Double Mountain Fork Brazos River Watershed, Texas
2D Base Level Engineering and Mapping Methods and Results

Texas Water Development Board Contract No. 2101792542, Task Order 1

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APPROVALS

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1. Introduction

Base Level Engineering (BLE) provides technically credible flood data for various geographies - community, county, watershed and/or state level. BLE data can be shared with Federal, State, local and tribal governments, this data sharing provides stakeholders at all levels the necessary data to make informed decisions to reduce future flood losses. Without the mapping of flood prone areas, there can be a lack of information to effectively communicate flood risk to community officials, citizens, and businesses.

BLE is a riverine hydrologic and hydraulic modeling approach that builds on lessons learned to produce a baseline understanding of flood risk to communities, produced to support the assessment and maintenance of the national flood hazard inventory. Engineering models are created during a BLE assessment, producing information that meets the mapping Standards for Flood Risk Projects (FEMA Policy Memo FP 204-078-1) to produce Zone A (1-percent-annual-chance flood) information. BLE data is intended to represent the base level of investment needed for all flood study efforts FEMA will undertake. The Double Mountain Fork Brazos watershed BLE documented here was designed to use two-dimensional (2D) modeling techniques with enhancements and calibration to develop products that can be communicated and shared with stakeholders, and transitioned into FEMA regulatory data development workflows.

The intent of BLE is to provide communities technically credible flood hazard information in a cost efficient and timely manner. Additionally, BLE provides communities a chance to review draft modeling information, reflecting the potential changes in risk within their community. Providing additional flood risk datasets, like water surface elevation (WSEL) grids and flood depth grids, delivers alternative information that reinforces the variability of flood risk within a designated floodplain and supports historic community requests for a source to determine a Base Flood Elevation in Zone A areas.

For floodplain management purposes, BLE data may be used as best available information in areas that are designated as Zone A floodplain. It may also be used to regulate development in areas where no Special Flood Hazard Area (SFHA) has been mapped before. Communities may adopt BLE data to support local regulations, which facilitates use of the data in local floodplain management activities, including in the post disaster environment where a need for updated and/or enhanced flood hazard information may be necessary.

BLE provides information to communities who are currently unmapped and provides a digital entry to communities that are currently un-modernized. BLE acts as a measuring tool to allow FEMA to assess the current Zone A inventory identified as unknown or unverified in FEMA's Coordinated Needs Management Strategy (CNMS), which FEMA is required to evaluate once every five years, as described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e). 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 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, a cost-effective approach for evaluating Zone A studies has been lacking. Another important goal of the BLE process is scalability of the results, meaning that the model produced during the BLE assessment may be refined to produce a more enhanced model with additional manual correction and on the ground survey. If BLE modeling exists, FEMA will recommend that it be used as the base model for any detailed studies performed in those areas.

BLE practices leverage high-resolution topography that meets or exceeds the United States Geological Survey (USGS) 3-D Elevation Program (3DEP) standards and often applies flood engineering at a large scale as opposed to targeting stream reaches within a watershed. BLE can be conducted at any scale, commonly for larger areas (Hydrologic Unit Code (HUC)-8 watershed) but may be produced at the county or local level too. It is encouraged to do BLE for wider areas in order to build on efficiencies in modeling and ensure cost efficiency. Using current technologies, multiple watersheds or watersheds with large land areas can be analyzed at a more efficient rate to produce water-surface elevations and site-specific hazard data replacing outdated flood studies shown in existing Flood Insurance Rate Maps (FIRMs). All flood prone areas within a watershed will have an engineering model calculating multiple flood recurrence intervals and defining floodplains with elevation grids using high-resolution topography.

Per standard identification SID #84 and #133, BLE will include all recurrence intervals (0.2-percent, 1-percent, 1-percent plus, 1-percent minus, 2-percent, 4-percent, and 10-percent-annual-chance floods). As such, hydrologic and hydraulic analysis should be performed to determine the expected WSELs for each of the seven recurrence intervals previously identified.

The Double Mountain Fork Brazos watershed 2D BLE project was scoped as described in the Texas Water Development Board (TWDB) Task Order 1 (Contract 2101792542). In an effort to increase and enhance the flood risk products in Texas, the study was contracted through the TWDB's Cooperative Technical Partner (CTP) program to AECOM Technical Services, Inc. This report documents the BLE process, products, and results for this watershed. Figure 1 depicts the Double Mountain Fork Brazos watershed footprint.

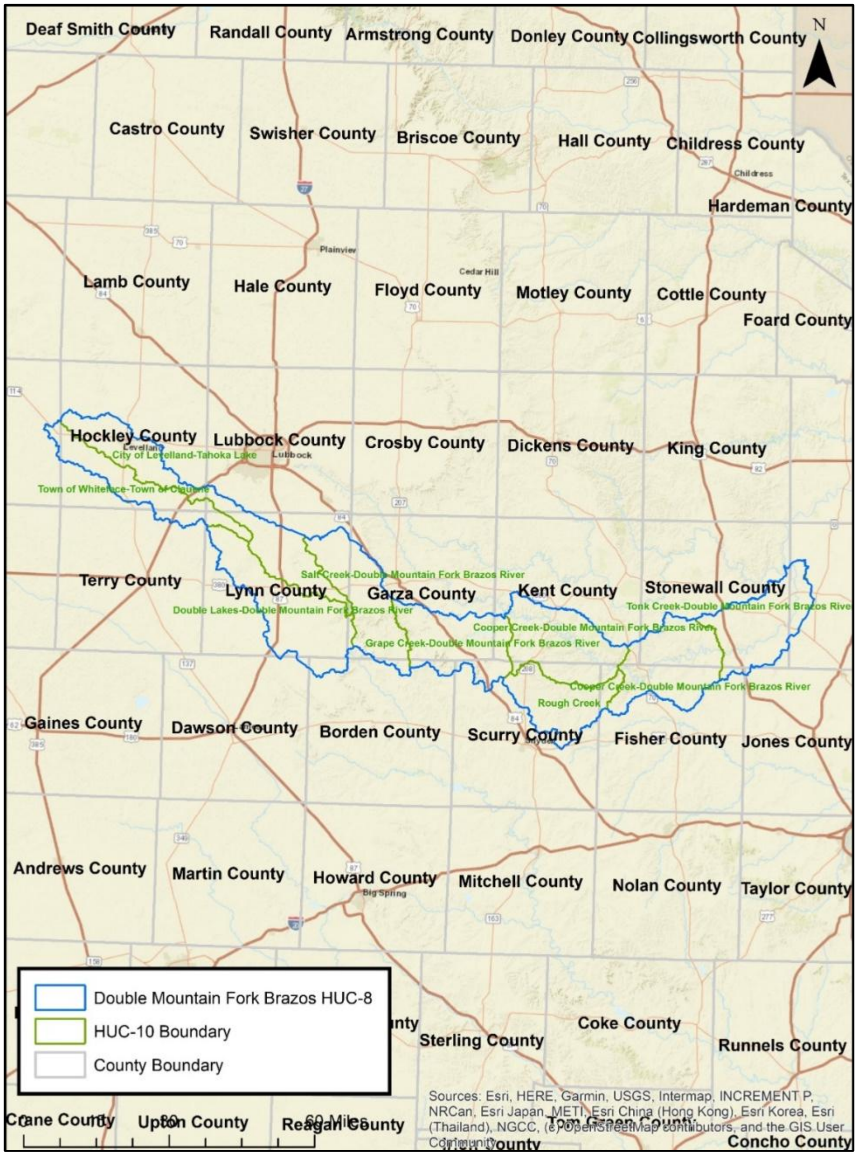

Figure 1: Double Mountain Fork Brazos Watershed

2. 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2D hydraulic engineering analysis for the Double Mountain Fork Brazos watershed using the Hydrologic Engineering Center's River Analysis System version 6.1 (HEC-RAS). Inputs such as elevation data, hydrology from rain-on-grid and inflow hydrographs, and hydraulic analyses and variables are defined herein. HEC-RAS' 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 2D engineering analyses by providing a detailed representation of the surface for hydraulic routing through the model area. As such, DEMs were developed for the Double Mountain Fork Brazos watershed BLE project by leveraging available high resolution gridded elevation data derived from Light Detection and Ranging (LiDAR) collections throughout the States of Texas. The 10 foot DEM developed to support the 2D BLE modeling and analysis, within the Double Mountain Fork Brazos 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 Geographic Information Systems (GIS).

4. Quality was assured using quantitative and qualitative assessment.

Documentation regarding leveraged data including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables and text within Section 0. 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 Double Mountain Fork Brazos watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the Double Mountain Fork Brazos watershed BLE watershed footprint. Figure 2 depicts the datasets identified and leveraged across the project area. FEMA, National Oceanic and Atmospheric Administration (NOAA), USGS, Texas Natural Resources Information System (TNRIS) and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

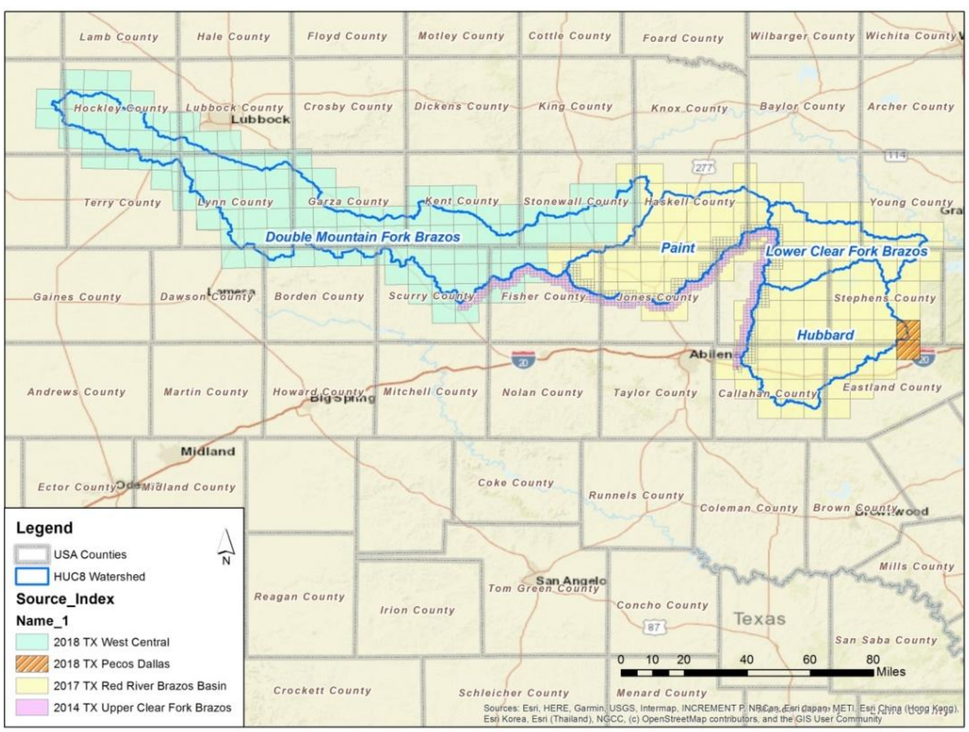

Figure 2: Task Order 1 BLE Source Terrain Data

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 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*	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 depicts the complete list of source elevation data and attributes leveraged for the Double Mountain Fork Brazos watershed. All datasets used for hydraulic analyses and mapping meet the highest specification level defined in Table 1. The following datasets were evaluated and prioritized as best available:

Table 2: LiDAR Topographic Data Available for the Double Mountain Fork Brazos Watershed

Year	Description	Source/Owner	Accuracy[1]	Approximate Footprint (mi^2)[2]
2018	2018 FEMA Texas West Central LiDAR	USGS/FEMA	9.1 cm	5,041
2017	2017 Texas Red River Basin LiDAR	FEMA	18.8 cm	464
2014	2014 Texas Upper Clear Fork Brazos LiDAR	FEMA	6.7cm	103

[1]RMSEz reported at the 95% confidence level

[2]Size of LiDAR DEM footprint utilized for BLE study

2.1.2.1 Double Mountain Fork Brazos Watershed Source Terrain Data

The source elevation data for the Double Mountain Fork Brazos watershed are DEMs derived from the 2018 FEMA Texas West Central; the 2017 Texas Red River Basin LiDAR; and the 2014 Texas Upper Clear Fork Brazos LiDAR. 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. Figure 2 depicts the extent of the data defined in Table 2.

2018 FEMA Texas West Central LiDAR

The 2018 FEMA Texas West Central Quality Level (QL) 2 Lidar project covers portions of Borden, Callahan, Cochran, Crosby, Dawson, Eastland, Fisher, Garza, Haskell, Hockley, Jones, Kent, Lubbock, Lynn, Palo Pinto, Scurry, Shackelford, Stephens, Stonewall, Taylor, Terry, Throckmorton, and Young Counties, Texas intersecting the Double Mountain Fork Brazos HUC8 study area and along the boundary of the Paint HUC8 watershed in Fisher, Haskell, Jones, and Stonewall Counties, Texas (see Figure 3). The USGS awarded this project to support the FEMA Risk MAP program. The acquisition was conducted from February 1, 2018 through May 27, 2018. Reflights were collected on November 5, 2018. Airborne Imaging, AXIS, Eagle, LEG, and Precision Aerial Reconnaissance completed Lidar data acquisition and data calibration for the project area. Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LAS classification, all Lidar products, breakline production, DEM production, and quality assurance. The source 1-meter bare earth DEM data was in Universal Transverse Mercator (UTM) Zone 13N, North American Datum of 1983 (NAD83) (2011), meters with elevations in North American Vertical Datum of 1988 (NAVD88) (GEOID 12B), meters.

For the 2018 FEMA Texas West Central QL2 Lidar Project, the tested RMSEz of the classified Lidar data vertical accuracy for checkpoints in non-vegetated terrain equaled 4.7 cm compared with the 10 cm specification; and the Non-vegetated Vertical Accuracy (NVA) of the classified Lidar data computed using RMSEz x 1.9600 was equal to 9.1 cm, compared with the 19.6 cm specification. Using National Standard for Spatial Data Accuracy (NSSDA) methodology, the horizontal accuracy at the 95 percent confidence level was reported as 61.4 cm (target was 100 cm).

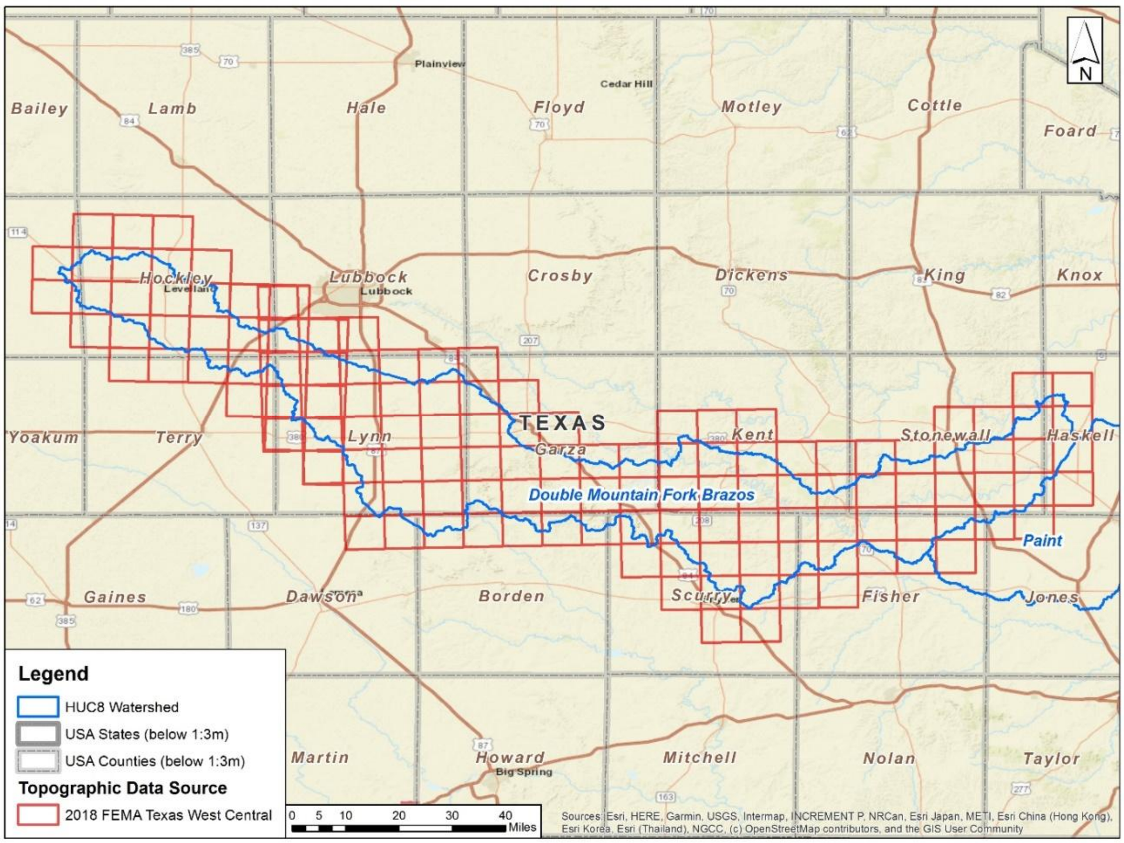

Figure 3: 2018 FEMA Texas West Central LiDAR

2017 Texas Red River Brazos Basin LiDAR

The 2017 Texas Red River Brazos Basin Lidar project covers Callahan, Eastland, Fisher, Haskell, Jones, Shackelford, Stephens, Stonewall, Throckmorton, and Young Counties, Texas (see Figure 4). This data set covers the majority of the Paint, Lower Clear Fork Brazos, and Hubbard HUC8 Watersheds. Dewberry served as the prime contractor for the project, and Leading Edge Geomatics Ltd. completed the Lidar data acquisition and data calibration for the project area. Lidar was collected between November 17, 2016 and May 28, 2018. The 1-meter bare earth DEM data was delivered in NAD83 (2011) UTM Zone 14N horizontal datum, NAVD88 vertical datum (GEOID12B), with horizontal and vertical units in meters.

The tested Root Mean Square Error (RMSEz) of the classified Lidar data vertical accuracy for checkpoints in non-vegetated terrain equaled 9.6 cm compared with the 10 cm specification. The NVA of the classified Lidar data computed using RMSEz x 1.9600 was equal to 18.8 cm, compared with the 19.6 cm specification. The tested VVA of the classified Lidar data computed using the 95th percentile was equal to 21.6 cm, compared with the 29.4 cm specification.

The horizontal accuracy, tested using NSSDA methodology at the 95 percent confidence level was computed as 88.4 cm (target was 100 cm).

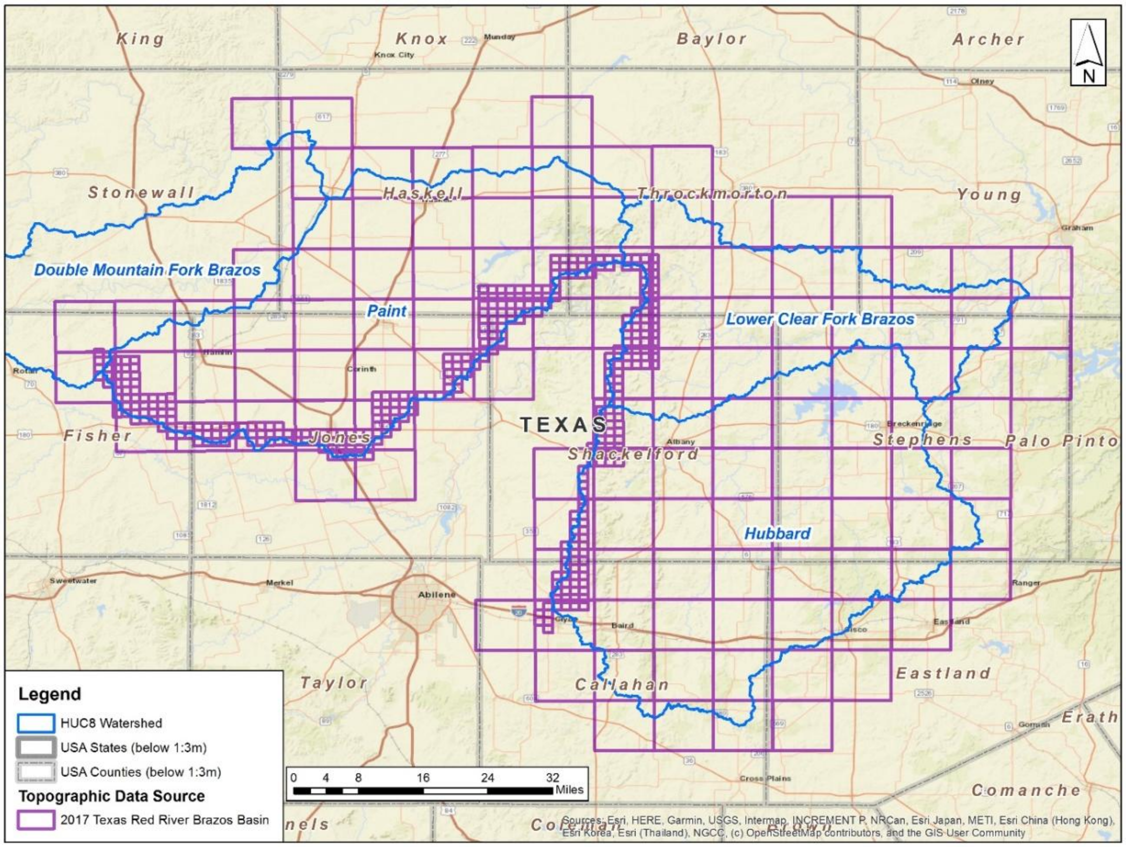

Figure 4: 2017 Texas Red River Brazos Basin LiDAR

2014 Texas Upper Clear Fork Brazos LiDAR

The 2014 Texas Upper Clear Fork Brazos QL2 Lidar project covers the buffer coverage along the southern border of the Double Mountain Fork Brazos and Paint HUC8 Watersheds within Fisher, Jones, and Scurry Counties, TX. The data set also covers a small area in Callahan and Shackelford Counties, TX to provide adequate buffer coverage for the Hubbard HUC8 Watershed (see Figure 5). Digital Aerial Solutions, LLC performed the Lidar data acquisition and data calibration for the project area. The data was collected December 12, 2014 through December 22, 2014. The 1-meter bare earth DEM data was delivered in NAD83 UTM Zone 14N horizontal datum, NAVD88 vertical datum, with horizontal and vertical units in meters.

The vertical accuracy tested RMSEz at the 95 percent confidence level was 3.10 cm compared to required accuracy of 9.25 cm. The NVA of the TIN tested RMSEz of 6.7 cm and 13.1 cm at the 95 percent confidence level in open terrain. The NVA of the DEM tested at an RMSEz of 6.7 cm and 13.0 cm at the 95 percent confidence level in open terrain. The tested horizontal accuracy was not provided within the Lidar project report.

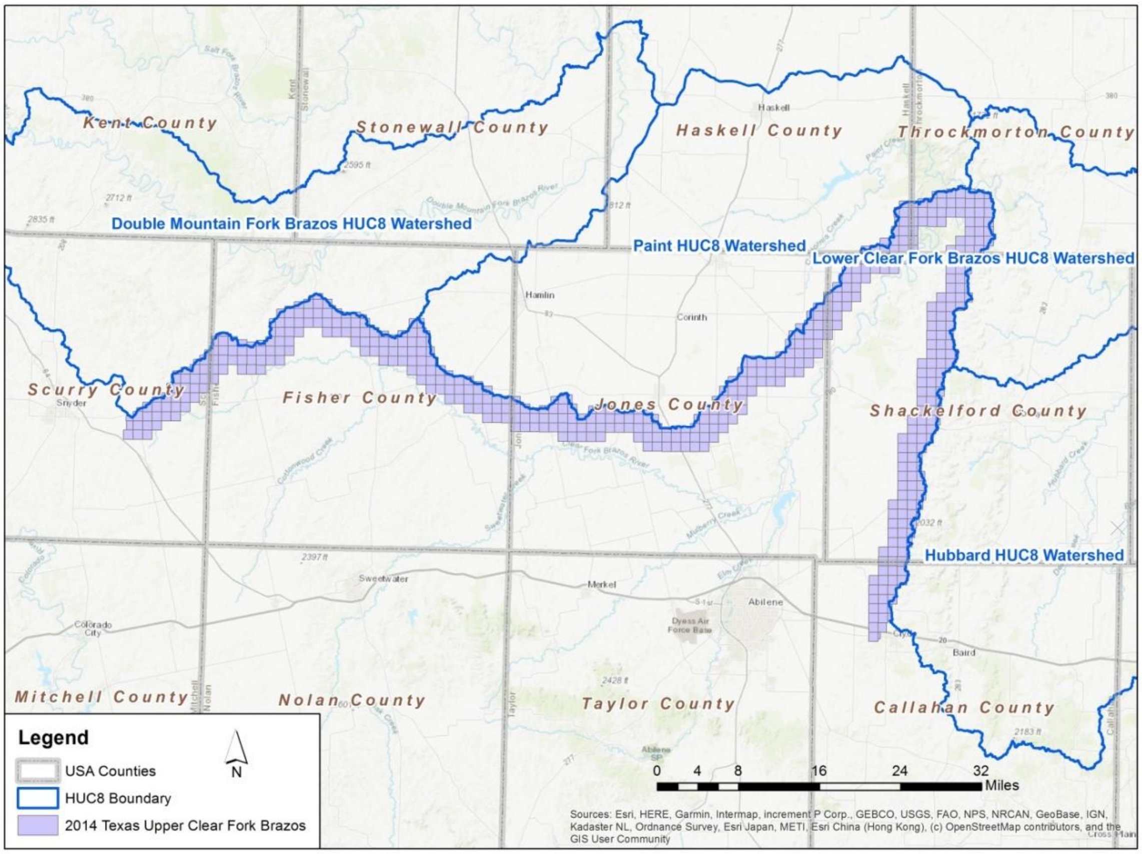

Figure 5: 2014 Texas Upper Clear Fork Brazos LiDAR

2.1.3 Data Processing

ArcGIS software was utilized in order to create a digital surface model for the Double Mountain Fork Brazos HUC-8 watershed project area. The LiDAR datasets were added to a mosaic dataset and prioritized by date with the most recent dataset taking the first priority. If two datasets are from the same year or flown at similar dates, the accuracy was reviewed to determine the priority. The mosaic dataset was exported to make a seamless bare earth DEM.

The exported DEM was reviewed through automated quality control (QC) to check for anomalies and outlier locations based on slope and cells that exceed z value differences from surrounding cells. Visual review was also performed to check for ground differences at the extents of the datasets for differences in ground values.

2.1.4 DEM QA/QC

DEMs developed for use in the Double Mountain Fork Brazos watershed BLE analysis were developed and independently assured to meet quality standards of the project. The data were developed using a controlled process, were evaluated and assured by a topographic data development team, and were evaluated and assured by the engineering team. Quality assurance (QA) 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 QC 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 was 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

QA 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 analysis.

The final DEM data developed for the Double Mountain Fork Brazos watershed is 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

HEC-RAS' 2D hydraulic modeling and rain-on-grid utility was applied in the Texas 2D BLE products workflow. The following sections describe the engineering methods and model inputs used.

2.2.1 2D Computational Mesh and Settings

Due to the size of the Double Mountain Fork Brazos watershed (approximately 2,604 sqmi), and to account for computational and modeling limits, the HUC-8 was split into four separate HEC-RAS geometries as shown in Figure 6. The HUC-8 was split into DMFB1, DMFB2, DMFB3, and DMFB4 modeling areas. Initially model area footprints were aligned with HUC10 boundaries, combining some where the size of the smaller HUC-10s allowed. Minor adjustments were made to those initial model footprints to improve modeling and/or mapping efficiency. The HEC-RAS boundaries were created for the model areas using ArcGIS toolsets, which reduced the need for manual edits to mesh cells within HEC-RAS that can results in error generation. Adjustments to the boundaries of each model allowed for inflow using external boundary conditions to more accurately model inflow and assist with mapping tie-in with the downstream model. The DMFB1, DMFB2, DMFB3, and DMFB4 2D meshes contain approximately 980,000 cells, 461,000 cells , 460,000 cells, and 507,000 cells respectively, consisting of 200 foot cells, with the exception of 100 foot along the 1 square mile streams and 50 foot cells within community boundaries using refinement regions. Within community boundaries the streamlines were also extended to the 0.5 square mile extent and assigned 50 foot cell spacing in order to be more detailed. Internal connections were used to extract flow readings for gage locations throughout the model, while profile lines were used for all other flow extractions. An adaptive 1 minute time step was used to allow the model to lower the time step, as necessary, to keep the maximum sscourant number under 3 for the duration of the simulation. The time step was allowed to reach 64.00 minutes for a maximum and 7.50 seconds for the minimum. A theta value of 1.0 was used. The HEC-RAS model was run with Diffusion Wave (simplified Full Momentum) equations.

2.2.2 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires a 2D computational mesh boundary and often requires defining inflow boundary conditions and application precipitation values. Spatially varying precipitation DSS values were applied as a meteorological data boundary condition. The process to determine the excess precipitation DSS values to be applied is outlined in the hydrology section. Figure 6 depicts the DMFB1, DMFB2, DMFB3, and DMFB4 model boundaries, flow transition points between models, and USGS stream gages in the watershed. Although there are four gages present in the watersheds, only two were used in the study.

Outflow boundary conditions (from the computational 2D mesh) were used along model boundaries without an inflow boundary condition. Because the Double Mountain Fork Brazos River HUC-8 was split into four work areas, the outflow from the DMFB1 model was used as an inflow hydrograph for DMFB2, outflow from DMFB2 was used as an inflow hydrograph for DMFB3, and DMFB3 outflow was used as an inflow hydrograph for DMFB4. This hydrograph was extracted from each model using a 2D connection and then placed as a flow hydrograph external boundary condition for the downstream model.

Unique outflow boundaries were established for obvious riverine outflows, while the remaining boundaries were defined as continuous boundaries to allow drainage to 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.

Figure 6: RAS6 2D Computational Mesh and Boundary Conditions and USGS Peak Streamflow Gages

2.2.3 Hydrology

HEC-RAS (specifically version 6.1, used for this analysis) can implement spatial precipitation and infiltration methods. This capability has improved the efficiency and hydrologic representation of a study area. HEC-RAS version 6.1 cannot directly import ASCII format gridded precipitation data. Therefore, spatially varied precipitation Data Storage System (DSS) files were used for the precipitation hyetograph boundary condition in the HEC-RAS models.

2.2.3.1 Precipitation Frequencies

Precipitation frequency data from NOAA's Atlas 14 Precipitation Frequency Data Server (PFDS) was used for this study (NOAA, 2018). The 10-, 4-, 2-, 1-, and 0.2-percent-annual-chance precipitation depths for the 24-hr duration were determined by area-weighted intersection of the gridded PFDS data with the model area boundaries. Specifically, precipitation depths for return periods as rare as 1-in-1,000 annual chance for the state of Texas are available as raster data with 1/12-degree spatial resolution. No areal reduction factors were applied to these depths for any of the model areas since it would be inappropriate for the majority of smaller-sized tributaries within each model; however, flow and stage results throughout the model area were analyzed against historic gage and previous study data as discussed later in the Calibration and Validation section of the report.

The 1-percent-plus flood elevation is defined as the flood elevation using discharges at the upper 84% confidence limit for the 1-percent-annual-chance flood. Similarly, the 1-percent-plus flood elevation is derived using discharges at the lower 84% confidence limit for the 1-percent-annual-chance-flood. The plus and minus standard error was determined as the upper and lower 84% confidence limits (i.e., the 68-percent confidence interval) on the nominal 1-percent depth. In addition to recurrence interval precipitation estimates, 90% confidence intervals of reported Atlas 14 precipitation values are provided on the PFDS (NOAA, 2018). 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, so the provided 95% confidence limits were used to determine the 84% confidence limits using this relationship.

The 1%-plus and 1%-minus storm events were defined by utilizing a 68% confidence interval around the 1% event. The 68% confidence interval was estimated using the following equations:

$$\hat{\sigma} = \frac{X_{95} - X_{05}}{Z_{95} - Z_{05}}$$

$$CI_{68} = (X - \hat{\sigma}, X + \hat{\sigma})$$

Where :

1. $\hat{\sigma}$ represents the standard deviation of an assumed normal distribution around the NOAA Atlas 14 frequency estimates.
2. X_{95} and X_{05} represent the upper and lower estimates of the 90% confidence interval, respectively.
3. Z_{95} and Z_{05} represent the corresponding z-scores of the upper and lower estimates, respectively (i.e., Z_{95} = 1.645; Z_{05} = -1.645).
4. CI_{68} the 68% confidence interval is approximated by applying one standard deviation above and below the baseline 1% storm event.

2.2.3.2 Temporal Rainfall Distribution

Temporal rainfall distributions were computed for the Double Mountain Fork Brazos HUC-8 model areas following the NRCS synthetic rainfall distribution procedure as described in the National Engineering Handbook Part 630 – Chapter 4 (NRCS, 2019). NOAA Atlas 14 data was extracted for the areas, and a unique 24-hour temporal distribution was computed for each recurrence interval (note: the 1-percent annual chance temporal distribution was used for the 1%-plus and 1%-minus frequencies). The temporal distributions are expressed in probability terms as cumulative percentages of precipitation totals at various time steps. The NOAA Atlas 14 precipitation-frequency grids only provide total depths for each frequency. Precipitation grids were spatially distributed across the 24-hour duration using a 6- minutes time series data shown in Figure 7. The resulting 6-minute interval precipitation grids were used to develop spatially distributed precipitation DSS data for the model areas. The "Meteorological Data" tab under the

Unsteady Flow Boundary Conditions editor in HEC-RAS was used to import the spatial precipitation DSS data into the 2D hydraulic model.

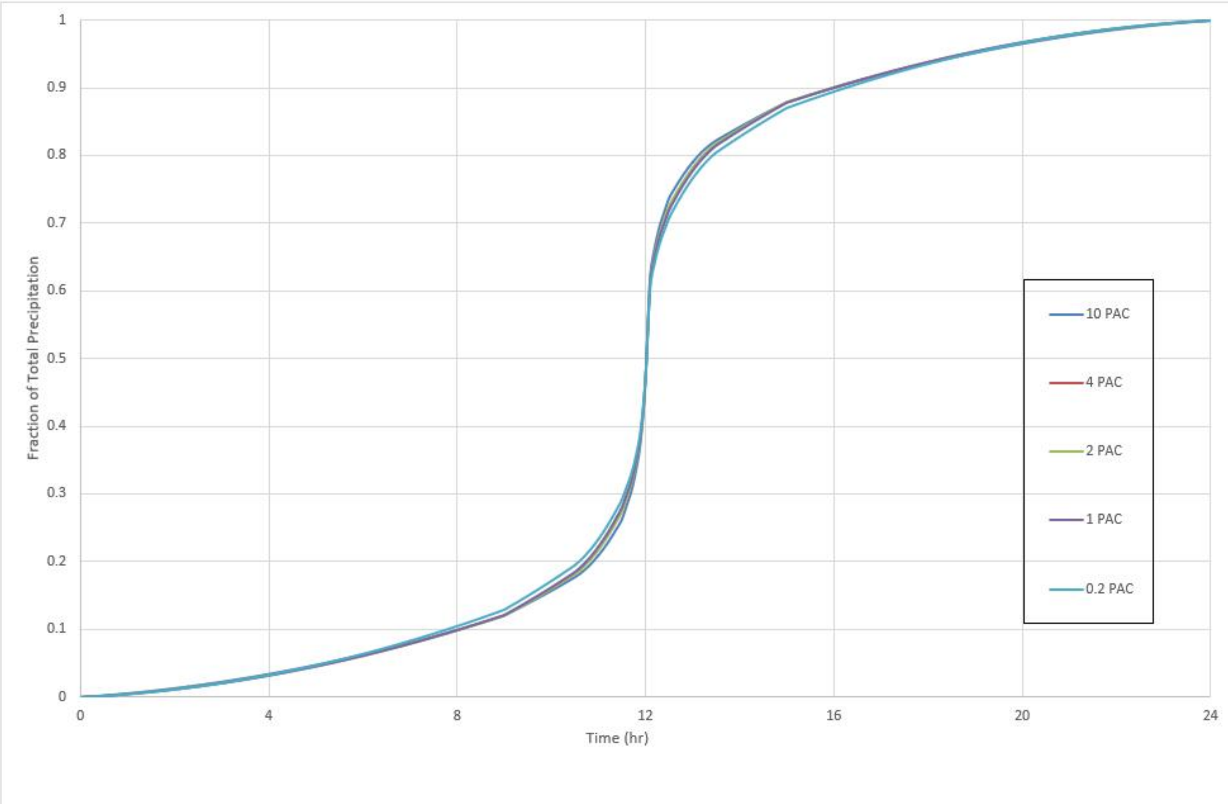

Figure 7: NRCS Nested Rainfall Distributions for Double Mountain Brazos River HUC-8 Watershed Study

2.2.3.3 Infiltration Parameters

The infiltration layer containing attributes for Soil Conservation Survey (SCS; now the Natural Resources Conservation Survey (NRCS)) curve numbers (CN), abstraction ratio, and minimum infiltration rate was initially calculated in ArcGIS using the National Land Cover Database (NLCD, 2019) and NRCS soil data. This infiltration layer was then imported the RAS6 2D hydraulic model where it is then used to estimate rainfall-runoff losses and surface runoff was used in hydraulic calculations.

A land use – soils – CN matrix can be used to determine CN for a particular study area. Table 3 details soil-water balance model lookup table for determining CN's for the intersection of soils and land use. The CN values are sourced from the NRCS's TR-55 (USDA, 1986), in lieu of CN guidance from TWDB since the current Texas Two-Dimensional BLE Guidelines (version 1.0) were not available during infiltration setup for this study. However, this matrix is intended as a general guide and then adjusted based on engineering judgment, as well as during calibrations and validation of the model, for a given study area.

Table 3: Land Use(LU)-Soils-CN Matrix for Defining Initial Curve Number

LU_GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	100	100	100	100
12	Perennial ice/snow	40	40	40	40
21	Developed Open Space	49	69	79	84
22	Developed Low Intensity	77	86	91	94
23	Developed Medium Intensity	89	92	94	95
24	Developed High Intensity	98	98	98	98
31	Barren Land	77	86	91	94
41	Deciduous Forest	32	48	57	63
42	Evergreen Forest	39	58	73	80
43	Mixed Forest	46	60	68	74
52	Shrub Scrub	49	68	79	84
71	Herbaceous	64	71	81	89
81	Hay Pasture	49	69	79	84
82	Cultivated Crops	71	80	87	90
90	Woody Wetlands	88	89	90	91
95	Emergent Herbaceous Wetlands	89	90	91	92

2.2.3.4 USGS Gage Analysis

The models were compared to known USGS peak flows to validate model results. USGS stream gages with less than 10-years of record were not considered for hydrological analysis or for calibration. USGS Gage 08080505 and USGS Gage 08079700 were located in the scoped area, but were not included in the calibration because of the insufficient length of recorded data. USGS gages 08079600 and 08080500, the gages used in for analysis in this study, are listed in Table 4, below.

Table 4: USGS Peak Streamflow Gages

Model Area	Gage ID	Flooding Source and Location	Published Drainage Area (mi^2)	Period of Record
DMFB2	08079600	DMF Brazos Rv at Justiceburg, TX	244	61
DFMB4	08080500	DMF Brazos Rv nr Aspermont, TX	1864	92

2.2.3.5 Inflow Hydrograph Boundary Conditions

Outflow from each model was used as inflow into the model downstream of it (DMFB1 to DMFB2, DMFB2 to DMFB3, DMFB3 to DMFB4). The inflow hydrograph was derived by utilizing the results of the each HEC-RAS model that is directly upstream. By using upstream model results as inflow hydrographs to the downstream model, this allows the four separate HEC-RAS models to act as one continuous model of the larger Double Mountain Fork Brazos watershed area. The inflow hydrographs were extracted from DMFB1, DMFB2, and DMFB3 model using a 2D connection. The inflow hydrograph applied to DMFB2, DMFB3, and DMFB4 RAS models are represented in Figure 8, Figure 9, Figure 10, respectively.

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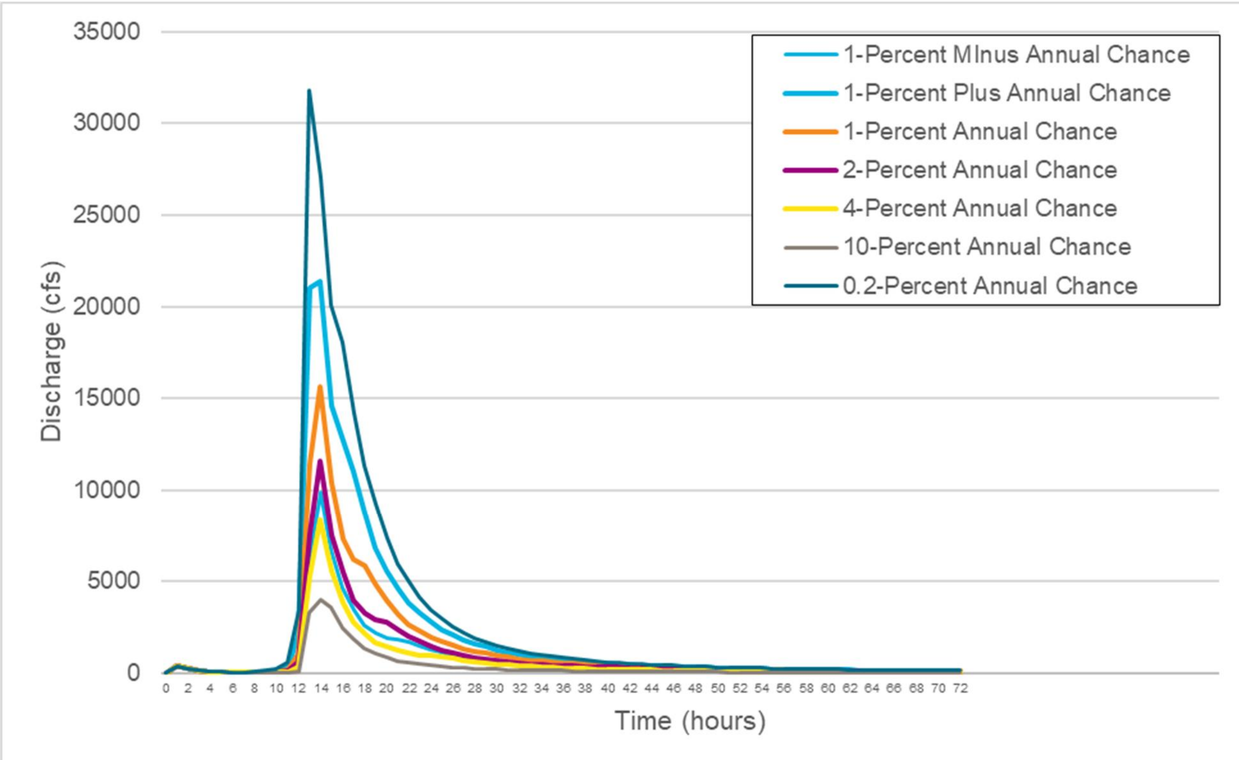

Figure 8: Inflow Hydrograph from DMFB1 Model Area

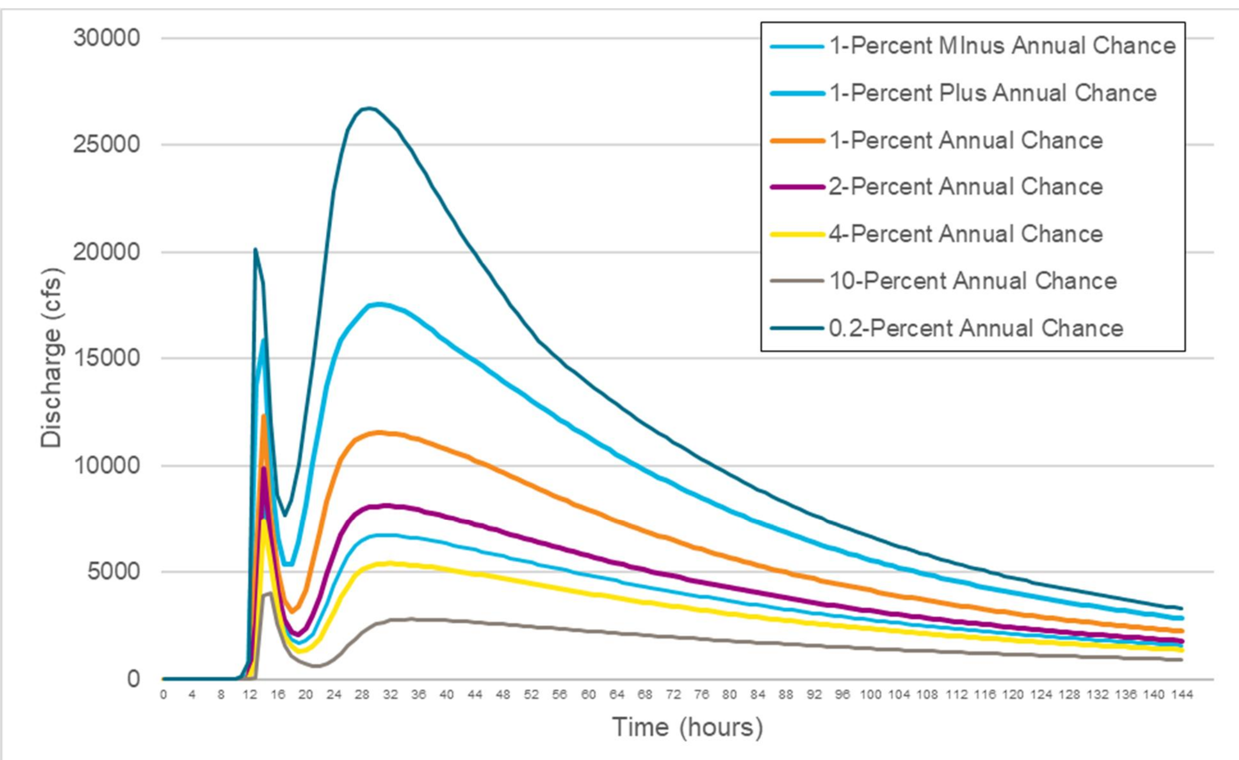

Figure 9: Inflow Hydrograph from DMFB2 Model Area

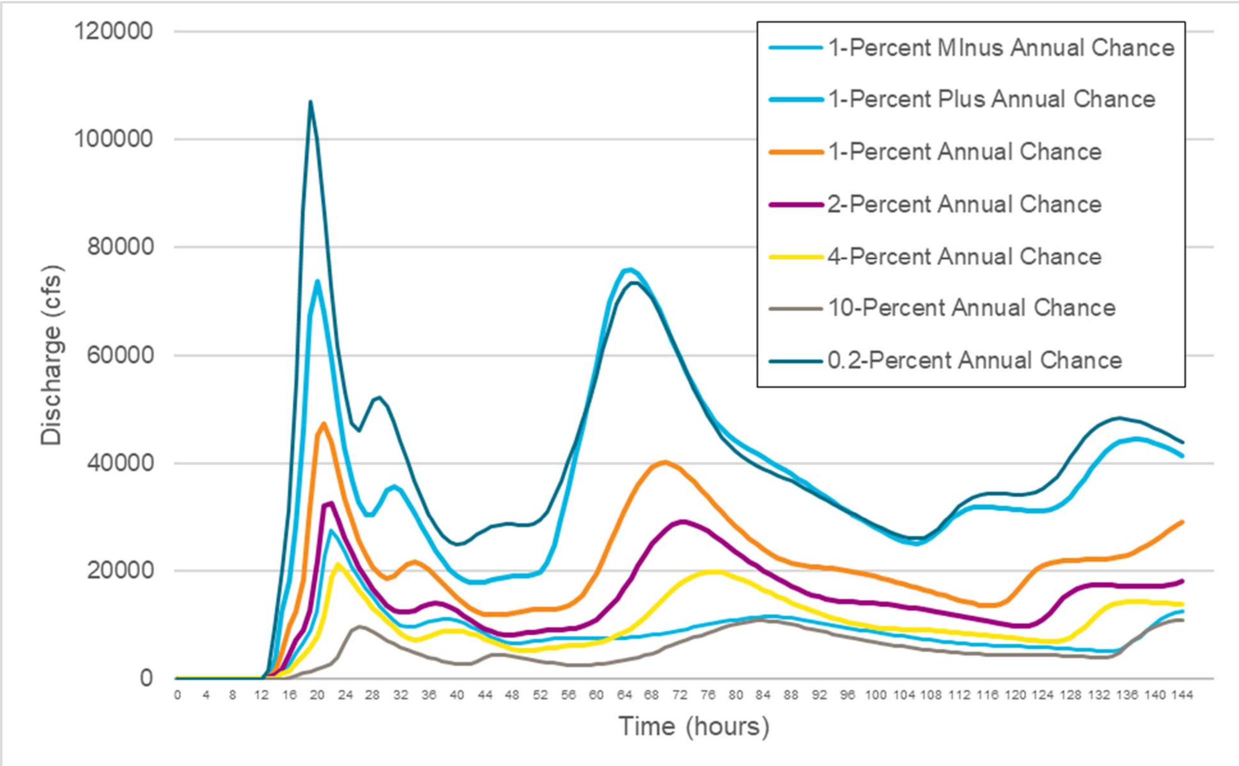

Figure 10: Inflow Hydrograph from DMFB3 Model Area

In order to achieve a seamless flood hazard result at a transition location (locations where flow is exchanged between 2D model areas), the water surface elevation (WSE) and inundation tie-ins between models must be made as close as possible. A 1,000 feet buffer was applied to each model work area for the mesh boundary. This is done so that the inflow boundary condition of the downstream model and the normal depth outlet boundary condition of the upstream model are far enough away from the work area transition location that they do not impact the WSE tie-ins between models in an undesired way. To make this overlap work without double accounting for rainfall, an internal 2D connection is placed in the upstream model at the exact same location as the inflow boundary condition for the downstream model. Approximately halfway between the model overlap is the actual model area boundaries where the mapped floodplain products switch from the upstream model results to the downstream model results. This transition location is the targeted area to have the water surface elevation and inundation tie-in as closely as possible.

2.2.4 Hydraulics

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

2.2.4.1 Roughness Coefficients

Manning's n roughness coverage was developed for the 2D computational mesh using typical roughness values for given NLCD land classifications. Manning's n values were used for all areas outside of the channels of the stream network, with one Manning's n value assigned to the Stream Channel. The channel layer was created using a 100 foot buffer. This allows for the model to accurately represent deep, swift flow within the channel and shallow overland flow outside of the channel areas. The table below shows a typical landuse-roughness matrix used in defining the roughness coverage for the study area for areas both inside and outside of the channel. Sources cited in the table were used to associate typical n values with the NLCD classifications.

Table 5: NLCD 2016 Manning's n Roughness Matrix

NLCD Classification	N Value	Source
Stream Channel	0.04	NRCS KS Dam Breach, 2016, Chow, 1959
Open Water	0.04	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, Open Space	0.04	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, Low Intensity	0.08	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, Medium Intensity	0.1	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, High Intensity	0.15	NRCS KS Dam Breach, 2016, Chow, 1959
Barren Land	0.025	NRCS KS Dam Breach, 2016, Chow, 1959
Deciduous Forest	0.16	NRCS KS Dam Breach, 2016 , Chow, 1959
Evergreen Forest	0.16	NRCS KS Dam Breach, 2016, Chow, 1959
Mixed Forest	0.16	NRCS KS Dam Breach, 2016, Chow, 1959
Scrub/Shrub	0.1	NRCS KS Dam Breach, 2016, Chow, 1959
Grassland/Herbaceous	0.035	NRCS KS Dam Breach, 2016 , Chow, 1959
Pasture/Hay	0.03	NRCS KS Dam Breach, 2016, Chow, 1959
Cultivated Crops	0.035	NRCS KS Dam Breach, 2016 , Chow, 1959
Woody Wetlands	0.12	NRCS KS Dam Breach, 2016, Chow, 1959
Emergent Herbaceous Wetland	0.07	NRCS KS Dam Breach, 2016, Chow, 1959

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. Road embankment features were delineated in GIS and imported into HEC-RAS as breaklines to contain water where appropriate. Similarly, significant bridge/culvert crossings that were not processed out of the terrain data were modeled by v-notch breaklines adjacent to the road embankment to align grid cells around the embankment and allow water to be routed through the embankment without creating artificial backwater. An example of the v-notch breakline approach is shown in Figure 11.

County, interstate, common name, state recognized, and U.S. roads were incorporated for road breaklines from the U.S. Census Bureau TIGER/Line road layer.

The SA/2D connections placed on Lake Alan Henry Resevoir were enforced as breaklines. Private dams were not modeled as showing protection. This is to lessen the burden on private dam owners to maintain their dams in order to sustain the regulatory products that could be created in the future as a result of this study. The study area does not include any FEMA accredited levees.

Breaklines were also used along all the stream centerlines of streams draining greater than one square mile of drainage area, and 0.5 square miles of drainage area within densely populated areas. Each streamline was topo-derived and the stream centerline was enforced with 100 feet cell spacing in order to align cells along the stream line and capture more detail along the one square mile stream network. Streamline alignment was also hand checked with the terrain by the modeler to ensure accuracy. Stream names were referenced from other sources such as NFHL and NHD datasets. In the HEC-RAS model, streams that passed through densely populated regions were enforced as breaklines using 50 ft cell spacing.

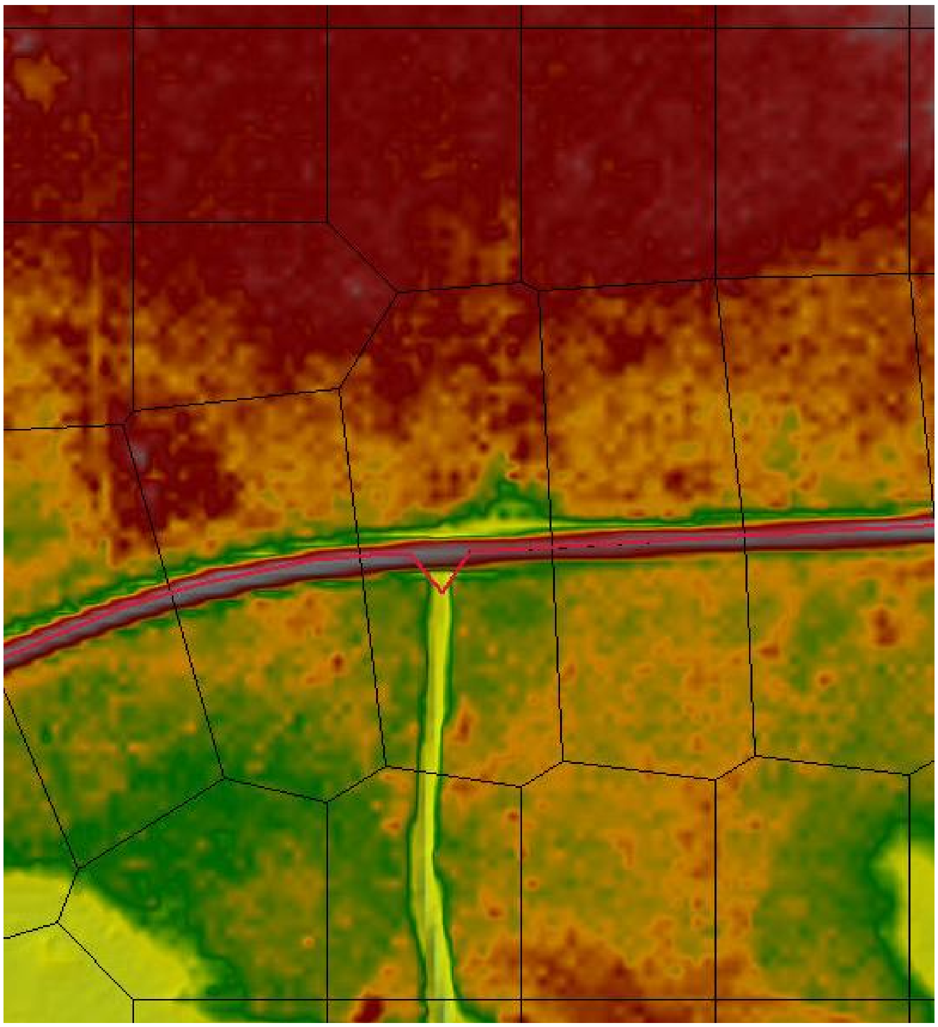

Figure 11: V-notch Breakline Approach at Bridge Crossing

2.2.4.3 Refinement Regions

Refinement regions were created for each community within the model. The political boundary was used to determine the shape of the refinement region. The regions were assigned a cell spacing of 50 feet by 50 feet. This finer cell spacing allows for more hydraulic calculations and mapping detail near areas where there are likely to be more structures. Table 6 shows the communities contained within Double Mountain Fork Brazos HUC 8 watershed that were modeled with refinement regions as well as the square mileage of the refinement region.

Table 6: Communities with 2D Mesh Refinement

Community Name	Area (mi^2)
Whiteface town	0.59
Wilson city	0.65
Tahoka city	2.39
New Home city	1.00
Meadow town	0.04
Ropesville city	0.36
Opdyke West town	0.22
Levelland city	10.05
Wilson city	0.65
Aspermont	2.14
Old Glory	0.14

2.2.5 Quality Control

The 2D BLE results were independently assured to meet quality standards of the project. Standard checklists complying with FEMA standards were used to review hydrology and hydraulics results, the resulting flood hazard area delineations and CNMS dataset. Quality assurance during the data development process includes, but is not limited to the following QC checks:

- Hydrological QC – included checks for curve number calculation, input precipitation, flood events, areal reduction factor and human error.
- Hydraulic QC – included checks for RAS geometry, breakline placement, v-notch placement to ensure water conveyance at crossings, refinement regions, roughness coefficients, boundary/initial conditions, timestep and mapping outputs
- Mapping – included checks for spot checking flood inundation accuracies based on floodplain mapping criteria described in section 4.1.2, ensuring flood extents from higher frequency events did not exceed lower frequency extents due to GIS smoothing algorithms, and topological overlap and cluster tolerance errors were resolved
- CNMS - Included review of the A1-A5 analysis for all effective approximate reaches in the HUC, geometry updates to newly studied reaches added as Zone X, and removal of scoped areas which lie outside of the final BLE footprint.

3. Results

The 2D BLE results for the study produced flood hazard area that compared reasonably well with effective SFHA in most cases, and provides additional estimated flood hazard risk area where not previously mapped. The HEC-RAS peak (max) results were exported for mapping and the RAS6 model was run with a hydrograph output interval of 30 minutes, mapping output interval of 1 hour and the detailed output interval of 1 hour. The Double Mountain Fork Brazos HUC-8 BLE watershed is sufficient to facilitate FEMA regulatory processes while also providing the best available information for planning purposes.

3.1 Calibration

Known USGS gages within the model area with more than 10-years of flow record were used as the first priority for calibration of the 1-percent annual chance event. Discharges at gages were compared to discharges in the 2D models at the exact same locations. If a published rating curve was available, WSEs from the model were compared to the calculated 1-percent WSE from the gage analysis. DMFB1 was calibrated based on DMFB2 flows, as there were no USGS gages in this area. DMFB2 was calibrated using USGS gages and supplemented with regression equations. DMFB3 was calibrated using regression equations, as there were no USGS gages in this area. DMFB4 was calibrated using USGS gages and supplemented with regression equations.

Two USGS gage that fall within the boundary of Double Mountain Fork Brazos watershed were utilized for calibration purposes. Regression equations were used for secondary calibrations in DMFB2 and DMFB4 study areas, and were used for primary calibration in the DMFB3 area. For areas with USGS gages, the USGS gage analysis results were given priority for calibration. The regression analysis was performed as per regional regression equations using the drainage area, dimensionless main channel slope (S), OmegaEM parameter and mean annual precipitation (P) (USGS- SIR 2009-5087). Regression comparison were made in seventeed locations with varying contributing drainage areas to ensure a reasonable amount of excess precipitation was being applied ot the 2D mesh.

Adjustments to hydraulic features within the model were made until the flows in the model matched closely with the peak flows determined from gage and effective data. Adjustments were made to curve numbers for the model areas, DMFB1, DMFB2, and DMFB3. Final results following model calibration at the calibration locations were presented in Table 7.

Table 7: Calibration Results

Model Area	Calibration Location	Source	Method Used	Reference			HEC-RAS 6.1.0 (2D) (cfs)
				Lower Limit (cfs)	1-percent (cfs)	Upper Limit (cfs)	
DMFB2	Gage 08079600	USGS	Peak FQ	59,450	77,000	108,000	63,142
DMFB4	Gage 08080505	USGS	Peak FQ	19,060	26,860	43,790	36,720
DMFB2	UNT 03 to Grape Creek, upstream of the confluence of Grape Creek	HEC-RAS	Regression Equations	1,677	2,958	8,934	9,098
DMFB2	Upstream of confluence with Double Mountain Fork Brazos River	HEC-RAS	Regression Equations	6,722	11,287	34,088	6,804
DMFB2	Upstream of confluence with Souble Mountain Fork Brazos River	HEC-RAS	Regression Equations	4,804	8,289	25,033	19,173
DMFB3	Lloyd Creek downstream of County Rd 1116	HEC-RAS	Regression Equations	6,707	11,441	34,551	19,257
DMFB3	Cox Hollow upstream of confluence with Double Mountain Fork Brazos River	HEC-RAS	Regression Equations	4,313	7,537	22,763	7,113

Table 7, continued: Calibration Results

Model Area	Calibration Location	Source	Method Used	Reference			HEC-RAS 6.1.0 (2D) (cfs)
				Lower Limit (cfs)	1-percent (cfs)	Upper Limit (cfs)	
DMFB3	Horse Hollow upstream of confluence with Rough Creek	HEC-RAS	Regression Equations	1,947	3,446	10,406	2,823
DMFB3	Rough Creek upstream of County Rd 357	HEC-RAS	Regression Equations	1,774	3,192	9,639	2,553
DMFB3	Maverick Creek upstream of confluence Double Mountain Fork Brazos River	HEC-RAS	Regression Equations	3,001	5,218	15,758	4,408
DMFB3	Gyp Draw upstream of confluence with Rough Creek	HEC-RAS	Regression Equations	1,686	3,030	9,151	2,384
DMFB3	Adair Canyon upstream of confluence with Double Mountain Fork Brazos River	HEC-RAS	Regression Equations	1,451	2,632	7,947	1,654
DMFB3	McKenzie Creek upstream of County Rd 316	HEC-RAS	Regression Equations	4,034	7,025	21,214	9,960
DMFB3	Rough Creek upstream of confluence with Ennis Creek	HEC-RAS	Regression Equations	5,479	9,309	28,112	13,293
DMFB4	Tonk Creek downstream of US 380	HEC-RAS	Regression Analysis	3,210	6,405	12,779	4,662
DMFB4	Willow Creek upstream of confluence with Double Mountain Fork Brazos River	HEC-RAS	Regression Analysis	2,107	4,205	8,390	2,121
DMFB4	Gyp Creek upstream of confluence with Double Mountain Fork Brazos River	HEC-RAS	Regression Analysis	3,739	7,459	14,883	7,367

Table 7, continued: Calibration Results

Model Area	Calibration Location	Source	Method Used	Reference			HEC-RAS 6.1.0 (2D) (cfs)
				Lower Limit (cfs)	1-percent (cfs)	Upper Limit (cfs)	
DMFB4	East Fork Salt Creek upstream of confluence with Double Mountain Fork Brazos River	HEC-RAS	Regression Analysis	4,433	8,844	17,646	5,442
DMFB4	Nicholson Creek upstream of confluence with Double Mountain Fork Brazos River	HEC-RAS	Regression Analysis	4,835	9,647	19,248	6,934

Figure 12, Figure 13, Figure 14, and Figure 15 show the final results of the calibration locations compared to modeled flows throughout the Double Mountain Fork Brazos watershed along with error bars created using the difference between 1-percent and 1-percent plus discharges and 1-percent and 1-percent minus discharge as minimum and maximum values. In addition to comparison with the two USGS gages, seventeen comparisons were made with varying drainage areas to ensure the calibration of excess precipitation for different points over the entire watershed area. This large collection of calibration points provides confidence in results throughout the entire watershed.

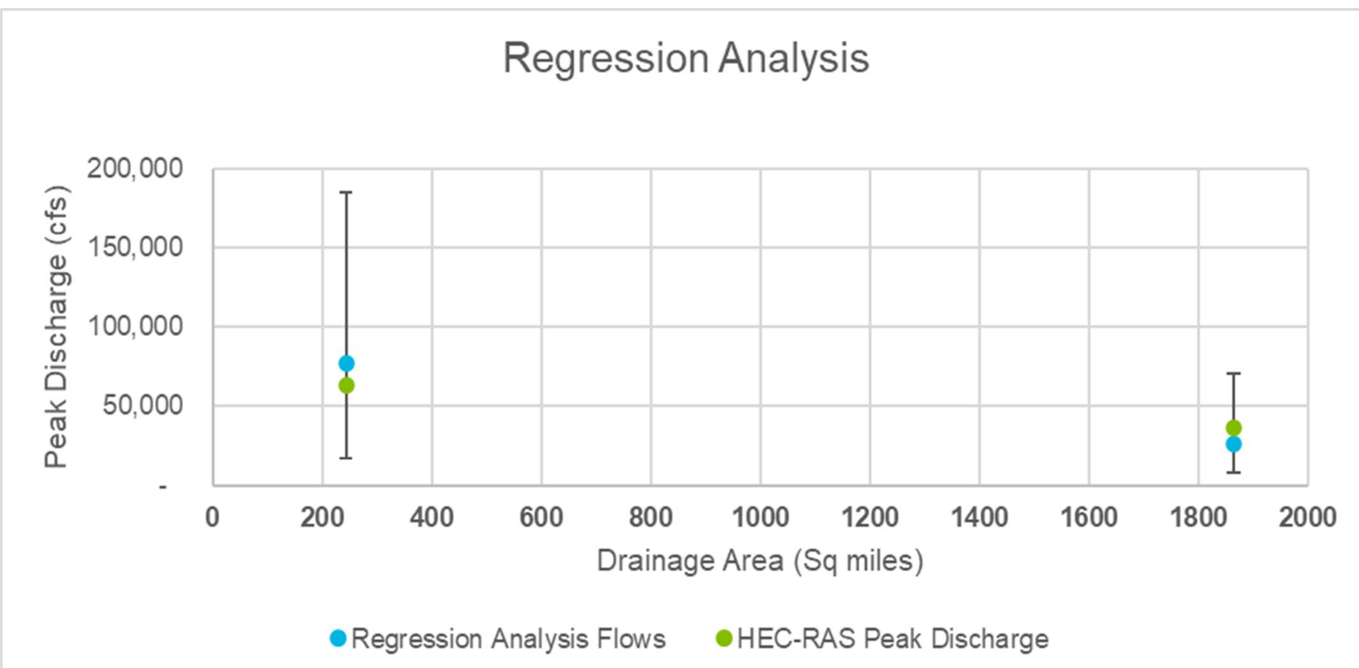

Figure 12: Calibration Comparison at Gage Locations for DMFB2 and DMFB4 Work Area

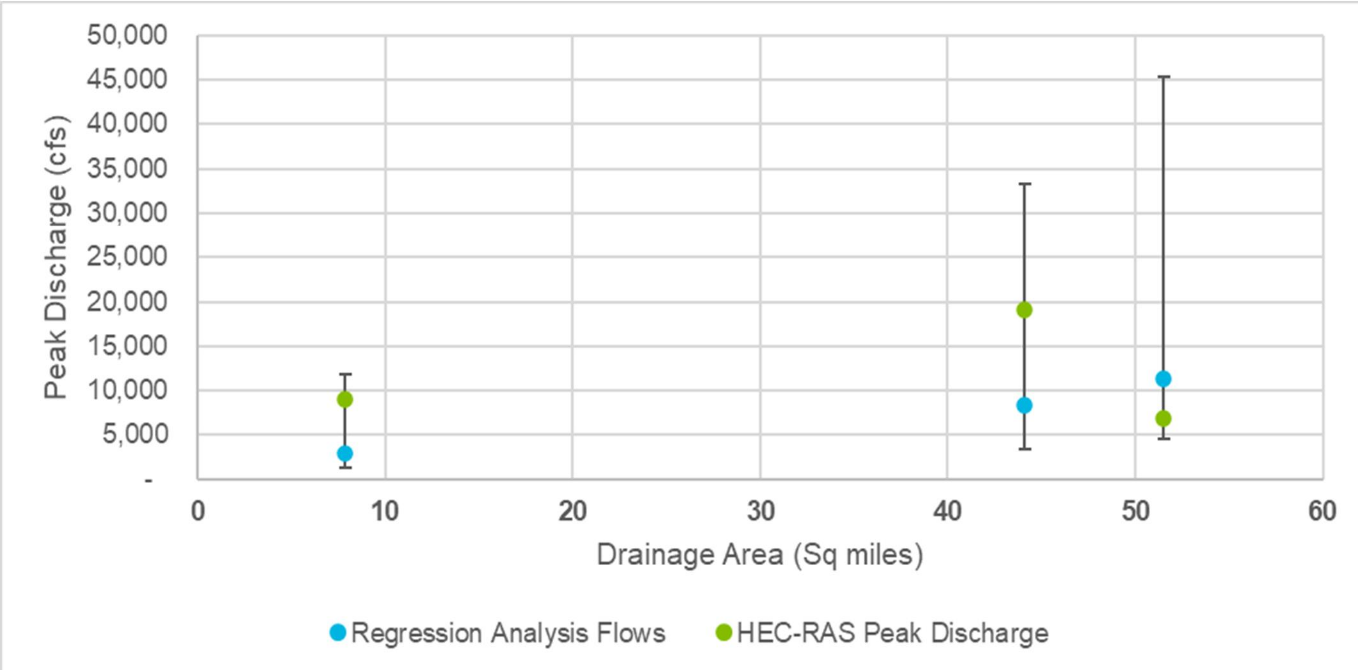

Figure 13: Calibration Comparison for DMFB2 Work Area

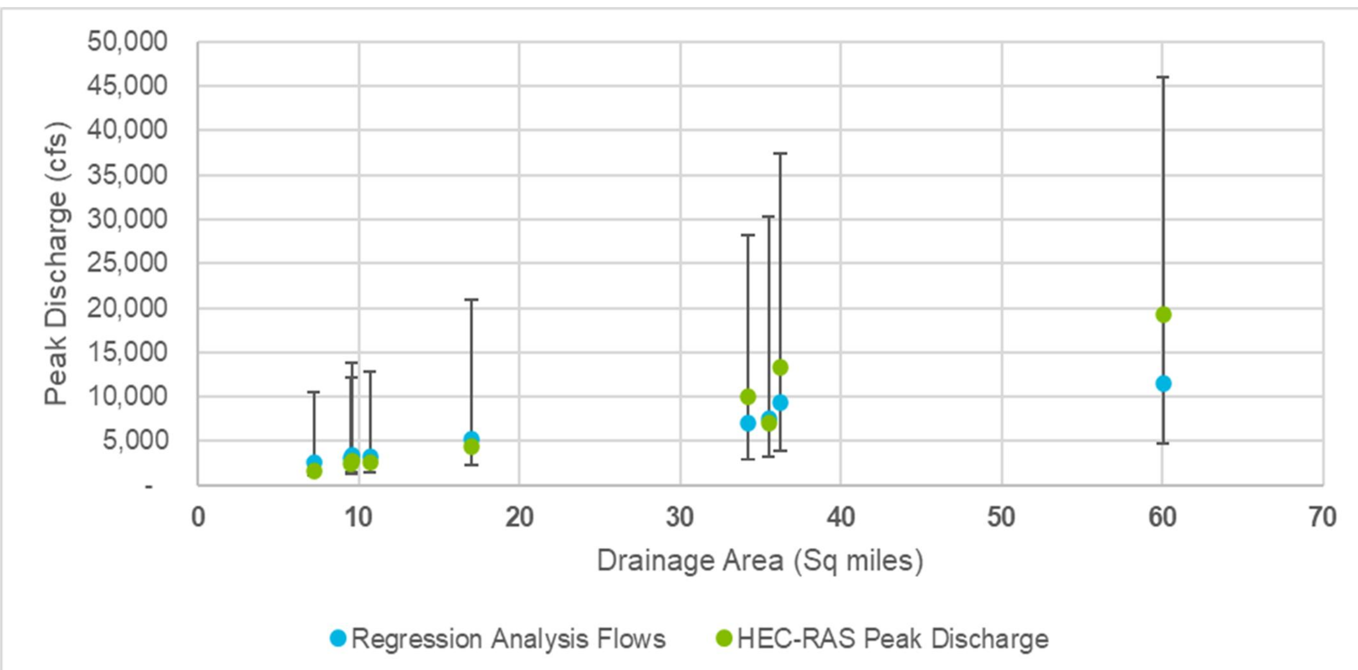

Figure 14: Calibration Comparison for DMFB3 Work Area

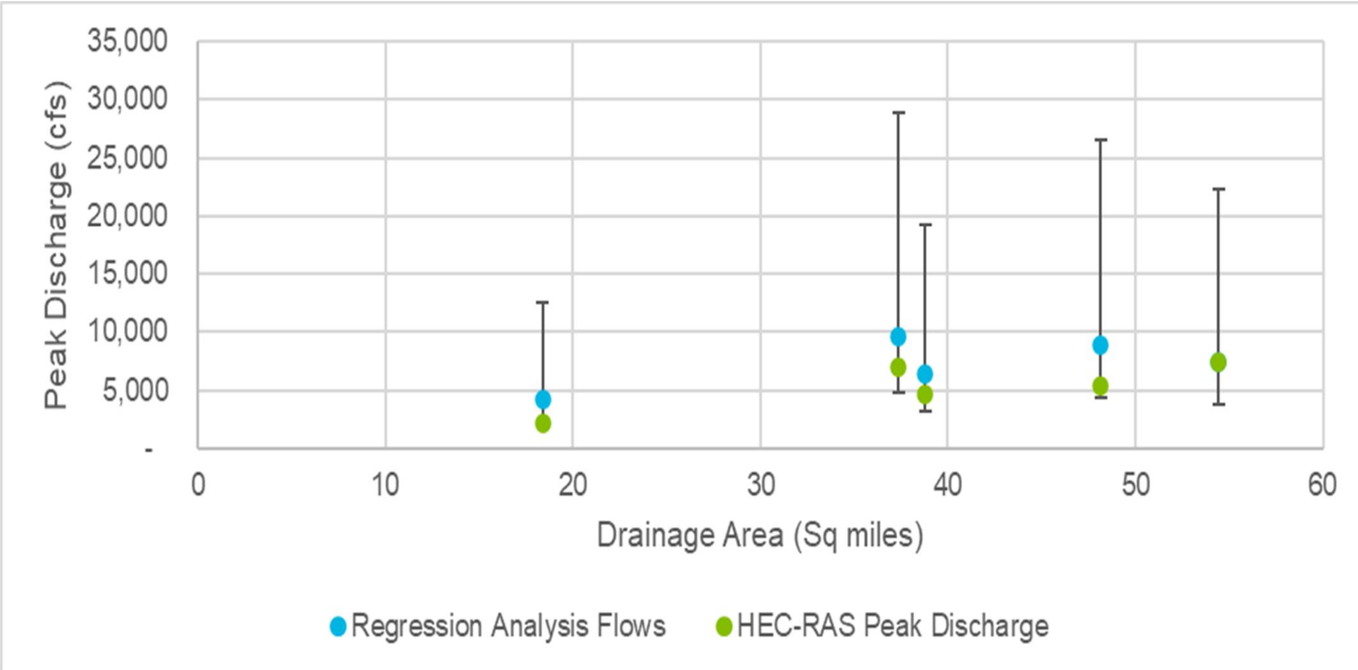

Figure 15: Calibration Comparison for DMFB4 Work Area

3.2 Challenges

DMFB1 workarea is well known for playa-driven flood storage. The initial condition for the playa based on the volume of runoff was developed from a 2-year, 1-hour duration rain event. This initial condition completely fills the playa and provides a conservative estimation of potential downstream flood conditions due to little/no playa storage capacity. The end of the 2-year, 1-hour duration rain simulation WSEL was used as an initial condition to run all of the events.

The DMFB2 work area contains the Lake Alan Henry Resevoir. The resevoir has no published discharge but there is a TWDB report that mentions the lake elevations. The terrain was modified to set it to the lake elevation from the report. From there the CN was adjusted to calibrate to gage 08079600 without activating the emergency spillway.

Two inflows come into the DMFB3 model area from two upstream 2D BLE model areas, North Fork Double Mountain Fork Model Area 3 (NFDMF3) and DMFB2. NFDMFB3 has a significantly larger area than DMFB2, 6,700 sq.mi compared to the latter's 1,500 sq. mi. To avoid coincident peak flows, a lag (delaying of the peak flow) of 24 hours was applied to the NFDMFB3 inflow. This also aided in calibration of the DMFB4 study area to the USGS gage results.

3.3 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.

Due to the size of the HEC-RAS hydraulic model area, nominal 200 foot cell sizes are utilized with refinement areas (and smaller cell sizes) implemented in specific areas of interest, as described in the modeling sections above. For detailed modeling and further improvements, smaller sized model is recommended to allow further refinement of infiltration parameters as well as use of smaller cell sizes, along with addition of structural and survey data for each crossing.

4. Floodplain Mapping and Effective Zone A Validation

The following sections provide a synopsis of how raw modeled depths were translated into Special Flood Hazard Areas (SFHA). In addition to developing a new SFHA, the BLE model data was leveraged to validate the effective Zone A studies within the project footprint.

4.1 Special Flood Hazard Area

4.1.1 Model Outputs

The HEC acknowledged RAS Mapper may not render water surface elevation values and/or delineate inundation extent appropriately for direct use in FEMA regulatory mapping products. To maintain a high level of consistency between modeling results and final mapping, minimal map clean up was performed while maintaining identification of both fluvial and pluvial flood risk as reflected by the models. Additional processing may be required to make the mapping products FEMA compliant.

4.1.2 Methodology

The sloping render mode plots water surface elevation (WSE) by interpolating the WSE between the 2D cell faces, producing a more continuous flood inundation extent. Depth rasters from the sloping render mode were exported for the 10-percent, 1-percent, and 0.2-percent flood events with a tolerance of 0.333333 feet. This approach was discussed with TWDB to remain largely in alignment with the mapping approach utilized in the previous task order for the adjacent Yellow House Draw and North Fork Double Mountain Fork Brazos HUCs. This approach differs from the TWDB GLE guidelines (May 2022) which would maintain larger extensive areas of shallower depths but would not align with the adjacent studies completed by AECOM. To reduce the extent of disconnected flood areas, raster grid processing is used to filter and remove disconnected, small, or shallow areas of flooding by processing through the 'Mapping Threshold Matrix' shown in Table 8.

Table 8: Mapping Threshold Matrix

Area (acres)	Average Depth (feet)
< 0.33	-
0.33 – 0.5	< 0.5

Polygon outputs from the 'Mapping Threshold Matrix' also fill in minor areas of high ground (islands) that are less than 0.33 acre. The outputs are then modified through a simplication and smoothing process to reduce unnecessary/erroneous vertices, remove rough edges and reduce the size and complexity of the raw floodplain polygons for the 1-percent, and 0.2-percent flood events. For the Double Mountain Fork Brazos watershed, the polygon outputs were simplified by retaining critical points at a 5 foot tolerance. The simplified polygon outputs were then smoothed utilizing the PAEK algorithm and the tolerance was set to 25 feet. The 10-percent flood event polygons are not modified through the simplification and smoothing process and are delivered in the rasterized polygon shape.

Due to topographic differences within a lake footprint, these areas sometimes appear partially mapped in the flood extents from the model results. Lakes and reservoirs larger than 40 acres are reviewed to ensure full inundation on the 1-percent, and 0.2-percent polygon extents. If necessary, lake boundaries were copied into the flood event polygons to make sure they are fully mapped.

Once the final polygon flood extents are complete, it is necessary to merge the 10-percent boundaries into the 1-percent and the 1-percent extents into the 0.2-percent extents. This step ensures that the extents of the 10-percent floodplain is smaller than the 1-percent floodplain, and the 1-percent is smaller than the extents of the 0.2-percent floodplain.

4.1.3 BLE Flood Hazard Layer

BLE database format FLD_HAZ_AR feature classes were developed and attributed with Zone A and Shaded Zone X features. The BLE FLD_HAZ_AR feature class was tested for topological errors described in the FIRM Database

Technical Reference and all errors were fixed for data integrity and schema agreement. The 10-percent boundaries have been included in the BLE TENPCT_FP feature class.

4.1.4 Additional 1-Percent Features

Once the final floodplain polygons were created, it is required that the depth and WSEL grids match the full extents of the flood inundation polygons. Because of the processing of the floodplain polygon boundaries through the above mentioned steps, there are areas in the model produced raster grids that no longer match the polygons. Final grids are interpolated for areas filled in with surrounding cell values and then clipped to the polygon extents to create the final water surface and depth grids for the 1-percent and 0.2-percent flood events.

4.2 Validation of Effective Zone A SFHA

The inventory of Zone A studies (721.0 miles) in the Double Mountain Fork Brazos watershed were classified in CNMS with validation status of “UNVERIFIED” (551.0 miles) or “VALID” (170.0 miles), and with status type of “BEING STUDIED.” The following is a summary of the results of the CNMS validation assessment for the effective Zone A studies in the study area. Initial Assessment checks A1-A3 were evaluated for the CNMS inventory of Zone A studies.

4.2.1 Intial Assessment A1 – Significant Topography Update Check

This check involves determining 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 Double Mountain Fork Brazos watershed, all effective Zone A topographic data utilized USGS topographic maps. The LiDAR sources now available used in this BLE study are considered significant improvements from the effective zone A topographic sources; therefore, all reaches fail this check.

4.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

This check involves first determining if regression equations were used for the effective study. Next, it must be determined 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.

For all Zone A streams in the Double Mountain Fork Brazos watershed, regression equations are not known to have been used for the effective studies and, therefore, pass this check

4.2.3 Initial Assessment A3 – Check for Significant Development

This check involves using the National Urban Change Indicator (NUCI) dataset to assess increased urbanization in the watershed of the Zone A study. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15% or more, and has increased by 50% or more since the effective analysis, the study would fail this check. Although the NUCI data provide year-to-year changes in urbanization, the NLCD also is needed to establish a baseline of urban land cover for this analysis. The check for significant development in this watershed was completed by evaluating percentage of urban change at the HUC-12 level.

The majority of Zone A studies within the watershed are classified as rural. Those studies that fall within urban watersheds have not experienced a significant increase in urbanization since their effective analyses. Therefore, all studies pass this check. All of the initial assessment results are shown in Table 9.

Table 9: Zone A Initial Assessment Results

Assessment Check	Pass / Fail	Notes
A1 – Topography	Fail	LiDAR sources available are a significant improvement from effective topography.
A2 – Hydrology	Pass	Regression equations not used in effective study
A3 – Development	Pass	Watershed does not meet urban threshold or urban watershed has not experienced a significant increase in urbanization

4.2.4 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.

No effective Zone A streams within the Double Mountain Fork Brazos watershed are known to be model backed and, therefore, all studies fail this check.

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

The BLE /effective Zone A comparison method leverages the existing Floodplain Boundary Standard (FBS) certification procedures described in FEMA SID 113, but with a slight modification. This modified FBS comparison approach uses the 1-percent plus and 1-percent minus flood profiles and horizontal and vertical tolerances described in FEMA's Automated Engineering guidance document dated May 2016. For the comparison of BLE and effective Zone A in the Texas study area, the following vertical and horizontal tolerances were used to conduct the modified FBS procedure. One point was placed every 200 feet along the floodplain boundaries for comparison.

- Vertical Tolerance: +/- 2.5 - 10 feet (one-half contour interval of effective topographic source).
- Horizontal Tolerance: +/- 75 feet (standard horizontal tolerance for BLE comparison testing).

Comparison results for thse streams were grouped at the HUC-12 level and are summarized in Table 10 to better understand the general health of the HUC-12 watershed, but the validation check was performed at the stream level. Streams where the percentage of passing FBS sample points is greater than or equal to 85% are marked as "Pass", otherwise marked as "Fail".

Table 10: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Double Mountain Fork Brazos Watershed	All Streams	25,642	7,815	17,827	70%	Fail	
120500040204	120500040204	1,758	404	1,354	77%	Fail	5.7
120500040205	120500040205	916	242	674	74%	Fail	6.6
120500040206	120500040206	1,176	384	792	67%	Fail	8.2
120500040207-Town of New Home	120500040207	201	43	158	79%	Fail	5.3
120500040907-Double Mountain Fork Brazos River	120500040907	400	93	307	77%	Fail	11.6
City of Levelland-Lobo Lake	120500040201	1,922	490	1,432	75%	Fail	6.5
Cox Hollow	120500040606	1,154	628	526	46%	Fail	27.2
Deadman Branch-Double Mountain Fork Brazos River	120500040904	571	122	449	79%	Fail	10.7
Ennis Creek	120500040701	2,172	566	1,606	74%	Fail	13.0
Levelland Municipal Airport-City of Levelland	120500040203	432	143	289	67%	Fail	8.3
Little Rough Creek-Double Mountain Fork Brazos River	120500040607	644	388	256	40%	Fail	30.1

Table 10, continued: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Lower Rough Creek	120500040704	876	430	446	51%	Fail	24.5
Lower Tonk Creek	120500040906	38	3	35	92%	Pass	3.9
Maverick Creek-Double Mountain Fork Brazos River	120500040605	26	14	12	46%	Fail	26.9
McKenzie Creek-Double Mountain Fork Brazos River	120500040602	124	36	88	71%	Fail	14.5
McKenzie Mountain-Grape Creek	120500040505	673	170	503	75%	Fail	12.6
Middle Rough Creek	120500040703	2,298	994	1,304	57%	Fail	21.6
Rocky Creek-Double Mountain Fork Brazos River	120500040504	331	55	276	83%	Fail	8.3
Tahoka Lake	120500040209	19	18	1	5%	Fail	23.7
Town of Busterville-Town of New Home	120500040104	631	204	427	68%	Fail	8.1
Town of Clauene	120500040102	2,697	659	2,038	76%	Fail	6.1
Town of Coble	120500040202	787	125	662	84%	Fail	4.0
Town of Ropesville	120500040103	1,902	570	1,332	70%	Fail	7.5
Town of Tahoka	120500040304	27	14	13	48%	Fail	13.0
Town of Whiteface	120500040101	1,840	419	1,421	77%	Fail	5.7
Upper Rough Creek	120500040702	2,027	599	1,428	70%	Fail	14.8

4.2.6 Validation Results

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Double Mountain Fork Brazos watershed has been updated as summarized in Table 11, and illustrated in Figure 16.

Table 11: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	173.2
UNVERIFIED	BEING STUDIED	547.7

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 17 below shows the range of the HUC-12 priority scores which can be used to initiate discussions during the Discovery phase.

Little Rough Creek HUC-12 was determined to have the highest priority score and the most need while Lower Tonk Creek HUC-12 had the lowest score.

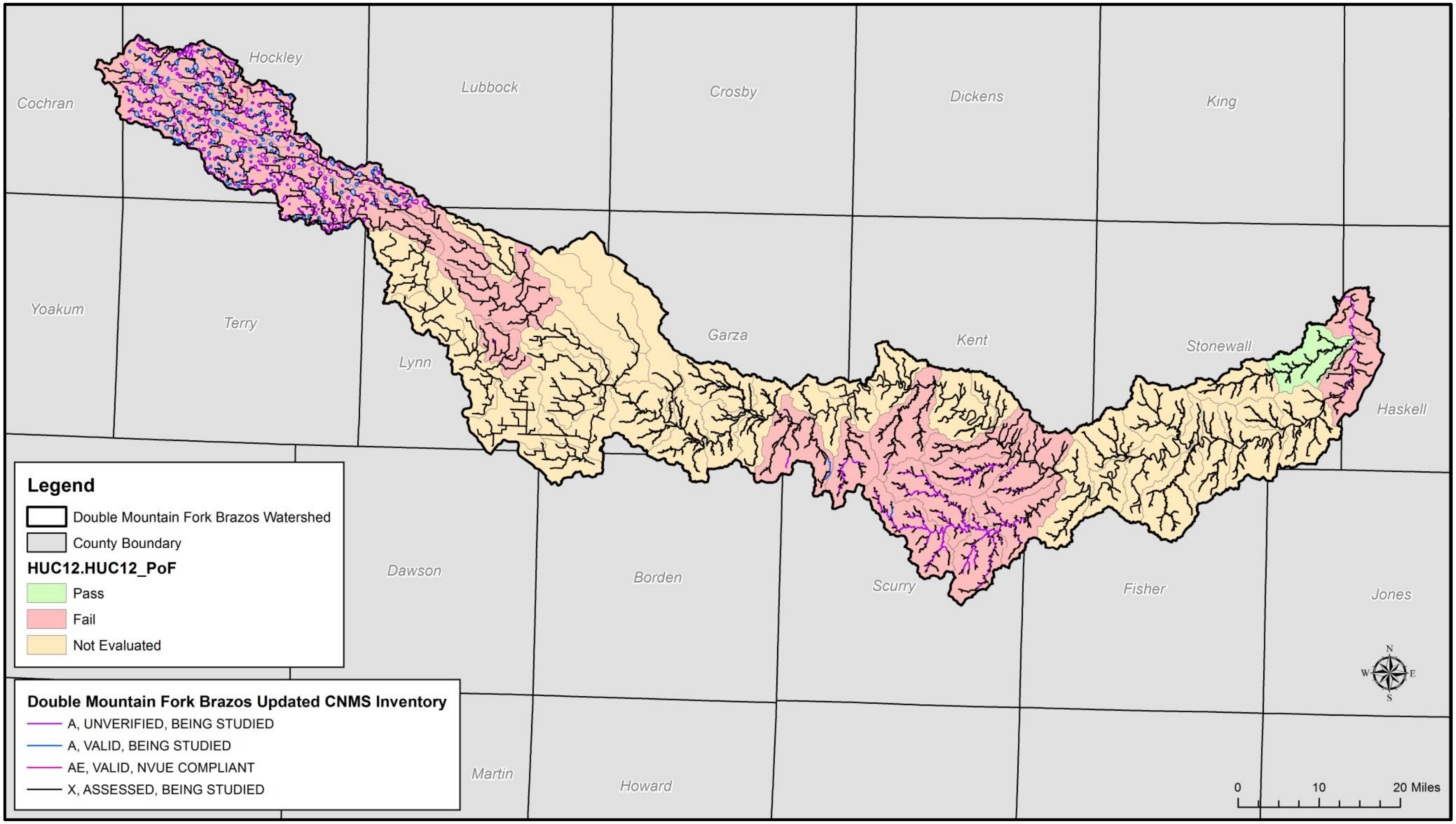

Figure 16: Double Mountain Fork Brazos Watershed CNMS Validation Results

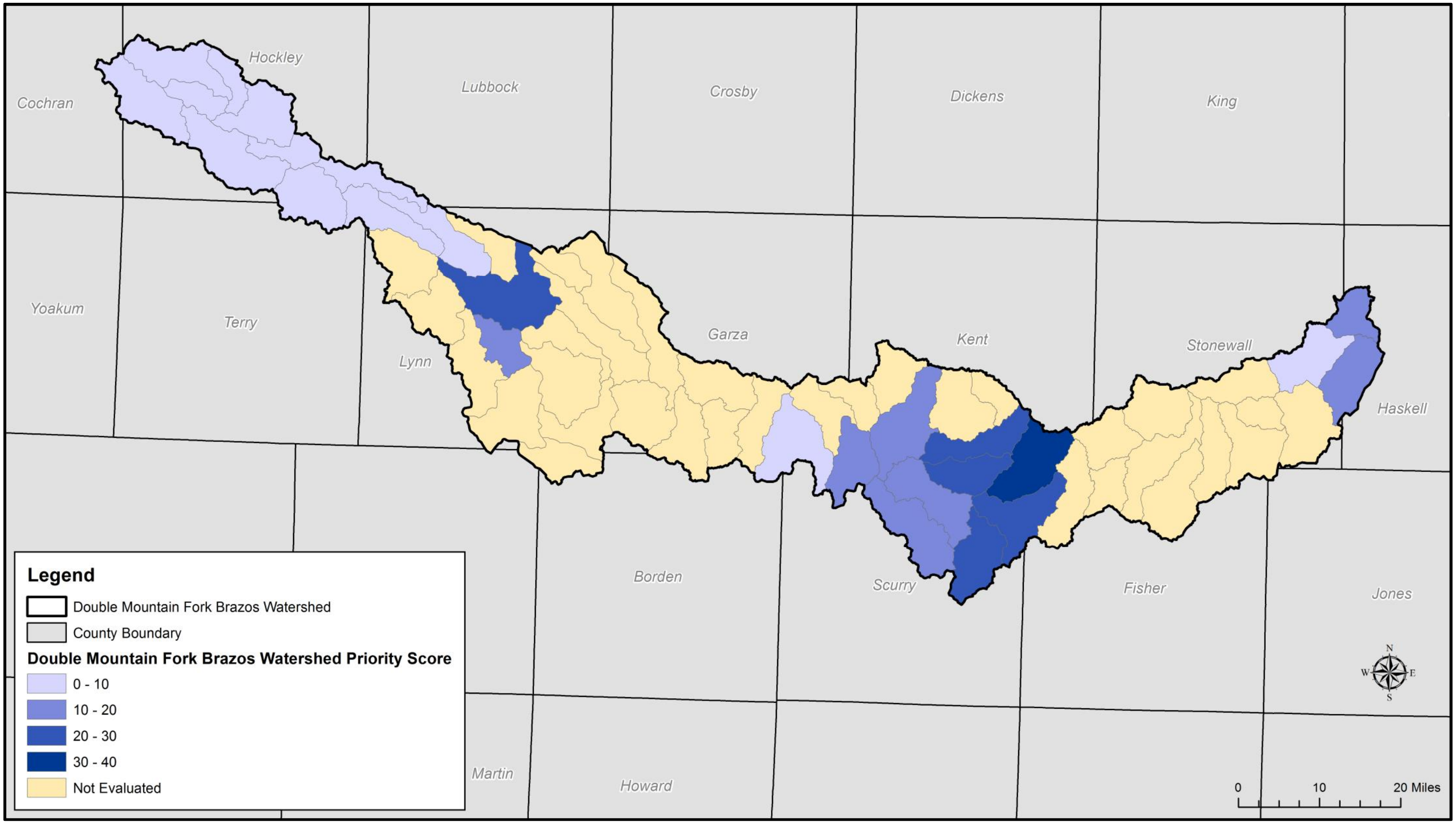

Figure 17: Ranking of Double Mountain Fork Brazos Watershed HUC-12s

4.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent annual chance and 0.2-percent annual chance depth grids were used to calculate the potential flood losses. The loss results are stored in the S_FRAC_AR spatial file within the FRD geodatabase. All results are reported in whole dollar values.

Hazus version 5.1 was used for the basic and refined loss analysis.

The losses are reported via census blocks. It is important to note that Hazus version 5.1 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 extents for each return period to ensure proper model processing. A summary of results for these counties for the 1-percent a.c.e. scenarios are shown in Table 12.

Table 12: Hazus 5.1 Results for 1-Percent-Annual-Chance (100 year) Scenario

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Borden	$142,000.00	$7,922,000.00	$4,716,000.00
Cochran	$6,061,000.00	$60,236,000.00	$39,965,000.00
Dawson	$0.00	$202,000.00	$101,000.00
Fisher	$511,000.00	$32,306,000.00	$21,702,000.00
Garza	$4,364,000.00	$132,333,000.00	$68,186,000.00
Haskell	$337,000.00	$20,524,000.00	$11,577,000.00
Hockley	$166,974,000.00	$1,474,913,000.00	$928,873,000.00
Jones	$0.00	$0.00	$0.00
Kent	$370,000.00	$18,036,000.00	$9,018,000.00
Lubbock	$2,964,000.00	$70,522,000.00	$40,606,000.00
Lynn	$27,571,000.00	$438,845,000.00	$265,735,000.00
Scurry	$258,000.00	$62,226,000.00	$37,587,000.00
Stonewall	$1,948,000.00	$99,968,000.00	$65,833,000.00
Terry	$451,000.00	$5,726,000.00	$3,778,000.00
Total	$211,951,000.00	$2,423,759,000.00	$1,497,677,000.00

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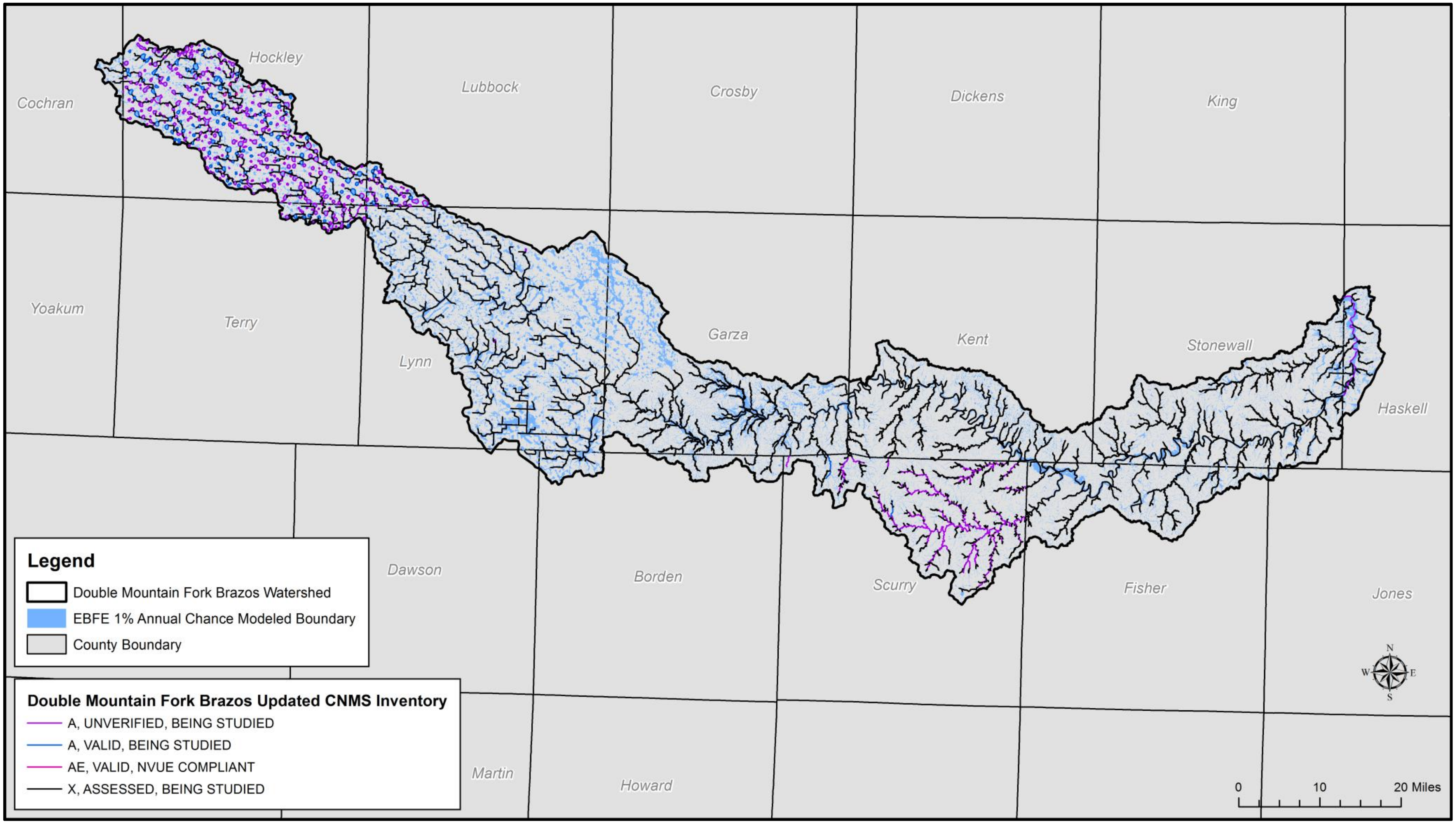
Appendix A BLE Map



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