.02**	0.025	0.03	0.033	Chow 1959
Developed, Open Space	**0.03**	0.01	0.013	0.016	Calenda, et al. 2005
Developed, Low Intensity	**0.05**	0.038	0.05	0.063	Calenda, et al. 2005
Developed, Medium Intensity	**0.07**	0.056	0.075	0.094	Calenda, et al. 2005
Developed, High Intensity	**0.11**	0.075	0.1	0.125	Calenda, et al. 2005
Barren Land	**0.02**	0.025	0.03	0.035	Chow 1959
Deciduous Forest	**0.11**	0.1	0.12	0.16	Chow 1959
Evergreen Forest	**0.11**	0.1	0.12	0.16	Chow 1959
Mixed Forest	**0.11**	0.1	0.12	0.16	Chow 1959
Scrub/Shrub	**0.05**	0.035	0.05	0.07	Chow 1959
Grassland/Herbaceous	**0.02**	0.025	0.03	0.035	Chow 1959
Pasture/Hay	**0.03**	0.03	0.04	0.05	Chow 1959
Cultivated Crops	**0.03**	0.025	0.035	0.045	Chow 1959
Woody Wetlands	**0.09**	0.08	0.1	0.12	Chow 1959
Emergent Herbaceous Wetland	**0.06**	0.075	0.1	0.15	Chow 1959
Main Channel[1]	**0.035**		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]Selected values based on validation efforts, values adjusted to accomplish validation goals as described in **Section 2.3.1.1**

2.2.3.4 Breaklines

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including road embankments,hydraulic structures, levees, and stream centerlines. Road embankments were identified in ArcGIS and imported into HEC-RAS as breaklines to prevent modeled flow from being routed past roads until it was deep enough to overtop the road. Road breaklines that are considered "at grade" and don't impact flow were removed. "At grade" refers to roads that are at similar elevations to surrounding topography without considering shallow (0.5-1ft) roadside ditches.

Similarly, bridge/culvert crossings that were not processed out of the terrain data were modeled by creating V-Notches, U-Notches, or other breakline offset adjustments adjacent to the road embankment to align grid cells around the embankment and allow water to be routed across the embankment. Using breakline offsets forces cell leakage and is useful in the approximation of most hydraulic structures as this approach can be implemented in ArcGIS on a large scale with much less effort than alternative methods. An example of the offset breakline approach is shown below.

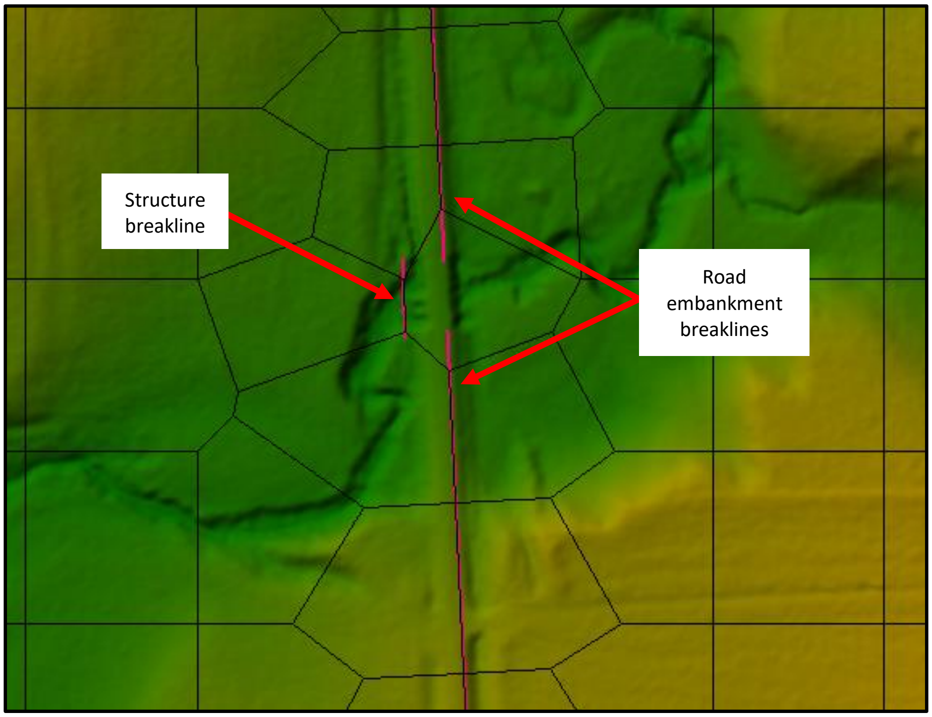

Figure 9: Offset Breakline Approach at Bridge Crossing

County, interstate, common name, state recognized, and U.S. roads were incorporated for road breaklines from the U.S. Census Bureau 2020 TIGER/Line road layer. The stream centerlines were modeled as breaklines so that cells lined up perpendicular to the stream to capture full stream conveyance.

The study area included multiple levee reaches which conveys the Rio Grande system and crosses through the length of the HUC-8 watershed. In order to represent the prominent features, breaklines were enforced for the non-FEMA accredited levee reaches throughout the area, identified in **Table 9**. Although the levee reaches are non-accredited, the levees were assumed to provide protection so the modeling could be leveraged for the NVP as described in **Appendix A**. Cells and breaklines were edited to minimize cell leakage and prevent any artificial flow from entering or leaving the levee reaches. In areas of coastal influence, established by effective VE, V and coastal AE zones, model refinement was reduced. This is due to flooding being influenced more by storm surge rather than precipitation or the floodways. In **Figure 10**, the coastal influence zone is outlined on the eastern portion of South Laguna Madre.

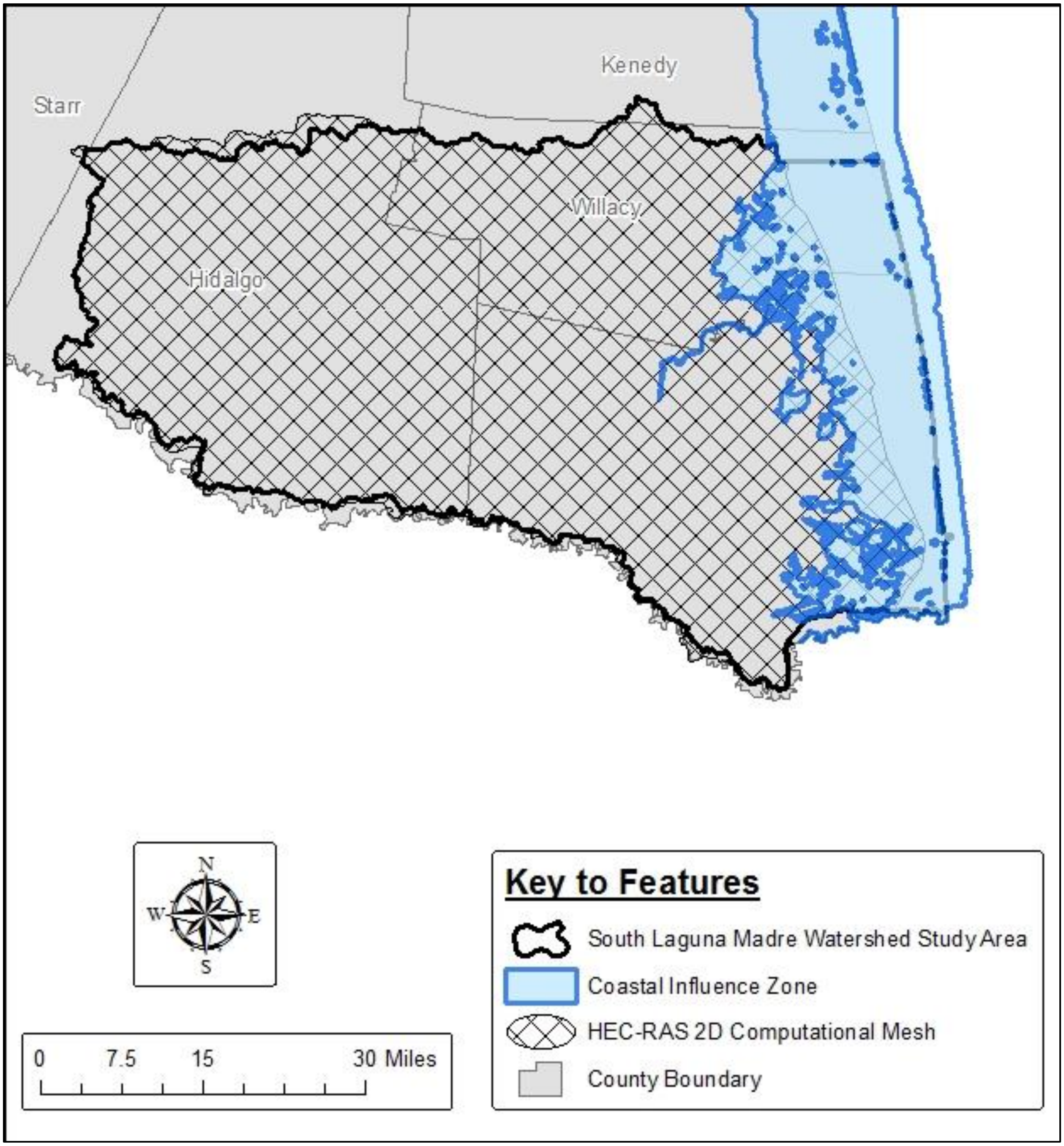

Figure 10: South Laguna Madre Coastal Influence Zone

Table 9: South Laguna Madre Levee Reaches

Levee Reach	Levee Abbreviation	Length (mi)
Arroyo Colorado North	ACN	10.15
Lower Rio Grande Levees - I	LRGI	24.67
Lower Rio Grande Levees - II	LRGII	15.38
Lower Rio Grande Levees - III	LRGIII	50.72
Main Floodway and Arroyo Colorado South	MACS	37.77
Mission Levee	ML	22.93
North Floodway Left Bank - I	NFLI	33.45
North Floodway Left Bank - II	NFLII	25.42
North Floodway Right Bank - I	NFRI	17.38
North Floodway Right Bank - II	NFRII	27.08

2.3 Model Results

The South Laguna Madre Interior Drainage Model results were combined with the Rio Grande Inflow Model results, with the non-accredited levees providing protection. All risk associated with this area and the non-accredited levee reach should consider the results of the Natural Valley Procedure discussed in **Appendix A**. For the 500-year mapping results, the Rio Grande River Inflow Model design flow value was used with the 500-year rain on mesh for the interior drainage model.

Results for this study aligned well with the Special Flood Hazard Area effective mapping in most areas throughout the watershed. **Table 10** shows a comparison of some the effective water surface elevation (WSE) data with the model results in Cameron County.

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 utilized for detailed modeling. The validity of the 2D BLE results should be verified through community work map meetings before being applied to a regulatory product.

Table 10: Effective and Model WSEL Comparison

Stream	Effective XS Line ID	Effective WSEL (feet)	Model WSEL(feet)	Difference (feet)
Main Ditch No 2	48061C_44	41	40	-1
	48061C_45	43	42	-1
	48061C_55	8	8	0
	48061C_57	12	12	0
Cameron County Drainage Ditch #1	48061C_31	11	8	-3
	48061C_69	7	6	-1
Harlingen Main Canal	48061C_38	38	38	0
	48061C_73	33	35	2

2.3.1.1 Validation & Sensitivity Analysis

Validation efforts were handled differently for each model based on available data and discussions with the Region and per coordination with the USIBWC. There were no known USGS gages within the interior drainage model area with more than 20 years of flow record that were not influenced by discharges from the Rio Grande. Due to this, no gages were used for validation of the 1% annual chance event.

Curve Numbers, n-values, and areal reduction factors were adjusted such that model results compared well to effective floodplain mapping. A sensitivity analysis revealed that curve number and n-value adjustments had minimal impacts on floodplains. Typical BLE areal reduction factors are around 0.91 and are based on the Rainfall Frequency Atlas of the United States (TP-40). Due to the shape and general characteristics of this watershed, including flatter slope and long times of concentration, a lower value of areal reduction is justified and consistent with other area hydrologic studies. For this study, the areal reduction factor was calculated to be between 0.6-0.8 with changes based on relative centroid of the watershed. By comparing the resulting floodplains and multiple validation runs with areal reduction values within that range, an areal reduction factor of 0.80 was chosen as it resulted in mapping that best represented the effective floodplains. A portion of the effective floodplains in the area were produced from water-surface elevations derived from aerial photos taken during Hurricane Beulah, further described in the June 2000 Hidalgo County Flood Insurance Study. This is noted because this type of mapping results in floodplain limits similar to those of a 2D analysis, including some disconnected ponding.

For the Rio Grande Inflow Model, validation was accomplished through terrain adjustments and structure incorporation to target the established design flows at primarily three locations: just upstream of the US diversion at Anzalduas dam, the amount of flow entering the Main Floodway, and at the diversion from the Main Floodway to Arroyo Colorado, and North Floodway systems.

Terrain adjustments were made due to large discrepancies in the 3DEP terrain, which were addressed by removing the model mesh to the edge of the 2011 USIBWC LiDAR data in the upstream section of the Rio Grande Inflow Model. To prevent flow from arbitrarily leaving the system, no normal depth boundary condition was added to the area, creating a wall. This adjustment kept flow in the system between the beginning upstream section and the Anzalduas dam and kept our resulting flow values within 5% of the design flows. It is recommended to that the model be rerun with updated terrain when available.

At Anzalduas dam, field verification discovered of a controlled obstruction regulating flow into an irrigation canal, as shown in **Figure 11**. To account for this, a structure was added to prevent excess flow from leaving the system. In the terrain, the top of the Anzalduas dam was lower than the apparent normal pool elevation upstream. Terrain was raised in the HEC-RAS model to increase the height of the top of the dam to the approximate normal pool elevation. With these adjustments, the resulting model produced a flow value entering the Main Floodway of 104,048, which is within 1% of the design flow. The **Along the** levee reaches, a missing structure was identified at the confluence of a stormwater channel and the main floodway where flow was leaving the system, located 1,155 feet southwest of West Hall Acres road. Due to this, hat structure was approximated and incorporated to prevent flow from leaving. All structures added were validated by imagery and field site investigations. For future analysis, surveyed structure data and dam operations will need to be added for more detailed modeling.

Table 11 shows the comparison of the design flows with the resulting flows. **Figure 12**Error! Reference source not found. shows the developed flow hydrographs for different sections along the Rio Grande and the Floodway Systems.

Figure 11: Irrigation Canal Structure at Anzalduas Dam

Downstream of Anzalduas dam there is significant flow lost to storage, which would not have been captured in a traditional 1D (one-dimensional) model. This storage, captured in the 2D model, accounts for some of the differences between the design flows and the resulting flows downstream of Anzalduas Dam.

Along the levee reaches, a missing structure was identified at the confluence of a stormwater channel and the main floodway where flow was leaving the system, located 1,155 feet southwest of West Hall Acres road. Due to this, hat structure was approximated and incorporated to prevent flow from leaving. All structures added were validated by imagery and field site investigations. For future analysis, surveyed structure data and dam operations will need to be added for more detailed modeling.

Table 11: Comparison of Design and Modeled Flows

Location	IBWC Flows (cfs)*	With Levee Discharges (cfs)	% Difference
Upstream Limit of Study		243,553	
Rio Grande at Penitas	235,000	223,354	-5%
US of U.S. Diversion		226,782	
Diversion to the U.S. Main Floodway	105,000	104,048	-1%
Channel Diversion US of Dam			
Anzalduas Dam		113,024	
Rio Grande at Hidalgo/Reynosa	130,000	109,493	-16%
Diversion to the Mexican Floodway	105,000	45,651	-57%
DS of Mexico Floodway		38,488	
Rio Grande at Matamoros	20,000	8,405	-58%
Main @ International Blvd		102,800	
North	84,000	74,836	-11%
Arroyo Colorado	21,000	26,288	25%
***Flows obtained from Flood Operations Criteria in *Hydraulic Model of the Rio Grande and Floodways within the Lower Rio Grande Flood Control Project* prepared by the IBWC in June 2003**			

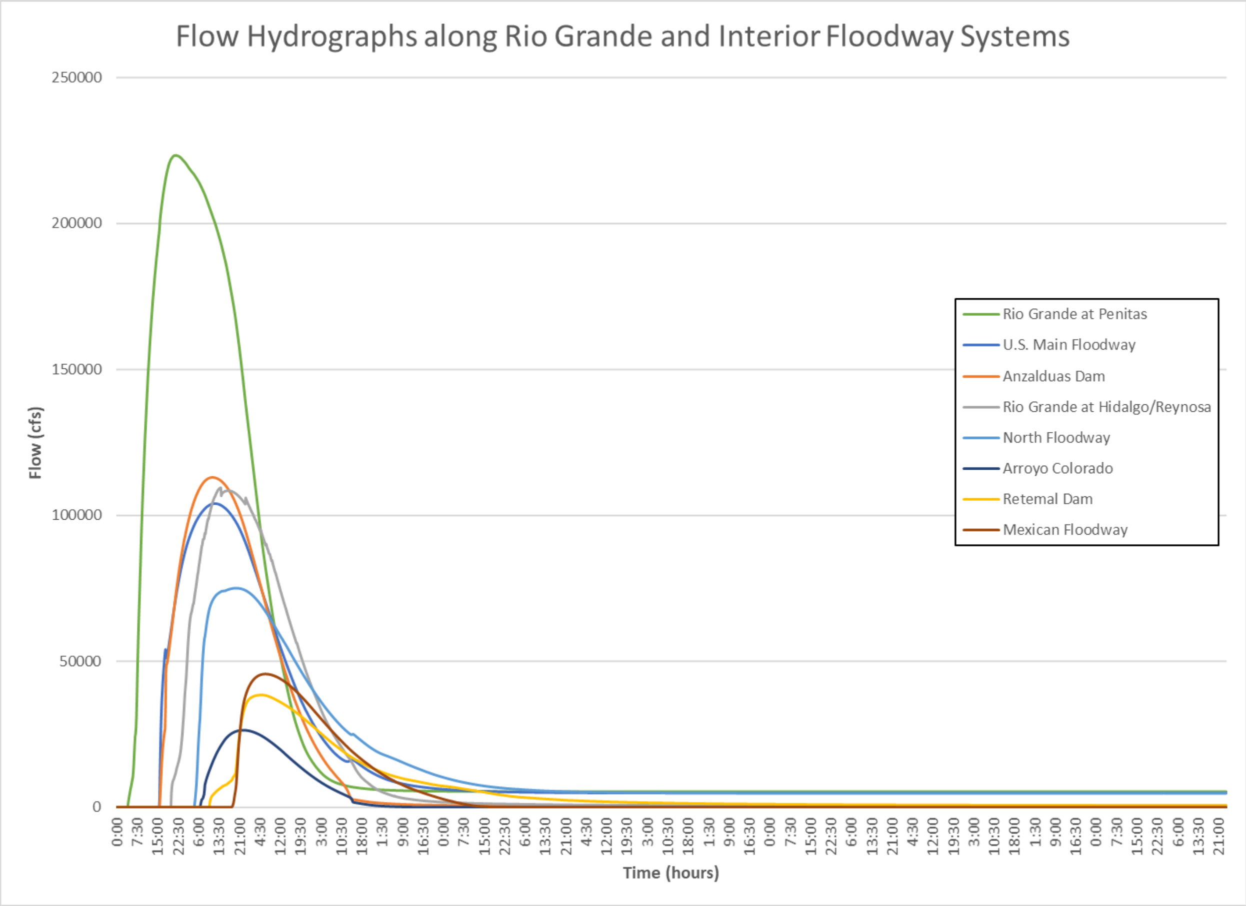

Figure 12: Inflow Hydrographs along Rio Grande and Interior Floodway Systems

2.4 Challenges

Major challenges included a lack of gage peak streamflow record within the interior drainage model area, within the recommended 20-year time frame and outside the impact of the interior floodway operations. Several of the effective floodplains in the area were unavailable, paper panels, or based on aerial imagery from Hurricane Beulah, which hindered our ability to have comparisons throughout the entire HUC. Although there is sufficient data available to provide confidence in the results, incorporation of more detailed information would enhance model results.

Additional challenges include the incorporation and assumptions of the irrigation canals and the floodway systems controlled by dam and floodway operations. All significant topographic features including the non-accredited levees reach were left in place, creating the base model for the natural valley procedure. The Natural Valley Procedure (NVP) performed in conjunction with this study is discussed in **Appendix A**.

Detailed structures have not been added to the model. There is aerial imagery and topographic evidence of structures that could be added in more detailed analysis. 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. In addition, the watershed's proximity to the Rio Grande delta low lying areas often made it more difficult to determine the direction of flow, with many areas ponding, having no defined channelized flow.

2.5 Recommendations

Coordination with the USIBWC has been instrumental in understanding how the floodway system operates. Additional detailed hydrologic analysis may update risk. Design flows used in the Rio Grande Inflow model were based on discharge analysis resulting from Hurricane Beulah in 1967. This 2D BLE and the accompanying NVP will help inform local leaders and community stakeholders of the associated flood risk with the levee reaches.

When available, incorporating new LiDAR to the model, especially for the Mexico portion of the project area, will provide more reliable results. The modeling approach for structures was also limited and additional detail should be added in the future to better represent the geometry and the operations of structures in the study area. This includes surveyed structure data, Anzladuas and Retemal dam operations and sluice gate operations.

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. To decrease the "cupping effect" along the extent of the floodplain boundaries, an intermediate step was completed by taking the extents of the sloping raster from the model and placing points parallel to the boundary by 25 feet on either side every 50 feet along the line. Those points were then given a value from the horizontal model raster and combined with the mesh cell center points and a new interpolated raster was created for the floodplain mapping. For the purposes of the South Laguna Madre BLE project, 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 0.5 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. 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 was used as reference data to verify that the extent of the BLE results represent the appropriate flooding extent.

The 0.2% flood areas were produced for the entire watershed for all depths greater than 0.5. The methodology applied for the 1% to convert the raster to polygon, smooth and simplify the polygons were applied to the 0.2% boundaries. After both layers were developed, a union of the two products was performed to develop the deliverable format 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 South Laguna Madre HUC-8 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 the study area in the South Laguna Madre Watershed, the effective Zone A topographic data sources leveraged were lower quality than LiDAR sources, except for one LOMR study in Hidalgo County. The topographic data sources discussed in Section 2.1.1 of this report represent a significant improvement for the areas that did not use LiDAR for their effective studies. Therefore, all reaches in the study area FAIL this check except for those associated with the LOMR in Hidalgo County.

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% annual chance flow. Regression equations were not utilized for the effective analyses or are unknown. For this reason, all reaches in the study area PASS this check.

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. 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 South Laguna Madre Watershed was completed by evaluating percentage of urban change at the HUC-12 level. Two HUC-12 polygons within the study area met the threshold of 15% or more urban cover, (121102080101 and 121102080102). Therefore, all reaches were set to PASS this element except for reaches within those two HUC 12s.

Table 12 presents the summarized results of checks A1 through A3.

Table 12: A1-A3 Validation Results

Assessment Checks	Pass / Fail	Notes
A1 – Topography	Pass/Fail	Available LiDAR significantly better than effective topo source/LiDAR utilized in effective study
A2 – Hydrology	Pass	Regression equations not used in effective analysis OR New equations have not been published since the effective analysis
A3 – Development	Pass/Fail	Majority of study area is rural/Two HUC-12s met threshold of 15% of study area is urban cover

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 South Laguna Madre Watershed, check A4 has been marked as FAIL for all reaches but one in the study area where the effective study is model backed.

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 South Laguna 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 Floodplain Boundary Standards (FBS) methodology (2019). 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 points placed along its perimeter every 200 feet.

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

A total of 543.1 miles of available CNMS features representing the effective Zone A studies were categorized as VALID – BEING STUDIED and UNVERIFIED – BEING STUDIED. Total miles in each of these categories are summarized in **Table 13** and illustrated in **Figure 13** below. **Table 14** summarizes the validation results based on the individual HUC 12 watersheds within the South Laguna Madre Watershed.

Table 13: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	0.28
UNVERIFIED	BEING STUDIED	542.8

Table 14: HUC 12 Zone A Validation Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>90%)	Priority Score
Watershed Name	Watershed Number						
South Laguna Madre	12110208	49,563	23,671	25,892	52.2%	FAIL	
Llano Grande Lake-SArroyo Colorado	121102080100	8,299	3,474	1,825	34.4%	FAIL	60.5
Lake Edinburg-Edinburg North Main Canal	121102080200	8,352	5,092	3,260	39.0%	FAIL	46.6
Upper Pilot Channel-Laguna Madre	121102080300	3,820	2,322	1,498	39.2%	FAIL	43.4
West Main Drain-Laguna Madre	121102080400	8,791	5,093	3,698	42.1%	FAIL	34.3
East Main Drain-Laguna Madre	121102080500	687	513	174	25.3%	FAIL	34.5
La Feria Main Canal-Arroyo Colorado	121102080600	3,978	1,653	2,325	58.4%	FAIL	37.2
Line V Canal-Arroyo Colorado	121102080700	2,480	1,030	1,450	58.5%	FAIL	40.9
Laguna Atascosa	121102080800	5,921	1,834	4,087	69.0%	FAIL	27.9
Bahia Grande-Brownsville Ship Channel	121102080900	10,235	2,660	7,575	74.0%	FAIL	23.8

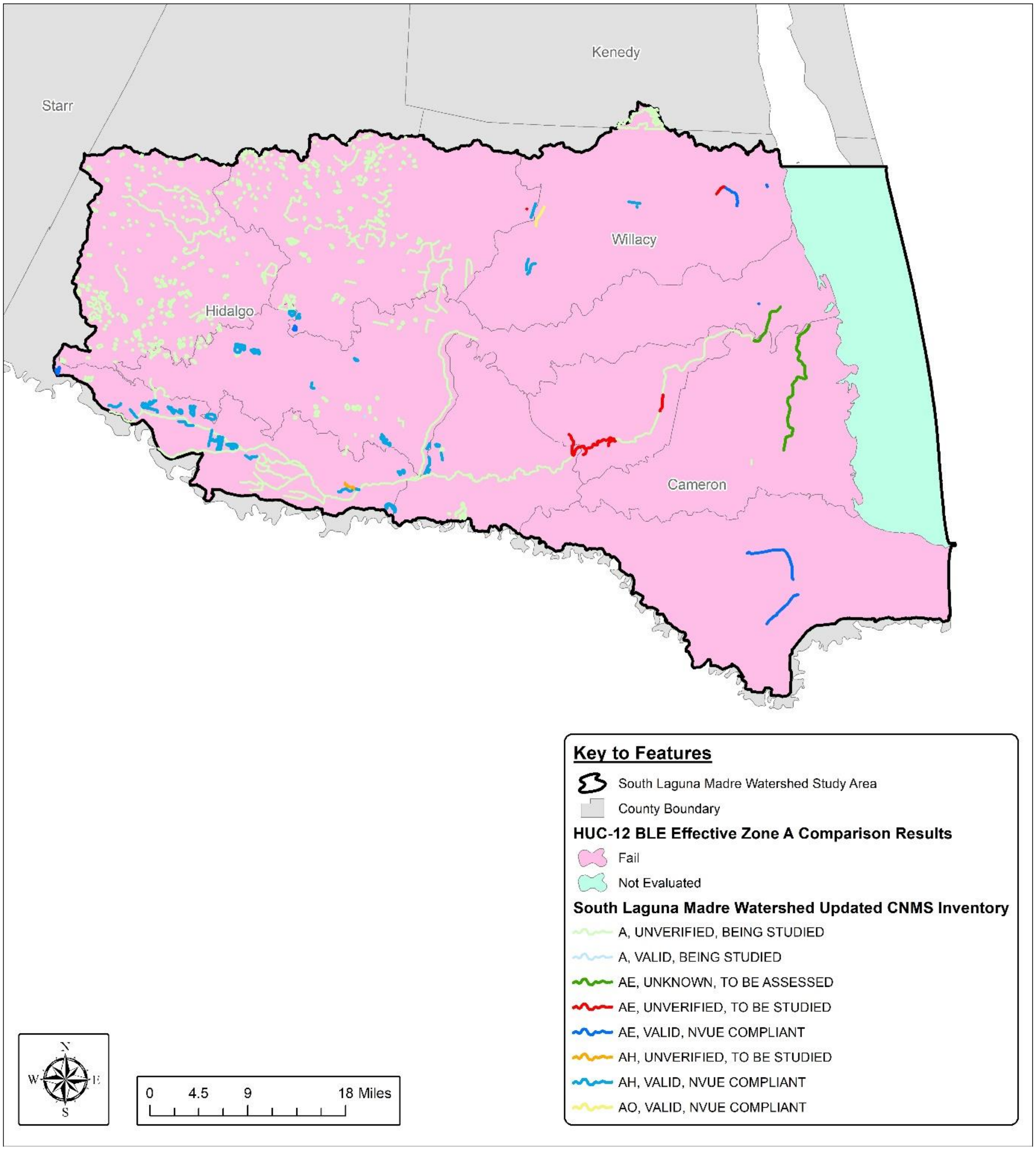

Figure 13: South Laguna Madre Watershed CNMS Validation Results

An overall risk for each HUC-12 watershed was calculated using the National Flood Risk Percentages Dataset and its proportional area. The weighted risk was multiplied by the percentage of points in the watershed that failed the CNMS comparison to effective to determine the priority score. **Figure 14** below shows the range of the South Laguna Madre HUC-12 priority scores which can be used to initiate discussions during the Discovery phase. Llano Grande Lake-Arroyo Colorado HUC-12 was determined to have the highest priority score and the most need while Bahia Grande-Brownsville Ship Channel HUC-12 has the lowest score.

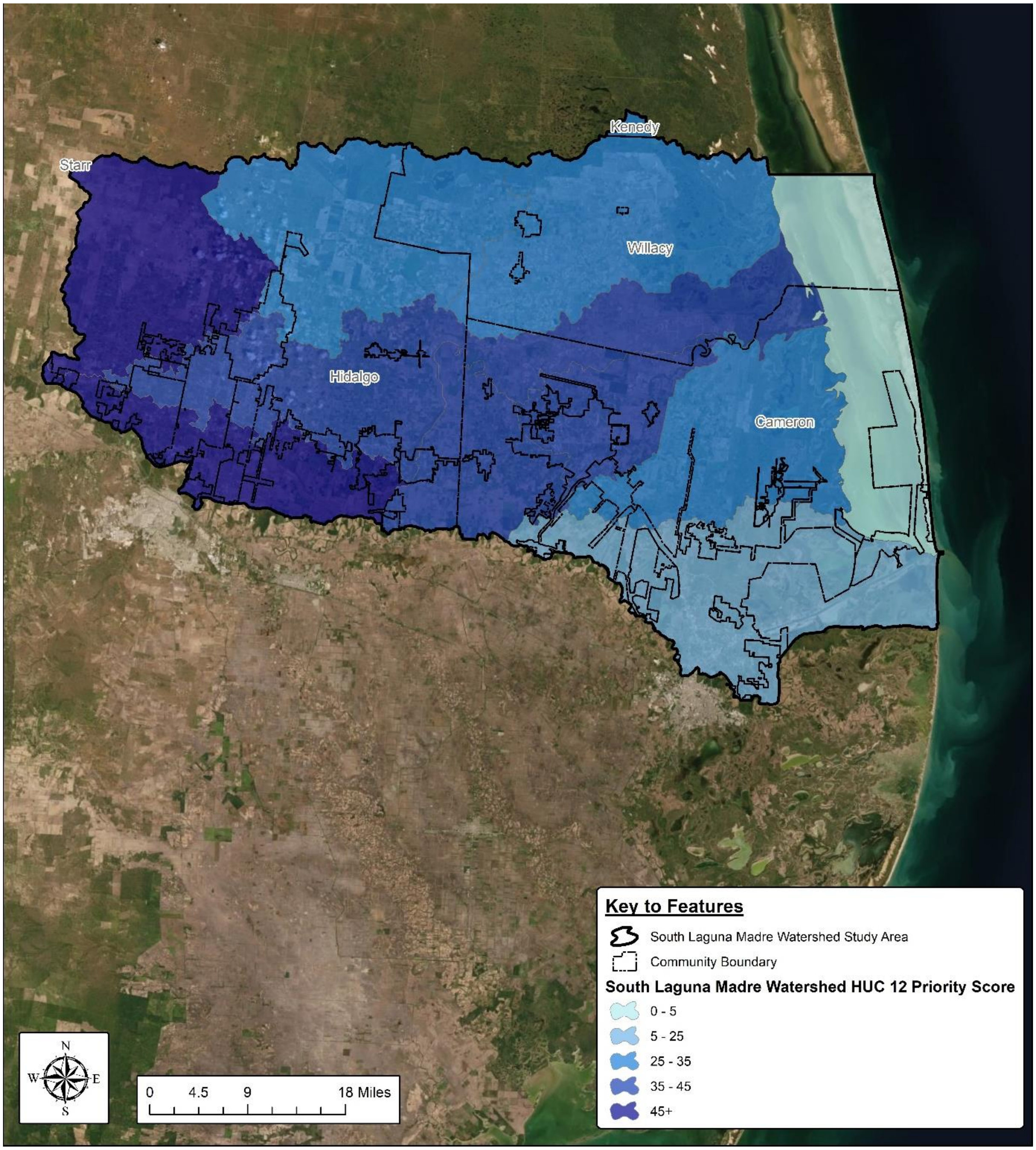

Figure 14: Ranking of South Laguna Madre Watershed HUC-12s

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 parish within the project watershed extends for each return period to ensure proper model processing. A summary of results per parish for the 100-year scenarios are shown in **Table 15**.

Table 15: Hazus 4.2 Results for 1-percent-annual-chance (100 year) scenario for South Laguna Madre Watershed, Texas

County	Full Replacement - Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Cameron	$2,435,595,000	$26,223,346,000	$16,376,284,000
Hidalgo	$6,186,410,000	$43,916,858,000	$26,806,453,000
Kenedy	$0	$0	$0
Starr	$0	$162,000	$81,000
Willacy	$194,905,000	$1,167,087,000	$683,180,000
Total	**$8,816,910,000**	**$71,337,453,000**	**$43,865,998,000**

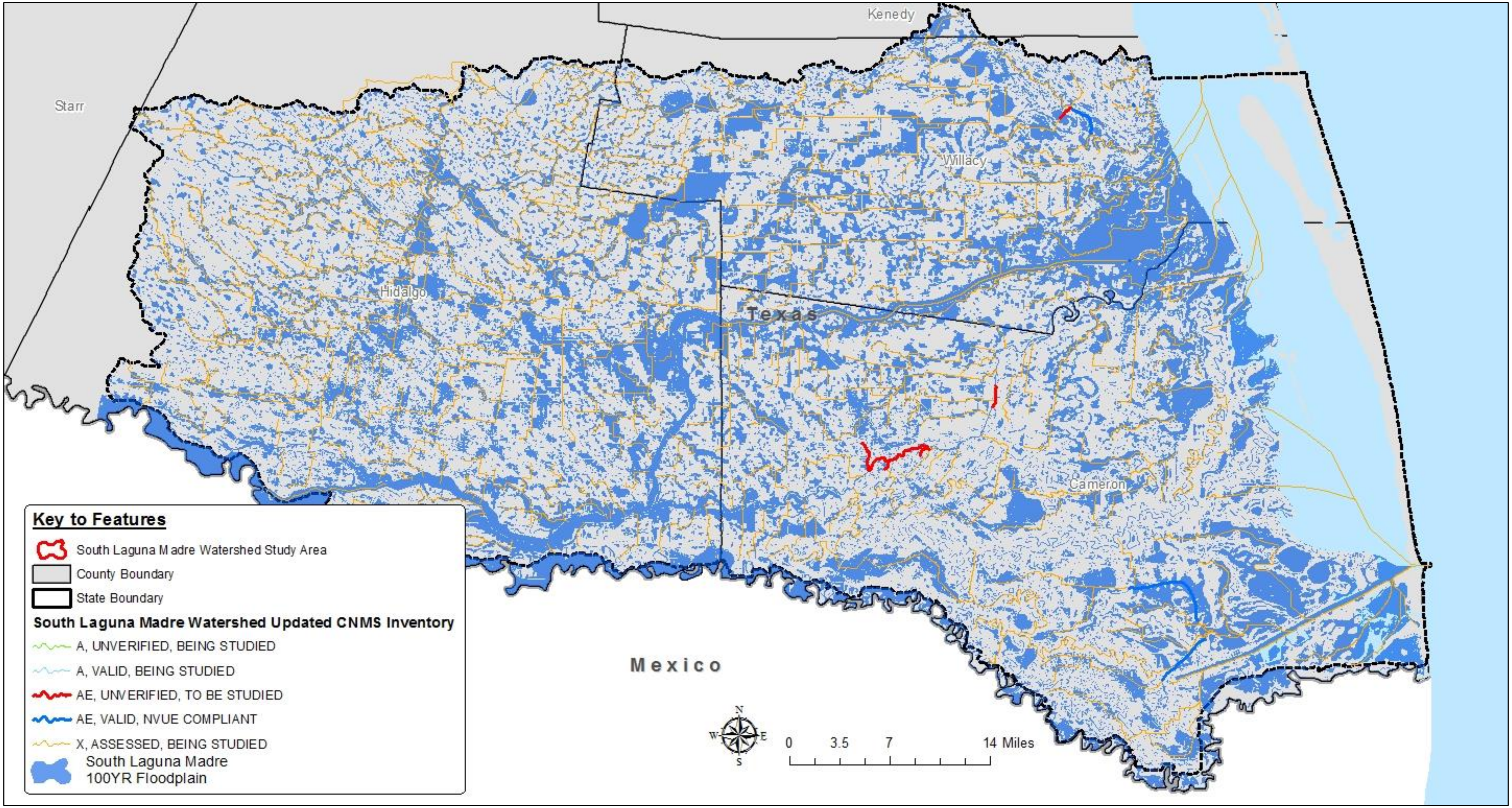

Figure 15: South Laguna Madre 100 Year Floodplain

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