Compass
Identify, Interpret, Integrate

Lake Fork Watershed, TX
1D Base Level Engineering (BLE) Results

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APPROVALS

This document requires the approval of the following persons:

Role	Name	Review Date	Approved Date
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CLIENT DISTRIBUTION

Name	Title/Organization	Location
FEMA's MIP	Region VI	See path above
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Executive Summary

FEMA Region 6 contracted Compass to complete a Base Level Engineering (BLE) analysis for Area E – Sabine River in southeastern Texas, to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). Area E includes the Upper Sabine, Lake Fork, Middle Sabine, Lower Sabine, and Sabine Lake HUC-8 watersheds. This report focuses on the Lake Fork HUC-8 watershed. This BLE study will provide significant data for several Texas counties previously lacking modernized flood models.

The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory-quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development in support of hydrologic and hydraulic analysis as well as mapping activities were leveraged from various local, State, and Federal partners. Details regarding the different datasets used are provided below in Section 1.1.

Flood discharges for this study were calculated using both the United States Geological Survey (USGS) regression equations and gage analysis, where stream gages with sufficient record exist. Regression equations were obtained from the USGS Scientific Investigations Report (SIR) 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach* (2009).

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 5.0.7 was used to compute water surface elevations on a stream by stream basis. All hydraulic models were computed using 1-D steady state analysis.

The stream mile network that was validated for these watersheds was compiled using FEMA's Community Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risks. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-1 lists the Zone A stream miles associated with this validation analysis.

Table ES-1: Summary of Stream Miles

Source	Lake Fork Stream Miles
CNMS	721.4

The full inventory of Zone A studies in the watershed were classified in CNMS. Total miles validated in CNMS are summarized in Table ES-2 and illustrated in Figure ES-1 below.

Table ES-2: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	212.8
UNVERIFIED	BEING STUDIED	508.6

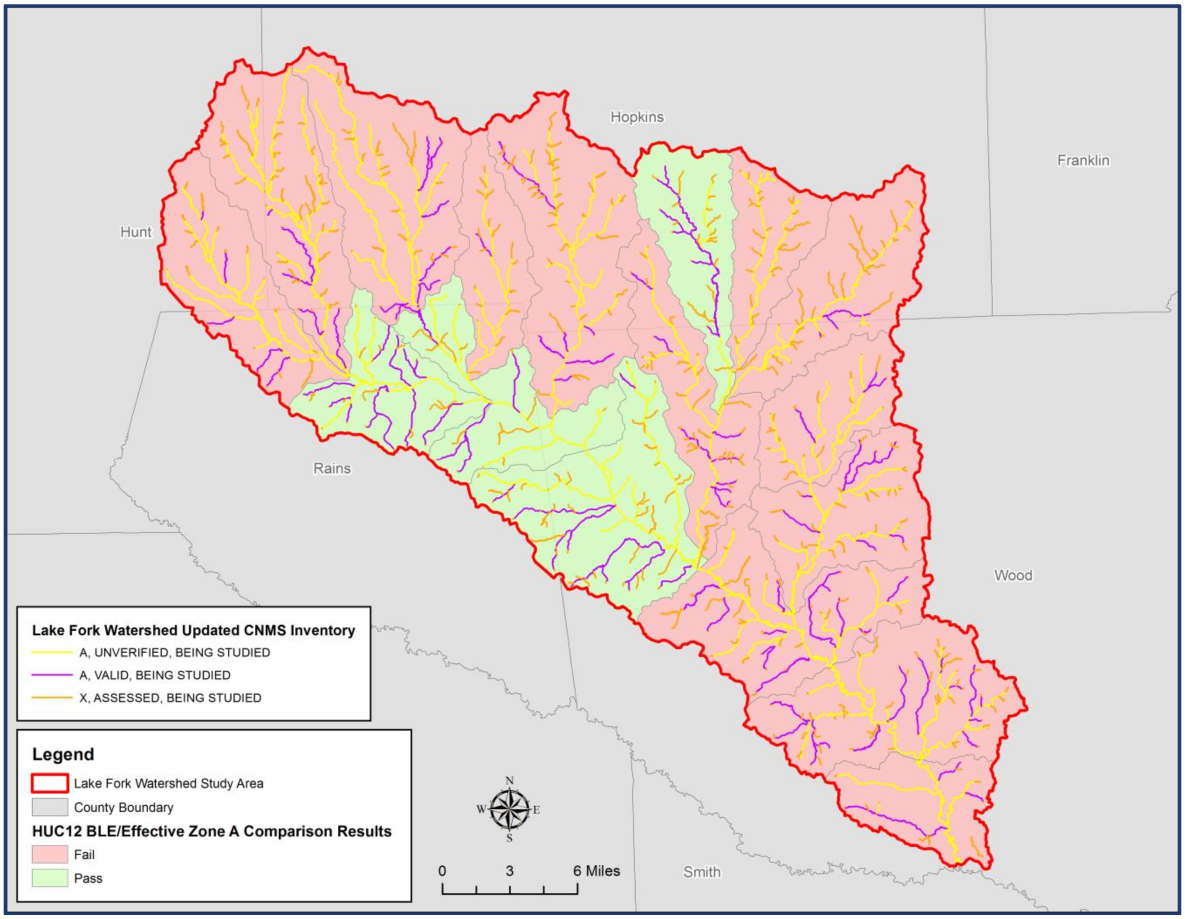

Figure ES-1: Lake Fork Watershed CNMS Validation Results

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 ES-2 below shows the range of the Lake Fork HUC-8 priority scores which can be used to initiate discussions during the Discovery phase.

Arr Branch-Lake Fork Creek HUC-12 was determined to have the highest priority score and the most need while Dry Creek-Running Creek HUC-12 had the lowest scores.

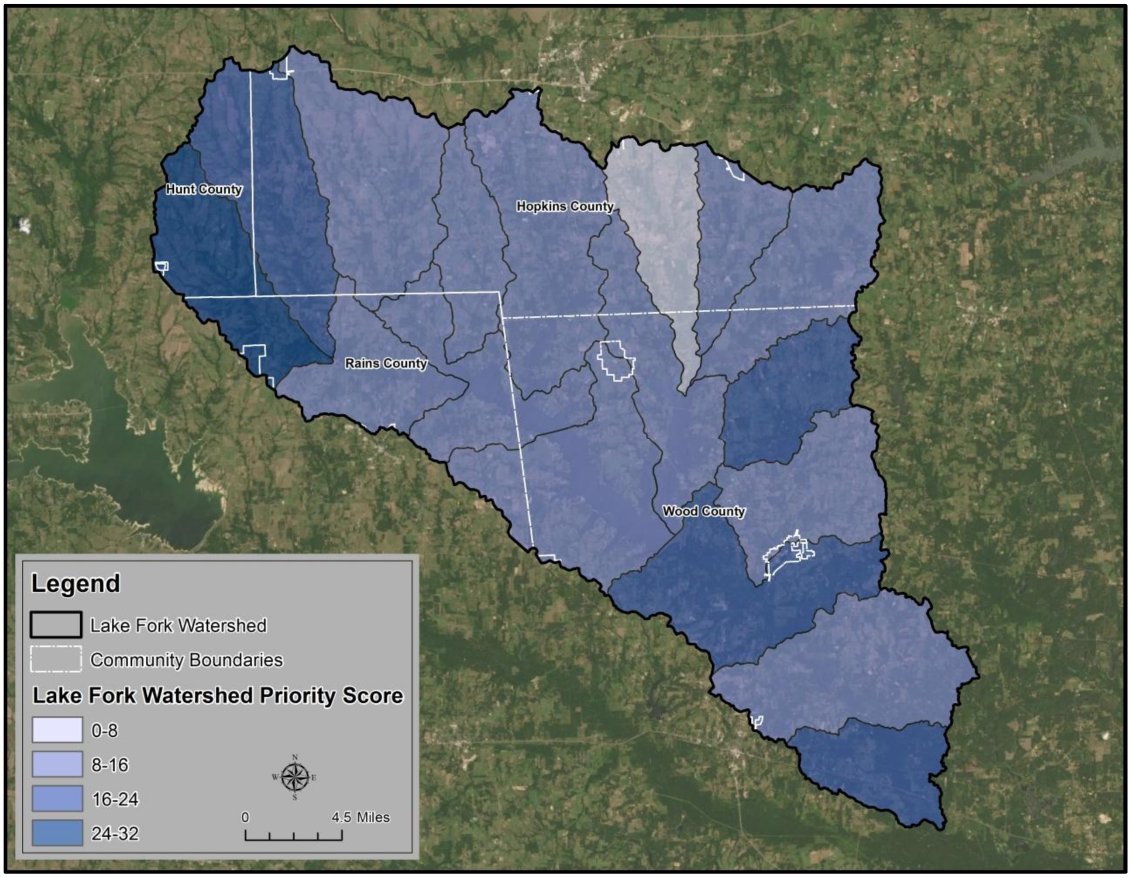

Figure ES-2: Ranking of Lake Fork HUC-12s

Base Level Engineering (BLE) Methodology

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

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every five years, FEMA must evaluate whether the information on Flood Insurance Rate Maps (FIRMs) reflects the current risks in flood-prone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the 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.

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

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

FEMA Region 6 contracted Compass to complete a BLE analysis for the Lake Fork Watershed in East Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Hunt, Hopkins, Rains, and Wood Counties, and include the following communities: the Cities of Cumby, Emory, Lone Oak, Minieola, Point, Quitman, Sulphur Springs, Yantis, and the Towns of Alba and Como. The study area consists of three HUC-10 basins: Lake Fork Creek-Case Lake, Running Creek-Case Lake, and Dry Creek-Lake Fork Creek. Figure 1 shows the orientation of the Lake Fork HUC-10 basins with respect to the counties.

Figure 1: Lake Fork Watershed HUC-10 Basins

Compass studied approximately 1,007 miles of stream reaches within the Lake Fork Watershed with a minimum drainage area tolerance of one square mile outside of population centers and half a square mile inside population centers. The selection and extent of stream reaches studied were based upon the number of stream miles with a minimum drainage area of one square mile (or half a square mile, where appropriate) and not the number of effective Zone A stream miles. Study reaches were extended above this threshold as appropriate to ensure all effective Zone A flood areas received an updated analysis. Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. The following sections summarize the BLE process and discuss the results along with their recommended use.

1.1 Topographic Data

Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. Topographic data were obtained from the Texas Natural Resources Information System (TNRIS), and the United States Geological Survey (USGS).

All available metadata, survey reports, and other leverage documentation are available with the source dataset. Figure 2 shows the extents of the source Digital Terrain Model (DTM) data used for Area E and the Lake Fork Watershed.

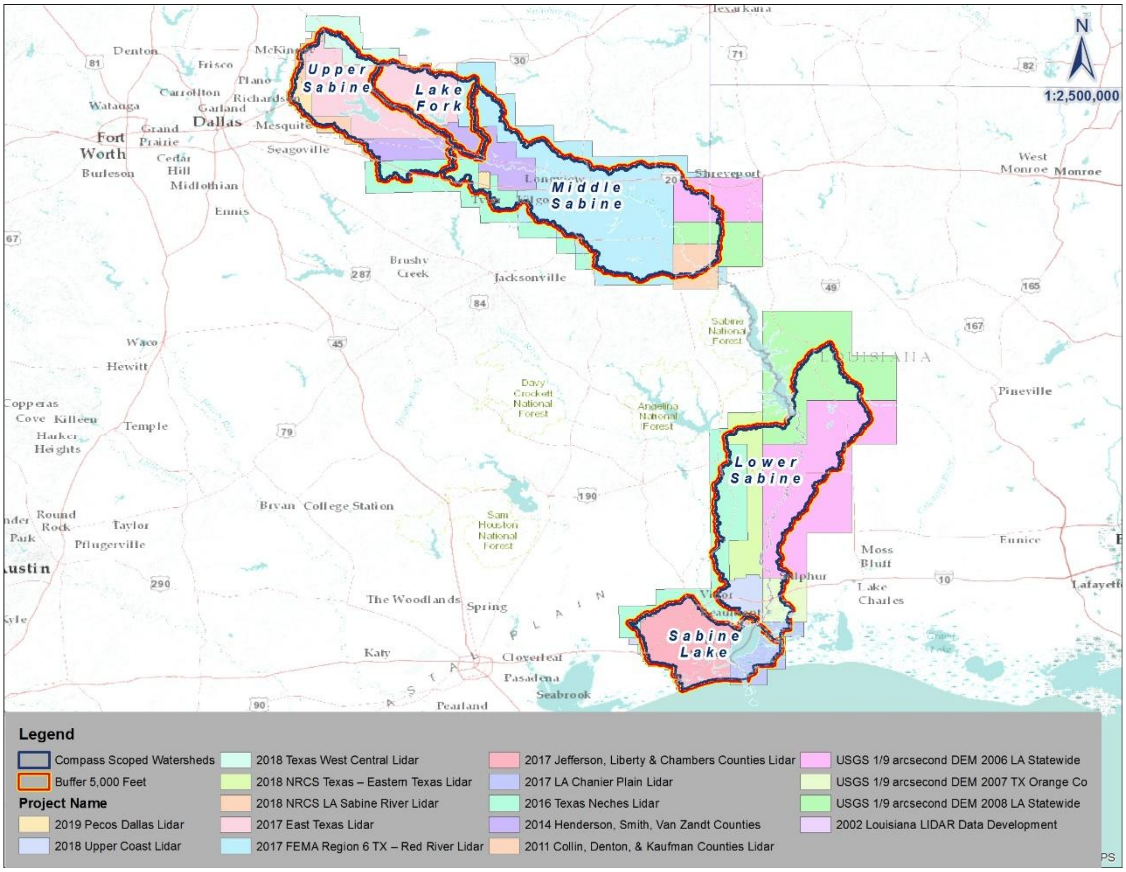

Figure 2: Extent of LiDAR Data for Area E

1.1.1 Source Terrain Data

Three topographic datasets were used in the development of the BLE hydraulic models. Details on each dataset are outlined below.

1.1.1.1 2017 East Texas LiDAR 1 Meter DEM

Fugro was tasked to collect and process a LiDAR-derived elevation dataset for the Texas counties of Collin, Delta, Fannin, Hopkins, Hunt, Lamar, Liberty, Montgomery, Polk, Rains, San Jacinto, Van Zandt, Walker, and Wood with QL 2 Specification.

The 2017 East Texas LiDAR data was available as 1 meter rasters from TNRIS (https://data.tnris.org/collection/f09f36b9-12b1-4c88-bccb-017afa9bc3d8). The data was downloaded on September 9, 2020. The data was in NAD83 UTM Zone 15 projection with elevations in NAVD88 with units in meters. The data was collected from December 29, 2016 through April 14, 2017.

Data Specification:

Modern era LiDAR data collection is typically expected to meet specifications of the NGP - LBS. The national LBS have been modified through a series of revisions throughout time and can be accessed at 'LiDAR Base Specification Online' for reference (https://www.usgs.gov/core-science-systems/ngp/ss/LiDAR-base-specification-online). This LiDAR survey and derivative products produced in compliance with the task order are based on:

- USGS LiDAR Base Specifications v1.2
- ASPRS Positional Accuracy Standards for Digital Geospatial Data

The measured accuracy was 0.066 meters for NVA at 95% confidence level and the VVA measured as 0.096 meters.

1.1.1.2 2017 FEMA Region 6 Red River TX 1 Meter DEM

The 2017 FEMA Region 6 Red River TX LiDAR data was acquired from January 20, 2017 to March 1, 2017. Dewberry served as the prime contractor for the project and was responsible for LAS classification, all LiDAR products, breakline production, DEM production, and quality assurance. Dewberry also performed ground surveying for the project and delivered surveyed checkpoints. For independent testing of the vertical accuracy of the LiDAR-derived surface model and also collected ground control and LiDAR calibration points used during LiDAR data acquisition and processing.

Quantum Spatial and Precision Aerial Reconnaissance completed LiDAR data acquisition and data calibration for the project area which includes the Texas counties of McCurtain, Lamar, Red River, Bowie, Franklin, Titus, Morris, Cass, Camp, Wood, Upshur, Marion, Gregg, Smith, Harrison, Rusk, Panola, and Hopkins.

1.1.1.3 2014 Henderson, Smith, Van Zandt Counties & Trinity River LiDAR 1 Meter DEM

Atkins, McKim & Creed, and Williams Aerial and Mapping, Inc. were tasked to collect and process a LiDAR-derived elevation dataset for the Texas counties of Anderson, Cherokee, Dallas, Ellis, Freestone, Gregg, Henderson, Kaufman, Navarro, Rains, Smith, Upshur, Van Zandt, and Wood.

The 2014 Henderson, Smith, Van Zandt Counties & Trinity River LiDAR data was available as 1 meter rasters from TNRIS (https://data.tnris.org/collection/18c52542-dc6f-4a12-88b3-59ecc8e6d53d). The data was downloaded on September 9, 2020. The data was in NAD83 UTM Zone 15 projection with elevations in NAVD88 with units in meters. The data was collected from January 25, 2014 to February 18, 2014.

The measured accuracy was 0.067 meters for Fundamental Vertical Accuracy (FVA) at 95% confidence level in open terrain.

1.1.2 Terrain Data Processing

The LiDAR data were processed in Environmental System Research Institute (ESRI) ArcGIS software to create a composite Digital Terrain Model (DTM) dataset for the project area. The outputs from the processing described below were used during the hydrology, hydraulics, floodplain mapping and CNMS processes and validations.

The Watershed Information System (WISE) software platform was utilized in order to create a digital surface model for the Lake Fork Watershed project area. This module allows source data from a variety of sources to be prioritized based on level of accuracy or preference of the user. The 2017 East Texas LiDAR 1 meter DEM LiDAR dataset was prioritized as the best data source for the Lake Fork Watershed followed by the 2017 FEMA Region 6 Red River TX 1 Meter DEM and the 2014 Henderson, Smith, Van Zandt Counties & Trinity River LiDAR 1 Meter DEM dataset.

The 10-foot DEMs created from the LiDAR datasets described above were compiled in order of vertical accuracy into a mosaic dataset using ArcMap. From this mosaic, a tile index was created for the project area and the mosaic was clipped into 40,000-foot tiles, converted to asciis and imported into Wise Terrain Analyst (WTA). Visual inspection of the 10-foot DEMs was performed to ensure no voids and/or artifacts were present. The DEM surface model was affirmed to be suitable for hydraulic takeoffs and supporting other hydraulic analyses.

Stream centerlines were generated from ArcHydro processes and manually edited to match the 10-foot DEMs as a source for horizontal alignment and vertical elevation. These stream centerlines are created for use in the hydraulic analysis.

In addition to the quantitative assessment of the source digital terrain, a qualitative visual inspection of the composite DEM was performed using a hillshade derived from the 10-foot DEM. The visual inspection indicated that no unusual or non-terrestrial features were observed in the composite DEM assuring the surface files are sufficient for hydraulics analyses and floodplain mapping activities.

1.2 Hydrology

Flood discharges for this study were calculated using both the United States Geological Survey (USGS) regression equations and gage analysis, where stream gages with sufficient record exist. Regression equations obtained from the USGS Scientific Investigations Report (SIR) 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach* (2009) contain the most recent regression equations for Texas.

The Watershed Information System (WISE) software was used to delineate drainage basins in shapefile format using the 50-foot DEM. WISE was also used to calculate the main-channel slope for each basin. The basin shapefile attribution was automated by WISE with drainage area, main-channel slope, precipitation, and OmegaEM.

Table 1 shows the published equations used in this study. In these equations, Q_i represents peak streamflow for i-recurrence interval (annual chance exceedance (a.c.e.)) in cubic feet per second (cfs), P represents mean annual precipitation in inches, S represents dimensionless main-channel slope, Ω represents the OmegaEM parameter, and A represents cumulative drainage area in square miles.

Table 1: Summary of Regression Equations in Texas (SIR 2009-5087)

Recurrence Interval	Equation[1]
$Q_{10\%}$	$PREC^{1.203}S^{0.403} * 10^{[0.908*\Omega + 13.62 – 11.97*CONTDA\text{^}(-0.0289)]}$
$Q_{4\%}$	$PREC^{1.140}S^{0.446} * 10^{[0.945*\Omega + 11.79 – 9.819*CONTDA\text{^}(-0.0374)]}$
$Q_{2\%}$	$PREC^{1.105}S^{0.476} * 10^{[0.961*\Omega + 11.17 – 8.997*CONTDA\text{^}(-0..0424)]}$
$Q_{1\%}$	$PREC^{1.071}S^{0.507} * 10^{[0.969*\Omega + 10.82 – 8.448*CONTDA\text{^}(-0.0467)]}$
$Q_{0.2\%}$	$PREC^{0.988}S^{0.569} * 10^{[0.976*\Omega + 10.40 – 7.605*CONTDA\text{^}(-0.0554)]}$

Variables:

- Q_i, peak flow for i recurrence interval (a.c.e.), in cubic feet per second;
- PREC, mean annual precipitation, in inches;
- S, Main-channel slope (dimensionless);
- **Ω**, OmegaEM parameter;
- CONTDA, Contributing Drainage Area in square miles;

Discharges for the 1-percent plus and 1-percent minus a.c.e. were calculated as well. These values were computed as $Q_{1\%+/-} = Q_{1\%} \times (10^{\pm 0.30})$ where 0.30 is the residual standard error in log_{10}-unit of cubic feet per second for the $Q_{1\%}$ equation (Table 3 in SIR 2009-5087). In other words, these values were computed by multiplying the $Q_{1\%}$ discharges by 1.995 and 0.501 respectively, which account for the log10 format residual standard error of 0.30 associated with the $Q_{1\%}$ regression equation.

The mean annual precipitation values were determined based on a shapefile coverage obtained from the Texas Water Development Board (TWDB) and is available for download at the following location: https://www.twdb.texas.gov/mapping/gisdata.asp

The annual precipitation values reflect data for the climatological period 1981-2010 as recorded by the Natural Resources Conservation Service (NRCS).

Main-channel slope was calculated in WISE. An automated routine determined the longest flowpath from upstream of a reach to the outlet of the sub-basin of interest. Two points along the channel, one at 0 percent and the other at 100 percent of the channel length, determined the endpoints of the segment used in the main-channel slope calculation. The elevations for those endpoints were based on the 10-foot DEM developed from the LiDAR.

From SIR 2009-5087, the OmegaEM parameter is a generalized terrain and climate index that expresses relative differences in peak-streamflow potential. A shapefile was developed and populated with OmegaEM values based on Figure 2 in SIR 2009-5087. This shapefile was used to determine Omega EM values on a sub-basin basis. For sub-basins spanning more than one OmegaEM grid, the sub-basin's centroid determined its OmegaEM parameter.

Drainage area for each sub-basin was determined based on automated basin delineations performed by WISE. Break points were also set immediately upstream of stream confluences and at stream gages. Cumulative drainage area was determined based on these automated delineations performed by WISE in combination with a stream connectivity routine that defined the stream reach segments with upstream and downstream neighbors.

The sub-basin shapefile was attributed with the computed discharges, and those discharges were incorporated into the HEC-RAS 5.0.7 models using an automated routine in WISE. Discharges, as well as water surface elevation results, were associated with the hydraulic cross sections prior to generation of floodplain boundaries and grid mapping. Those results are available in GIS format as part of this BLE submittal package.

1.2.1 Stream Gage Analysis

Figure 3 shows the location of the two USGS stream gages evaluated in the Lake Fork Creek study to develop discharges for the gaged streams (see Table 2).

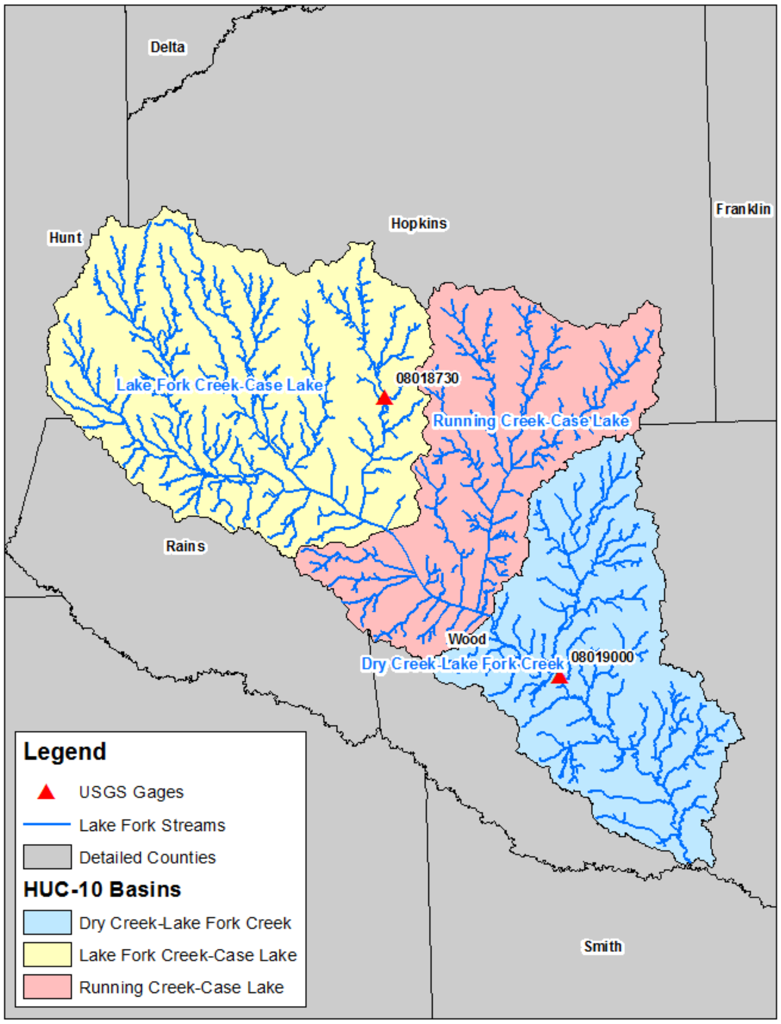

Figure 3: Locations of USGS Gages Utilized in Flood Frequency Analyses

Table 2: USGS Stream Gages in Lake Fork Watershed

Gage ID	Flooding Source and Location	Computed Drainage Area (mi.^{2})	Published Drainage Area (mi.^{2})	Period of Record
08019000	Burke Creek near Yantis, TX	33	33	1979-1989
08018730	Lake Fork Creek near Quitman, TX	578	585	1925-2020

Flood frequency analyses (FFA) were performed in Peak FQ Version 7.3 for both gages, according to Bulletin 17C (EMA) guidelines. For both gages, a confidence interval of 0.84 was used.

For the analysis of the Burke Creek gage, it was determined to not use the gage discharges to weight the regression flows due to the short period of record and the age of the record. The gage results were also significantly lower than the regression flows.

For the Lake Fork Creek gage, gage results were not used upstream of the reservoir due to the significant regulation. Regression equations were utilized upstream of the dam. However, the gage was used to define the flows downstream of the dam. At the gage location, the unweighted gage flow was used directly from the analysis and for the sub-basins below the gage, drainage area upstream of the dam was excluded from the gage weighting calculations. The gage flow and estimated flow below the gage was used to calculate an exponent (X) for the following equation:

$$Q_{ungaged}/\,Q_{gaged} = (DA_{ungaged}/DA_{gage})^{X}$$

This exponent (X) was then used to estimate the flows between the dam and the gage. Stream gage analysis worksheets are available as a part of this BLE submittal package.

1.3 Hydraulics

The hydraulic approach for this BLE analysis of the Lake Fork Creek Watershed consisted of using the terrain model described in Section 1.1 in combination with the hydrologic outputs from Section 1.2 to establish water surface elevations using 1-D steady state analysis. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 5.0.7 was chosen as the computer model to compute water surface elevations on a stream by stream basis. The WISE software was used to establish model stream orientation, generate initial hydraulic cross section layout and stationing, assign n-values to cross sections, and develop all input files for the HEC-RAS program. ESRI's ArcMap program was used to review and refine cross-section layout orientation.

First pass cross-section layout was performed using an automated routine in WISE that varies cross section spacing based on the cumulative drainage area at the cross section location. A first draft model was created based on this initial cross-section layout, and draft boundaries were developed. Next, a second pass inspection for cross-section placement and alignment occurred. Significant refinement occurred during this step. To improve the hydraulic models, additional cross-sections were added as needed to better define the BLE floodplain boundary. Cross-sections were extended in locations where overtopping occurred. Orientation of cross-sections was refined to improve on the perpendicular orientation to flow. Additional cross-sections were added at floodplain constrictions and at downstream portions of tributaries to ensure a proper tie-in with receiving streams. Cross-sections were adjusted to remove sections that intersected hydraulic crossings in the floodplain. For some of the largest studied streams, cross-sections were laid out manually in order to have more reasonable spacing and better capture the constrictions in the floodplain.

Cross-sections were not drawn on top of roadways or railroads but were placed at the upstream and downstream face of major roads and railroads. Ineffective flow stations were placed in the hydraulic models as appropriate to account for flow constrictions and other locations deemed by the engineer to be ineffective at conveying flow downstream.

Cross-sections were drawn on dam crests for dams with well-defined spillways in order to better represent ponded water upstream of the structures. In so doing, it was assumed that the vast majority of the flow during a flood event would pass the spillway and that the hydraulic model would reasonably estimate flow across the spillway as represented in the hydraulic cross-section. The elevations used in the modeling were checked against effective Zone A boundaries, and the results were deemed reasonable.

The relationship between cumulative drainage area and assigned channel geometry is shown in Table 3. These default values for dimensions and spacing were subject to change based on engineering judgment.

Table 3: Cross-Section Default Parameters

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
1	300	6	5	0.8
2	300	7	6	0.8
4	300	10	8	0.8
8	400	12	11	0.8
10	500	13	12	0.8
15	500	18	13	0.8
20	500	19	14	0.8
25	500	20	15	0.8
30	500	21	16	0.8
40	500	25	17	0.8
50	600	28	18	0.8
75	600	30	19	1
100	750	33	20	1
150	750	36	21	1
250	1000	38	22	2
500	1500	40	23	2
1000	2500	40	25	3
2000	2500	50	30	3
5000	2500	200	100	3

In typical BLE projects, Manning's roughness coefficients (n-values) are determined using the 2016 National Land Cover Data (NLCD) dataset in combination with n-values from Chow (1959) and Calenda et al. (2005). For this watershed, the n-values for the developed areas indicated an underestimation of the roughness coefficients when compared to the aerial imagery and were adjusted accordingly. The association between the n-values and the NLCD Classification is shown in Table 4. Manning's n-value takeoffs are performed by WISE (default values taken from the "Normal" column). N-values within channel banks are constrained by the automated routine to a range of 0.030 to 0.070. Then, overbank and channel n-values are manually adjusted in certain locations based on engineering judgment.

Table 4: Manning's "n" Roughness Based on 2016 NLCD Classification (Moore, 2011)

NLCD Classification	Selected Manning's N	Minimum	Normal	Maximum	Source
Open Water	0.033	0.025	0.03	0.033	Chow 1959
Developed, Open Space	0.04	0.01	0.013	0.016	Calenda et al. 2005
Developed, Low Intensity	0.08	0.038	0.05	0.063	Calenda et al. 2005
Developed, Medium Intensity	0.1	0.056	0.075	0.094	Calenda et al. 2005
Developed, High Intensity	0.15	0.075	0.1	0.125	Calenda et al. 2005
Barren Land	0.025	0.025	0.03	0.035	Chow 1959
Deciduous Forest	0.16	0.1	0.12	0.16	Chow 1959
Evergreen Forest	0.16	0.1	0.12	0.16	Chow 1959
Mixed Forest	0.16	0.1	0.12	0.16	Chow 1959
Scrub/Shrub	0.1	0.035	0.05	0.1	Chow 1959
Grassland/Herbaceous	0.035	0.025	0.03	0.035	Chow 1959
Pasture/Hay	0.03	0.03	0.04	0.05	Chow 1959
Cultivated Crops	0.035	0.025	0.035	0.045	Chow 1959
Woody Wetlands	0.12	0.08	0.1	0.12	Chow 1959
Emergent Herbaceous Wetland	0.07	0.07	0.1	0.15	Chow 1959

The boundary condition used for the majority of the study streams was normal depth with a default value of 0.005 ft/ft. For streams with large drainage areas (generally greater than 8 square miles), the normal depth slope was calculated based on the channel inverts of the downstream cross sections.

In cases where streams tie in to a lake, a normal depth slope was calculated based on the channel inverts of the downstream cross sections (typically between 0.0001 and 0.001 ft/ft). Several HUC-10s within this watershed are located in urban areas with storm drain systems, which are unaccounted for in the BLE models. Implications of these systems may considerably affect risk.

For the Lake Fork Creek mainstem, ineffective areas were added to cross-sections directly upstream of the Lake Fork Reservoir dam at the conservation pool elevation (402.93' NAVD88). The non-permanent ineffective areas ensured that the modeled events would not be below the conservation pool elevation. This modeling approach was also consistent with the downstream Toledo Bend base level engineering study.

1.4 Quality Control

Following the initial hydraulic model analysis in each watershed, the resulting flood hazard area delineations were reviewed for areas where the results were not ideal.

QC results indicated that some of the models should be extended to cover the scope of effective flood hazard data. Those streams were extended farther upstream to match the extents of the effective SFHA data.

Typical revisions resulting from reasonability checks included adding cross-sections, adjusting orientation of cross-sections, trimming cross-sections and reduction of the default “V” angle of cross-sections. Examples of default “V” angled cross-sections are shown in Figure 4. It is estimated that 75 percent of cross-sections were adjusted in some work areas while other areas did not require as much editing. Other examples of manual editing included the addition of cross-sections at confluence areas (see Figure 5 below), modifications to improve perpendicular orientation at the channel, adjustment of discharge breaks to better represent flow addition points, revisions to cross sections at dams, additional cross-sections bounding major hydraulic structures, and revisions to n-values.

A major component of the QC process was an automated check that identified locations where the 1-percent a.c.e profile was crossed by any other frequency profile. Significant effort was made to reasonably resolve all of these instances. Another automated check identified locations where there was a drawdown of greater than 0.5 foot on the 1-percent a.c.e. water surface profile. This check is particularly useful for identifying errors in the model such as a channel that is too wide, a poorly placed cross-section, or a need for additional cross-sections. Again, significant effort was made to reasonably resolve these drawdown situations.

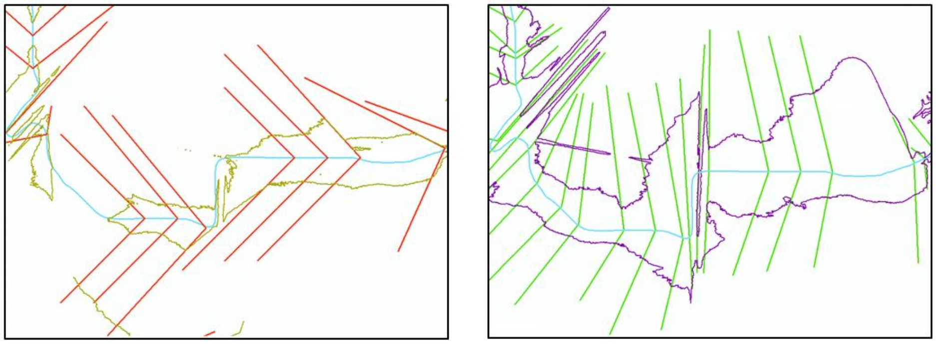

Figure 4: Default "V" angle cross-sections automated by WISE (left). Manually edited cross-sections to more accurately capture terrain (right). Resulting flood boundaries shown in gold (left) or purple (right) for clarity.

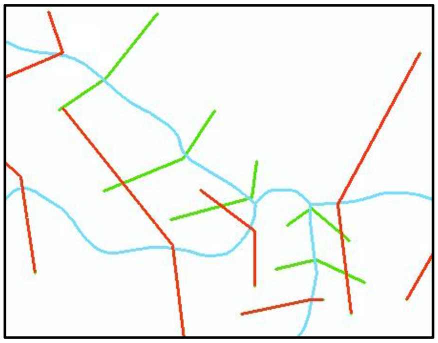

Figure 5: Manually added cross-sections (green) to improve accuracy of tie-ins at confluences.

1.5 Floodplain Delineation (10%, 1% and 0.2% events)

The 1-percent and 0.2-percent boundaries were mapped using a routine that develops water surface elevation grids based on the 10-foot cell size DEM developed from the LiDAR dataset used for this project (see Section 1.1). This product was converted to a polygon for cleaning. The cleaning routine involved manual inspection of the polygons to identify and remove areas of disconnected flooding. In general, all polygons greater than 5,000 square feet are investigated, but all polygons, including those less than 5,000 square feet that intersect the stream lines were included in the final output. This investigation was aided by the ground DEM and aerial imagery. Manual adjustments to the polygons were made to account for spillways on dams which could not be accurately modeled using HEC-RAS as well as disconnected areas along the flooding source that should reasonably be connected.

Following the removal of disconnected flooding areas and other boundary adjustments, the small islands in the floodplain were filled. In general, islands less than 2 acres were inspected and filled.

Once the island filling process was complete, the water surface raster mapping routine was run and set to conform to the polygon boundary. This ensures that the water surface raster and the floodplain boundary are consistent with each other. The depth raster product was created at the end of the process by performing a raster subtraction with the water surface elevation raster and the ground DEM.

Challenges

Area E – Sabine River (TX) is located in southeastern Texas, an area known for flat terrain. In some of the wide and flat floodplains, small tributaries run parallel to large streams. Parallel streams with shared floodplains were modeled by moving the combined discharge upstream to the cross-section that begins the shared floodplain.

A significant effort was made to achieve proper 1%-acf water surface elevation tie-ins at stream confluences. Cross-sections were manually added on the downstream end of nearly every stream, some of which traverse the receiving stream; so that the water surface elevation of the tributary would be lower than that of the receiving stream.

There are a few containment issues across the study area. In some areas the 0.2%-acf flows overtopped cross section. For these situations, additional investigation is recommended when upgrading these models for detailed study.

Coordination efforts were made with the Middle Sabine and Lake Fork BLE studies to ensure a tie-in. Incorporating the tie-ins from these watersheds may result in water surface elevation data within the modeling to be less than what is shown in the grids/floodplain results.

In Running Creek watershed, Wilson Branch had a section of the floodplain boundary overflowing into Upper Sabine HUC-8. This was resolved by clipping the final floodplain to the Lake Fork HUC-8 boundary. Because of this solution, a few cross-sections are overtopped in this area. On Running Creek, there is an area where the mapping is constrained and requires further study.

In Dry Creek Watershed, Turman Branch requires further study due to overflow. Majority of flow in AOMI area flows outside of streamline.

In Lake Fork Creek Case Lake Watershed, UNT 118 in LFCCL Watershed requires further study due to overflow. Stream has overflow outside the streamline that will require further study.

Results and Recommendations

The BLE results for this study produced an SFHA that compares favorably with the effective SFHA. These boundaries provide an estimated SFHA in areas that have not been previously studied and therefore do not currently have an SFHA mapped. These results provide context for flood risk communication as part of the Discovery process, and should be verified through community work map meetings before being applied to a regulatory product.

A map showing the BLE results is included as Appendix A.

3.1 CNMS Validation of Effective Zone A SFHA

The inventory of Zone A studies (721.4 miles) in the Lake Fork Watershed were classified in CNMS with validation status of “UNVERIFIED” (508.6 miles) or “VALID” (212.8 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.

INITIAL 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 Lake Fork Watershed, the effective Zone A topographic data leveraged was based upon United States Interagency Elevation Inventory. The LiDAR sources discussed in Section 1.1 are a significant improvement from the effective Zone A topographic source for the entire study area. Therefore, all reaches failed this check.

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.

Regression equations were not used for any effective Zone A study areas located in the Lake Fork watershed and, therefore, pass this assessment check.

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 entire study area is still classified as rural, so all reaches pass this check.

All of the initial assessment results are shown in Table 5.

Table 5: 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	HUC-12 watershed does not meet urban threshold

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. All Zone A studies within the Lake Fork Watershed are not model-backed studies and, therefore, fail this check.

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

Comparison results for these streams were grouped at the HUC-12 level and are summarized in Table 6 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 6: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Lake Fork Watershed	All Streams	36,425	6,903	29,522	81%	FAIL	
Arr Branch-Lake Fork Creek	120100030102	2,375	773	1,602	67%	Fail	27.0
Black Creek-Lake Fork Creek	120100030305	1,427	301	1,126	79%	Fail	18.3
Board Branch-Case Lake	120100030201	1,247	281	966	77%	Fail	15.8
Brier Branch-Case Lake	120100030202	1,369	264	1,105	81%	Fail	13.6
Dry Creek-Running Creek	120100030203	1,218	148	1,070	88%	Pass	6.1
Gideon Creek-Case Lake	120100030106	2,925	476	2,449	84%	Fail	11.6
Glade Branch-Dry Creek	120100030301	1,647	334	1,313	80%	Fail	16.1
Glade Creek-Lake Fork Creek	120100030303	3,037	648	2,389	79%	Fail	17.2
Hughes Creek-Turkey Creek	120100030101	2,865	708	2,157	75%	Fail	19.8
Ishmeal Branch-Elm Creek	120100030105	1,249	265	984	79%	Fail	15.8
Lake Fork Creek-Case Lake	120100030103	2,189	308	1,881	86%	Pass	12.7
Little Dry Creek-Dry Creek	120100030302	2,014	313	1,701	84%	Fail	10.6
Long Branch-Case Lake	120100030205	1,683	267	1,416	84%	Fail	8.5
Mill Race-Lake Fork Creek	120100030304	3,304	595	2,709	82%	Fail	14.9
Penson Spring Branch-Case	120100030107	2,039	311	1,728	85%	Pass	13.2
Reddig Creek-Big Creek	120100030104	3,117	608	2,509	80%	Fail	15.5
Williams Creek-Case Lake	120100030204	2,720	303	2,417	89%	Pass	9.0

VALIDATION RESULTS

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Lake Fork Watershed has been updated as summarized in Table 7 and illustrated in Figure 6 below.

Table 7: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	212.8
UNVERIFIED	BEING STUDIED	508.6

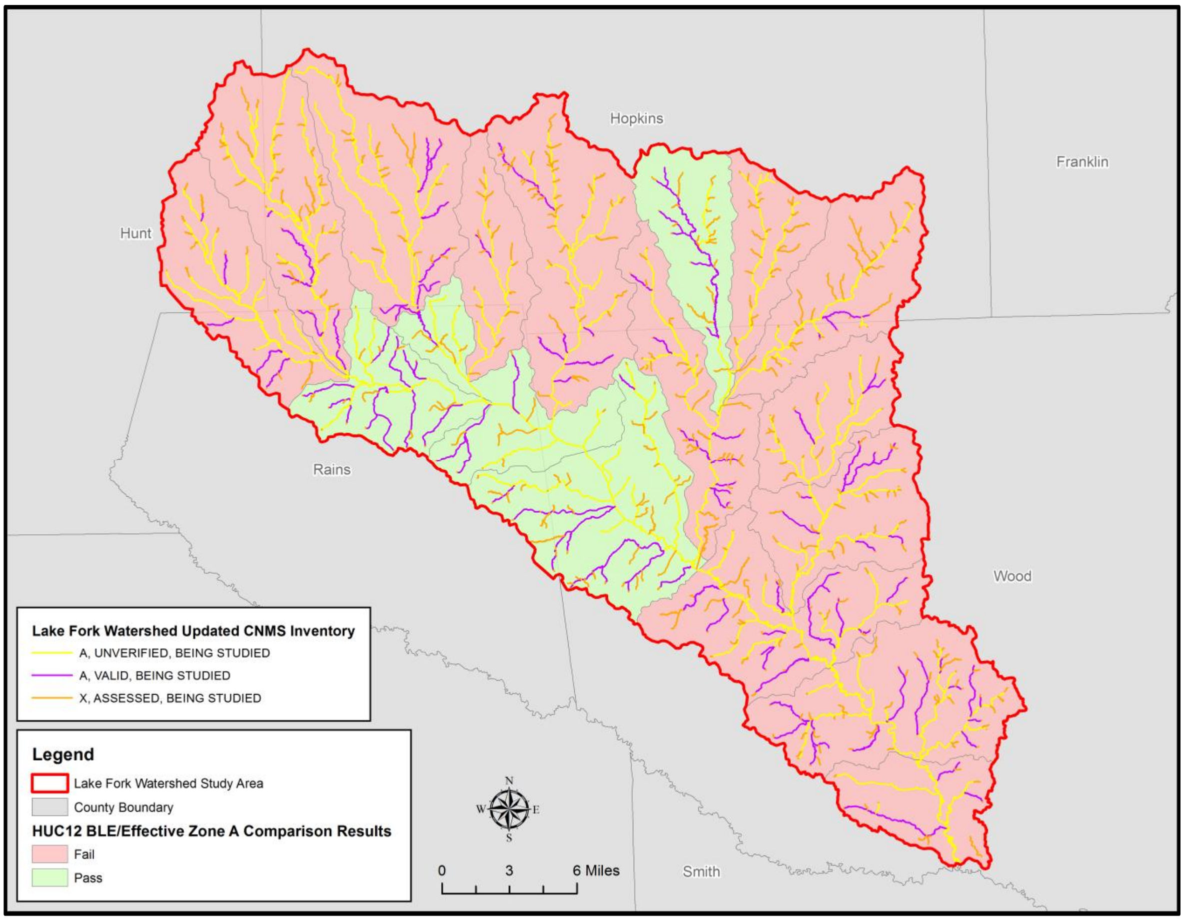

Figure 6: Lake Fork Watershed CNMS Validation Results

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

Arr Branch-Lake Fork Creek HUC-12 was determined to have the highest priority score and the most need while Dry Creek-Running Creek HUC-12 had the lowest scores.

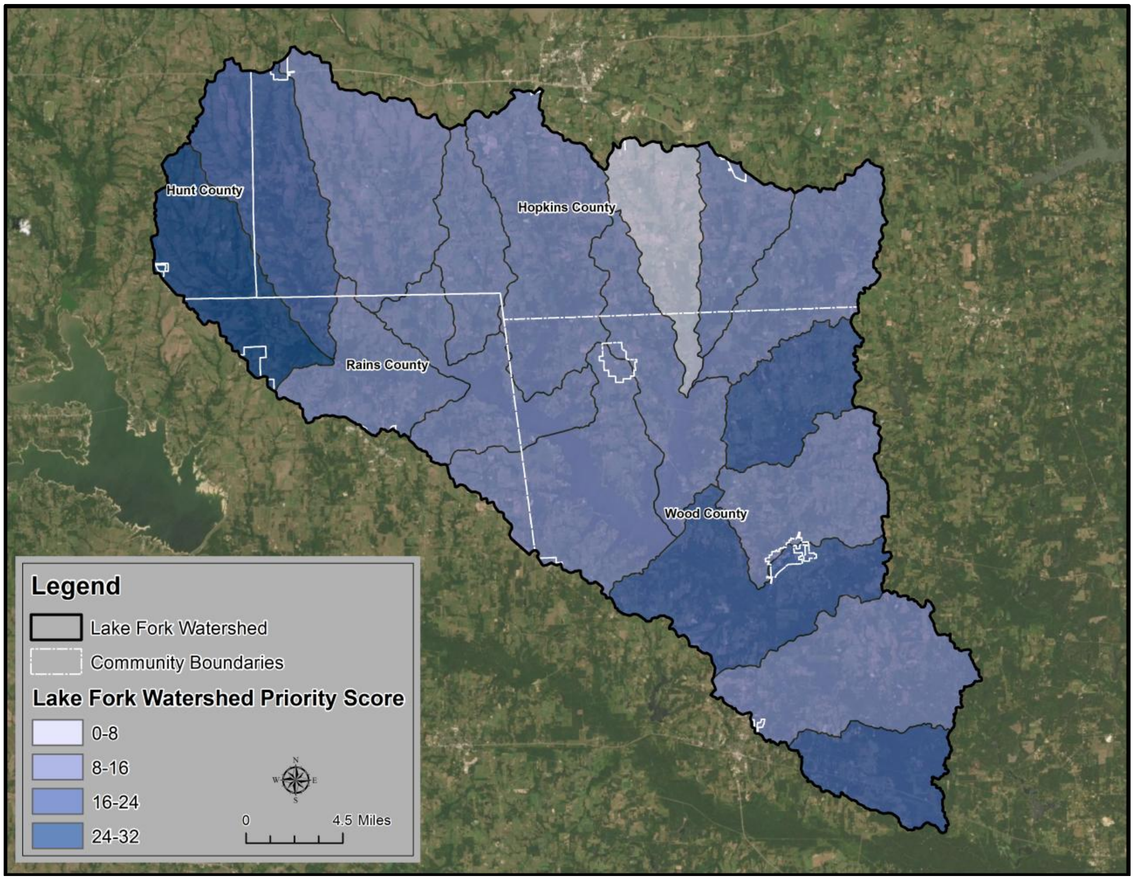

Figure 7: Ranking of Lake Fork Watershed HUC-12s

3.2 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1% annual chance and 0.2% 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 4.2 (SP03) 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 (SP03) 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 8.

Table 8: Hazus 4.2 (SP03) Results for 1-Percent-Annual-Chance (100 year) Scenario

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Hopkins	13,501,000	768,950,000	484,150,000
Hunt	2,637,000	131,166,000	77,548,000
Rains	6,757,000	412,890,000	226,937,000
Wood	36,309,000	1,611,556,000	956,462,000
Total	59,204,000	2,924,562,000	1,745,097,000

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Appendix A BLE Map