# Little Watershed, TX
# Base Level Engineering (BLE) Results

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## APPROVALS

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# Table of Contents

# Executive Summary

FEMA Region VI contracted Compass to complete a Base Level Engineering (BLE) analysis for the Little HUC-8 in Central Texas, to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). 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 5.0.5 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 | Little Stream Miles |
|---|---|
| CNMS | 317.8 |

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 | 0 |
| UNVERIFIED | BEING STUDIED | 317.8 |

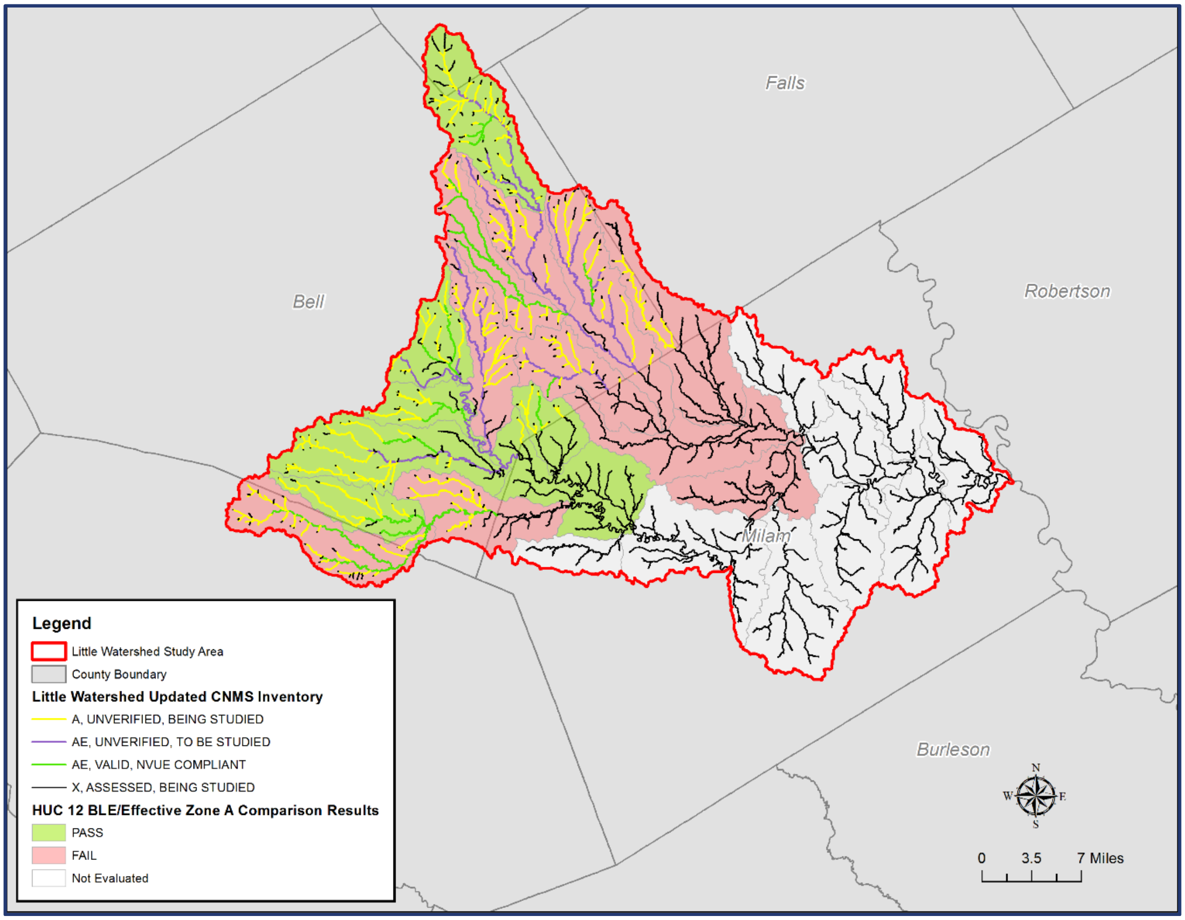


**Figure ES-1: Little Watershed CNMS Validation Results**

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 Little HUC-8 priority scores which can be used to initiate discussions during the Discovery phase.

North Elm Creek HUC-12 was determined to have the highest priority score and the most need while Boggy Creek-Little River HUC-12 had the lowest scores.

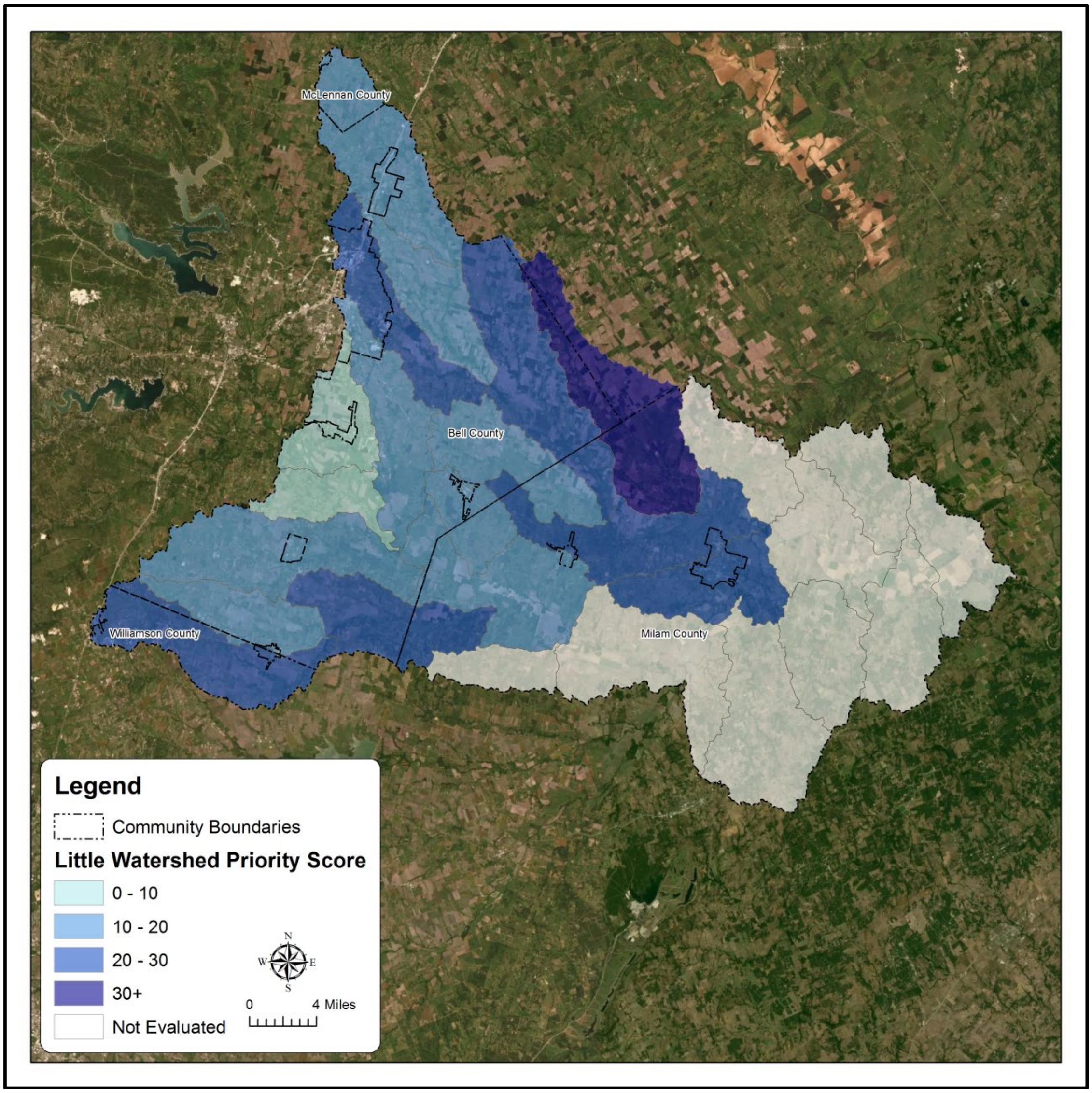


Figure ES-2: Ranking of Little Watershed HUC-12s

# 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 VI contracted Compass to complete a BLE analysis for the Little Watershed in Central Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Bell, Falls, McLennan, Milam, Robertson, and Williamson Counties, and include the following communities: the Cities of Bartlett, Cameron, Jerrell, Little River-Academy, Milano, Moody, Rockdale, Temple, and Troy, and the Towns of Buckholts, Holland, and Rogers. The study area consists of three HUC-10 basins: Big Elm Creek, Lower Little River, and Upper Little River. Figure 1 shows the orientation of the Little HUC-10 basins with respect to the counties.

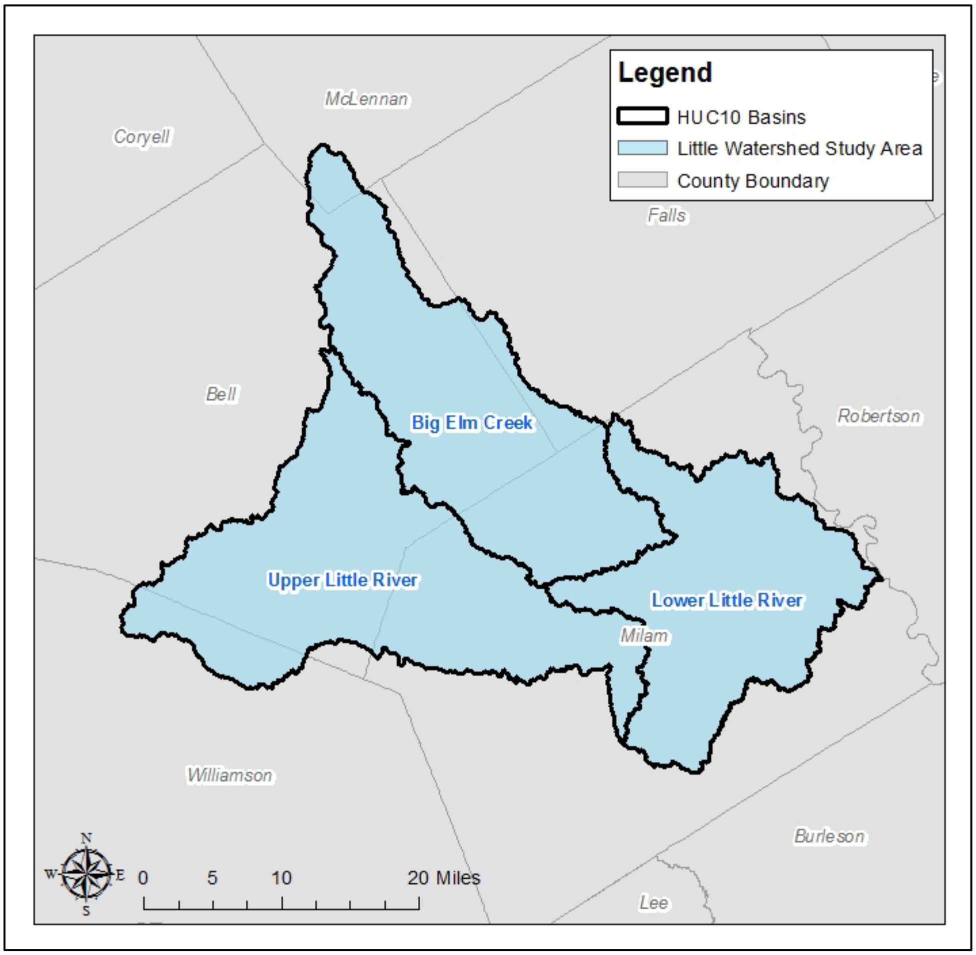


**Figure 1: Little Watershed HUC-10 Basins**

AECOM studied approximately 1,285 miles of stream reaches within the Little 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 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 the Little Watershed.

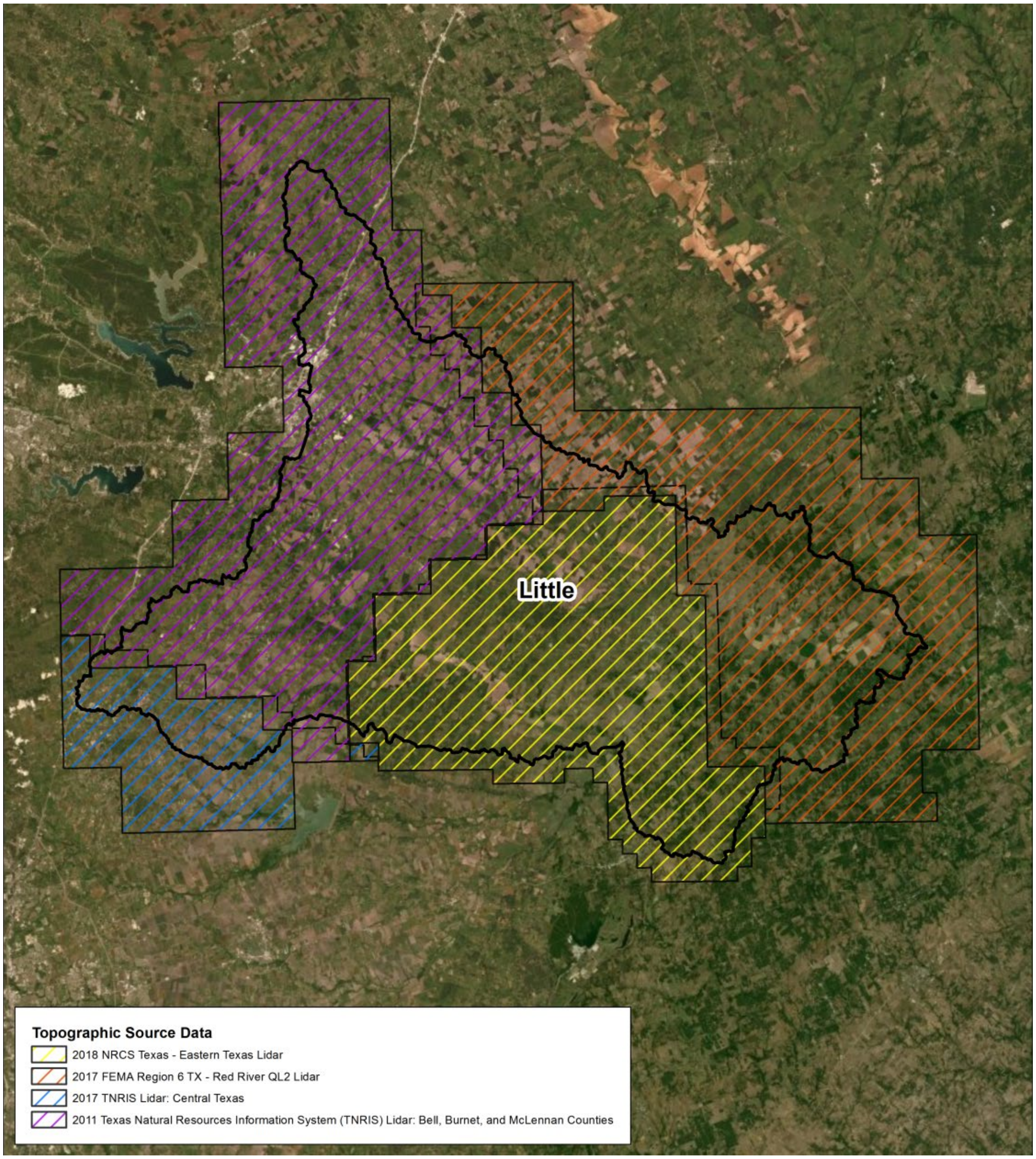


**Figure 2: Extent of LiDAR Data for Little Watershed**

### 1.1.1 Source Terrain Data

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

#### 1.1.1.1 2018 NRCS Texas – Eastern Texas LiDAR

The USGS LiDAR project covers Leon, Washington, Sabine, San Jacinto, Shelby, Grimes, Lee, Madison, Milam, Trinity, and Newton Counties. The acquisition was conducted from March 6, 2018 to March 21, 2018. Data was collected and processed by Digital Aerial Solutions (DAS), LLC.

LiDAR acquired from this project will be used for floodplain management and planning, feature extraction, water quality modeling, stream restoration potential analysis, change detection, 9-1-1, wildfire mitigation, habitat identification/modeling for endangered species, and hurricane recovery projects.

Further details regarding this acquisition can be found by downloading the USGS 2018 South Central Project Reports.

#### 1.1.1.2 2017 Texas Natural Resources Information System (TNRIS) LiDAR: Central Texas

The project was managed by the Texas Strategic Mapping (StratMap) Program and utilized the StratMap Contracts held by the Department of Information Resources (DIR). Collection took place January 28, 2017, through March 22, 2017. Data was collected and processed by Fugro EarthData, Inc. with third party quality assurance/quality control performed by AECOM.

LiDAR acquired from this project will be used for floodplain management and planning, feature extraction, water quality modeling, stream restoration potential analysis, change detection, 9-1-1, wildfire mitigation, habitat identification/modeling for endangered species, and dam safety. The project area of interest covers areas where previous LiDAR acquisition did not meet USGS Quality level 2 data specifications.

Further details regarding this acquisition can be found by downloading the USGS

#### 1.1.1.3 2017 FEMA Region 6 TX – Red River QL2 LiDAR

The USGS LiDAR project covers Brazos, McLennan, Freestone, Washington, Falls, Grimes, Navarro, Milam, Limestone, Hill, Robertson, and Burleson Counties. The project was developed to create a consistent and accurate surface elevation dataset for the USGS FEMA Region VI Red River, Texas Project Area. DAS collected and processed data for the project. Dewberry served as the prime contractor for the project and was responsible for LAS classification, all LiDAR products, breakline productions, DEM production, and quality assurance.

LiDAR acquired from this project will be used for floodplain management and planning, feature extraction, water quality modeling, stream restoration potential analysis, change detection, 9-1-1, wildfire mitigation, habitat identification/modeling for endangered species, and hurricane recovery projects.

#### 1.1.1.4 2011 TNRIS LiDAR: Bell, Burnet, and McLennan Counties

The Photo Science, Inc. acquisition team collected LiDAR covering the project area from March 11, 2011 to July 31, 2011. The collection was made possible with funding from TNRIS, USGS, and the Central Texas Council of Governments (CTCOG). This project was coordinated by the TNRIS StratMap Program and used the Council on Competitive Government's High Priority Imagery and Datasets (HPIDS) contract.

### 1.1.2 Terrain Data Processing

The LiDAR data were processed in Environmental System Research Institute (ESRI) ArcGIS software to create a composite 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 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.

For the Little Watershed, the 2018 South Central Texas LiDAR was the highest priority, with the 2017 Central Texas LiDAR prioritized second, the 2013 TNRIS Ellis Navarro LiDAR prioritized third, the 2010 Bexar County LiDAR fourth and the 2009 Goliad, McMullen, & Zapata Counties LiDAR prioritized fifth. These datasets were used as the data sources for creating the 10-ft and 50-ft DEMs.

The DEMs created from the LiDAR datasets mentioned above were compiled in order of vertical accuracy into a mosaic dataset using ArcGIS. From this mosaic, a tile index was created for the project area and the mosaic was clipped into 50,000-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 in the DEM. The DEM surface model was affirmed to be suitable for hydraulic takeoffs and supporting other hydraulic analyses.

After the DEM was imported, an additional 50-foot DEM was created from the same mosaic and tile index used for the 10-foot DEM. This 50-foot DEM was used for hydro enforcement of the project areas. Proprietary software was used to identify natural sinks, peaks and flat areas in the 50-foot DEM surface. Elevations of the cells in the DEM were algorithmically calculated and the best path to route flow was determined without filling sinks in the DEM. Once all calculations were completed, the flow was checked confirming that all drainage flowed downstream correctly and routed to outside of the project area.

Stream centerlines were manually digitized using the 10-foot DEMs as a source for horizontal alignment and vertical elevation. These stream centerlines are created for use in the hydraulic analysis, hydro-enforcement of the 50-foot DEMs, and visual reference on the FIRM products. Several routines were then used to take localized elevations from the source topographic data and apply them to the stream centerlines. This gave the stream centerline vertices elevation information along the Z axis. The resulting elevations ensure that the streams are lower in elevation than any overbank sumps. A separate routine was then used to ensure that the elevations of these vertices descend in height down to an outfall. The final stream centerline file is then "burned" into the 50-foot DEMs to force flow through structures while preventing it from jumping out of the channel banks.

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 used for hydrologic and hydraulic analyses and floodplain mapping activities are sufficient for BLE analysis.

## 1.2 Hydrology

Flood discharges for this study were calculated using both the 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. USGS Peak FQ Version 7.3 was used to perform the Flood Frequency Analysis (FFA) for the four gages within the Little Watershed (see below for further discussion).

### 1.2.1 Regression Analysis

The 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, all inputs for the USGS regression equations.

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 |
|---|---|
| $Q_{10\%}$ | $P^{1.203} \times S^{0.403} \times 10^{[0.918\Omega + 13.62 - 11.97A\wedge(-0.0289)]}$ |
| $Q_{4\%}$ | $P^{1.140} \times S^{0.446} \times 10^{[0.945\Omega + 11.79 - 9.819A\wedge(-0.0374)]}$ |
| $Q_{2\%}$ | $P^{1.105} \times S^{0.476} \times 10^{[0.961\Omega + 11.17 - 8.997A\wedge(-0.0424)]}$ |
| $Q_{1\%}$ | $P^{1.071} \times S^{0.507} \times 10^{[0.969\Omega + 10.82 - 8.448A\wedge(-0.0467)]}$ |
| $Q_{0.2\%}$ | $P^{0.988} \times S^{0.569} \times 10^{[0.976\Omega + 10.40 - 7.605A\wedge(-0.0554)]}$ |
| Variables:<br>$Q_i$, peak flow for i recurrence interval (a.c.e.), in cubic feet per second;<br>P, mean annual precipitation, in inches;<br>S, Main-channel slope (dimensionless);<br>Ω, OmegaEM parameter;<br>A, cumulative 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 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 OmegaEM 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. Basin break points were set by the user with a sub-basin target size of one square mile. This criterion was adjusted for the main stem of the Little River to avoid excessive and unnecessary discharge breaks. Break points were also set immediately upstream of stream confluences. 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 regression discharges, and those discharges were incorporated into the Hydrologic Engineering Center's River Analysis System (HEC-RAS) 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.

### 1.2.2 Stream Gage Analysis

Figure 3 shows the location of the two active USGS stream gages on the Little River mainstem used to develop mainstem discharges for Little River, and two gages on the tributaries were used to develop weighted discharges for tributaries in the study (Table 2). FFA were performed for eligible gages, according to USGS Bulletin 17C guidelines.

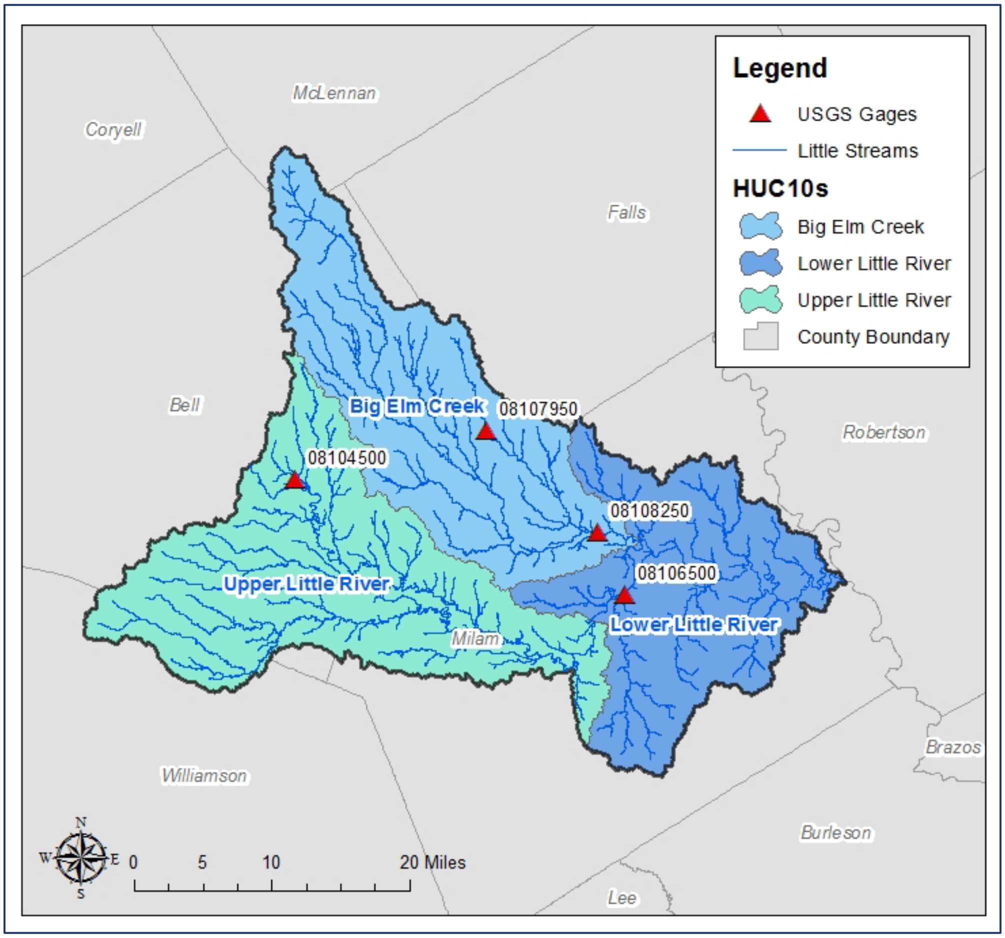


Figure 3: Locations of USGS Gages Utilized in Flood Frequency Analysis

Table 2: USGS Stream Gages in Little Watershed

| Gage ID | Flooding Source and Location | Computed Drainage Area (mi.$^2$) | Published Drainage Area (mi.$^2$) | Period of Record |
|---|---|---|---|---|
| 08104500 | Little River near Little River, TX | 5,228 | 5,228 | 1921-present |
| 08106500 | Little River near Cameron, TX | 7,065 | 7,065 | 1852-present |
| 08107950 | North Elm Creek at Rosebud Rd near Meeks, TX | 15.9 | 15.9 | 2011-2018 |
| 08108250 | Big Elm Creek at SH 77 near Cameron, TX | 315.2 | 314 | 2008-present |

The flood frequency data from these gages were weighted with the regression derived discharges using the procedure described in SIR 2009-5087. Adjusted discharges were held constant if the adjustment resulted in flows decreasing in the downstream direction.

Gage variances for each storm event were used to develop weighted discharges. These variances are provided in Table 3. Weighted discharges were adjusted using a gage adjustment factor developed from a comparison between the rural and gage discharges and rounded to determine final discharges. Final discharges for the Little River estimated by gage analysis adjustment, and used in the final BLE hydraulic models, are presented in Table 4.

**Table 3: Summary of Gage Variances Used**

| Gage ID | Variance | | | | |
|---|---|---|---|---|---|
| | 10PCT | 4PCT | 2PCT | 1PCT | 0.2PCT |
| 08104500 | 0.004 | 0.0069 | 0.0103 | 0.0147 | 0.0291 |
| 08106500 | 0.0036 | 0.0059 | 0.0086 | 0.0122 | 0.0242 |
| 08107950 | 0.0398 | 0.0539 | 0.0668 | 0.0812 | 0.1203 |
| 08108250 | 0.0042 | 0.0065 | 0.0087 | 0.0111 | 0.0175 |

The two mainstem gages, 08104500 (Little River near Little River, TX) and 08106500 (Little River near Cameron, TX), have been regulated by Belton Lake since 1954, and by Stillhouse Hollow Lake since 1968. Accordingly, the gage Flood Frequency Analysis (FFA) for these two gages only used the regulated period of records. The flows computed for the regulated period are significantly lower than the effective flows for Bell County that were used as upstream discharge boundary. According to the effective Bell County FIS, it appears that the effective flows for the Little River were developed using a rainfall-runoff model that did not reference the gage 08104500. The flows used for the BLE study of Little River mainsteam were based on the FFA using the regulated period of records.

The discharges for the reaches between gages were calculated using the flowing equation.

$$Q_{ungaged} = Q_{USgage}\ x10\text{^}(((\log(DA_{ungage})-\log(DA_{USgage}))*(\log(Q_{DSgage})-\log(Q_{USgage}))/(\log(DA_{DSgage})-\log(DA_{USgaged}))).$$

**Table 4: Final Adjusted Discharges at USGS Stream Gages in Little Watershed**

| Gage ID | 10PCT (cfs) | 4PCT (cfs) | 2PCT (cfs) | 1PCT (cfs) | 0.2PCT (cfs) |
|---|---|---|---|---|---|
| 08104500 | 26,500 | 38,900 | 50,000 | 63,000 | 101,300 |
| 08106500 | 60,800 | 89,200 | 113,600 | 140,500 | 213,400 |
| 08107950 | 3,820 | 5,850 | 7,670 | 9,780 | 15,900 |
| 08108250 | 22,100 | 31,900 | 40,500 | 50,200 | 76,700 |

## 1.3 Hydraulics

The hydraulic approach for this BLE analysis of the Little 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. HEC-RAS program version 5.0.5 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 ArcGIS 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 5. These default values for dimensions and spacing were subject to change based on engineering judgment.

**Table 5: Cross-Section Default Parameters**

| Drainage area (upper limit) | XS Spacing | Channel Top Width | Channel Bottom Width | Channel Depth |
|---|---|---|---|---|
| 1 | 300 | 7 | 6 | 0.8 |
| 2 | 300 | 8 | 7 | 0.8 |
| 4 | 300 | 11 | 10 | 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 |

| Drainage area (upper limit) | XS Spacing | Channel Top Width | Channel Bottom Width | Channel Depth |
|---|---|---|---|---|
| 100 | 750 | 33 | 20 | 1 |
| 150 | 750 | 36 | 21 | 1 |
| 250 | 1000 | 38 | 22 | 2 |
| 500 | 1500 | 40 | 23 | 2 |
| 1000 | 2500 | 100 | 50 | 3 |
| 2000 | 2500 | 150 | 75 | 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 6. 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 6: 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 downstream 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.

## 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.

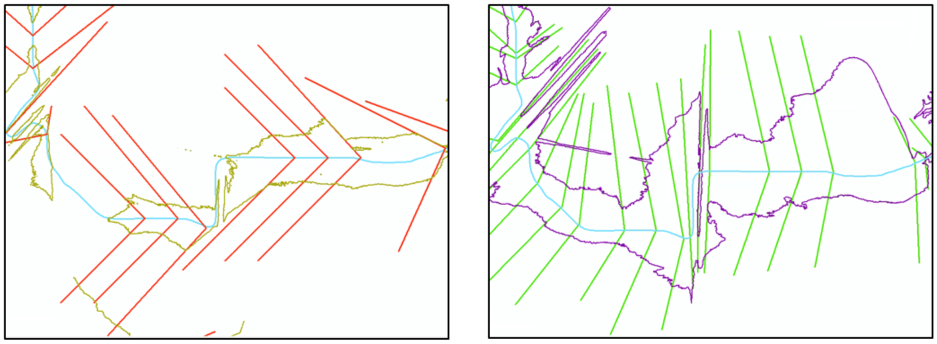

**Figure 4: Default "V" angle cross-sections automated by WISE (left). Manually edited cross-sections to more accurately capture terrain (right). Resulting flood boundaries shown in gold (left) or purple (right) for clarity.**

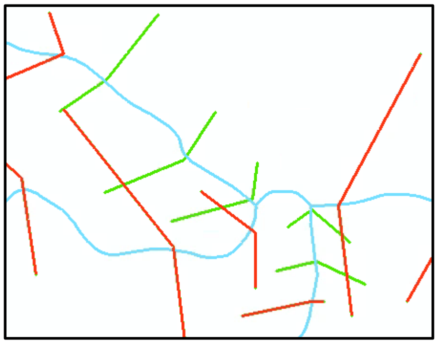

Figure 5: Manually added cross-sections (green) to improve accuracy of tie-ins at confluences.

### 1.5 One-percent Special Flood Hazard Area Delineation

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 line are 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 20,000 square feet 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

Several streams in the Lower Little River watershed required iterative n-value manipulation in order to achieve proper tie-ins. In general, stream centerlines in the watershed need further study. There were several instances in which sizable portions of stream centerline were altered to be within mapping. In particular, UNT 077, UNT 070, UNT 006, Davidson Creek Tributary 2, and East Pin Oak Creek stream centerlines should be reviewed more in-depth. In addition, due to presence of low lying area between cross sections and a few cross sections being over-topped in streams like Maysfield Creek, UNT 060 in Lower Little River Watershed and UNT 070 in Lower Little River Watershed further detailed study is suggested.

In the Big Elm Creek HUC10 watershed, UNT 351 in Little Watershed needs further details study to verify its alignment and the potential overflow between Pecan Creek and UNT 351. A potential over-topping between South Elm Creek and UNT 038 in Little Watershed nearby the upstream of the UNT 038 stream needs further details study. A low-lying area noted into the AOMI between Camp Creek and Salt Creek require further study for split flow and overtopping. Also, UNT 002 in Little Watershed needs details study due to flat-slope surface in some areas.

In Upper Little River watershed, a few cross sections for Dry Hollow were clipped at higher elevation along the mainstem. Due to presence of low lying areas between the cross sections mapping gets clipped, thus suggesting a need for more in depth analysis.
Furthermore, at a point where Knob Creek bifurcates to a diversion channel we were not able to contain the mapping within bounds of the cross sections so a further detailed study is recommended.

In the Lower Little watershed, the downstream XSs of UNT 061 in Lwrr Little Rv Watershed were unable to contain the 500YR. Cross-sections were clipped to the basin extent and further analysis is suggested on these streams.

# Results and Recommendations

The BLE results for this study produced an SFHA that conforms to the existing topography and compares favorably with the effective SFHA. These boundaries provide an approximate 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 (317.8 miles) in the Little Watershed were classified in CNMS with validation status of "UNVERIFIED" or "VALID" 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 Little Watershed, LiDAR was not available at the time of the effective analyses except for a single reach in Williamson County updated by a Letter of Map Revision (LOMR), which utilized LiDAR data. The LiDAR sources discussed in section 1.1 are a significant improvement from the effective Zone A topographic sources for the majority of the study area. Therefore, all reaches except the single LOMR reach in Williamson County 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 used only for the effective Zone A studies in McLennan County. Therefore, all other reaches passed this check because regression was not used for their studies. The reaches in McLennan County failed this check because new equations (SIR 2009-5187) have been published since those used in the effective study. A comparison of the equations to determine the significance of the change affecting the 1-percent annual chance flow because the effective equations used are significantly older.

### 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 7.

**Table 7: Zone A Initial Assessment Results**

| Assessment Check | Pass / Fail | Notes |
|---|---|---|
| A1 – Topography | Fail/Pass | LiDAR sources available are a significant improvement from effective topography/Effective study used LiDAR data |
| A2 – Hydrology | Pass/Fail | Regression equations not used in effective study/New regression equations have been published since those used in the 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. Four reaches in Bell and Williamson Counties were updated as part of LOMRs and are model-backed studies, therefore, they pass this check. All other reaches within the Little HUC-8 Watershed are not model-backed and 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 Little 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 8 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 they are marked as "Fail".

Table 8: BLE Comparison Results

| HUC-12 Watershed | | Total FBS points | Fail | Pass | %Pass | BLE Comparison Pass? (>85%) | Priority Score |
|---|---|---|---|---|---|---|---|
| Watershed Name | Watershed Number | | | | | | |
| Little Watershed | All Streams | 14,393 | 3,047 | 11,346 | 79% | FAIL | |
| Bear Creek-Little River | 12070204030 | 69 | 22 | 47 | 68% | FAIL | 22.4 |
| Boggy Creek-Little River | 12070204010 | 827 | 78 | 749 | 91% | PASS | 6.1 |
| Camp Creek-Big Elm Creek | 12070204020 | 1,218 | 312 | 906 | 74% | FAIL | 21.7 |
| Cottonwood Creek-Big Elm | 12070204020 | 893 | 239 | 654 | 73% | FAIL | 17.4 |
| Cutoff Slough-Little River | 12070204011 | 100 | 15 | 85 | 85% | PASS | 12.0 |
| Darrs Creek | 12070204010 | 1,804 | 241 | 1,563 | 87% | PASS | 10.6 |
| Knob Creek | 12070204010 | 1,478 | 254 | 1,224 | 83% | FAIL | 14.4 |
| Lipan Creek-Big Elm Creek | 12070204020 | 15 | 4 | 11 | 73% | FAIL | 21.3 |
| Little Elm Creek | 12070204020 | 579 | 182 | 397 | 69% | FAIL | 24.9 |
| Lower Donahoe Creek | 12070204010 | 985 | 269 | 716 | 73% | FAIL | 23.6 |
| North Elm Creek | 12070204020 | 827 | 374 | 453 | 55% | FAIL | 31.5 |
| North Fork Indian Creek-Indian | 12070204010 | 895 | 126 | 769 | 86% | PASS | 11.8 |
| Pecan Creek-Big Elm Creek | 12070204020 | 963 | 176 | 787 | 82% | PASS | 18.7 |
| Runnells Creek-Little River | 12070204010 | 732 | 70 | 662 | 90% | PASS | 9.4 |
| South Elm Creek | 12070204020 | 602 | 155 | 447 | 74% | FAIL | 20.0 |
| Sypert Branch | 12070204010 | 458 | 69 | 389 | 85% | PASS | 12.3 |
| Upper Donahoe Creek | 12070204010 | 1948 | 461 | 1487 | 76% | FAIL | 21.6 |

## VALIDATION RESULTS

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Little Watershed has been updated as summarized in Table 9 and illustrated in Figure 6 below.

Table 9: Zone A Validation Results

| Validation Status | Status Type | Total Miles |
|---|---|---|
| VALID | BEING STUDIED | 0 |
| UNVERIFIED | BEING STUDIED | 317.8 |

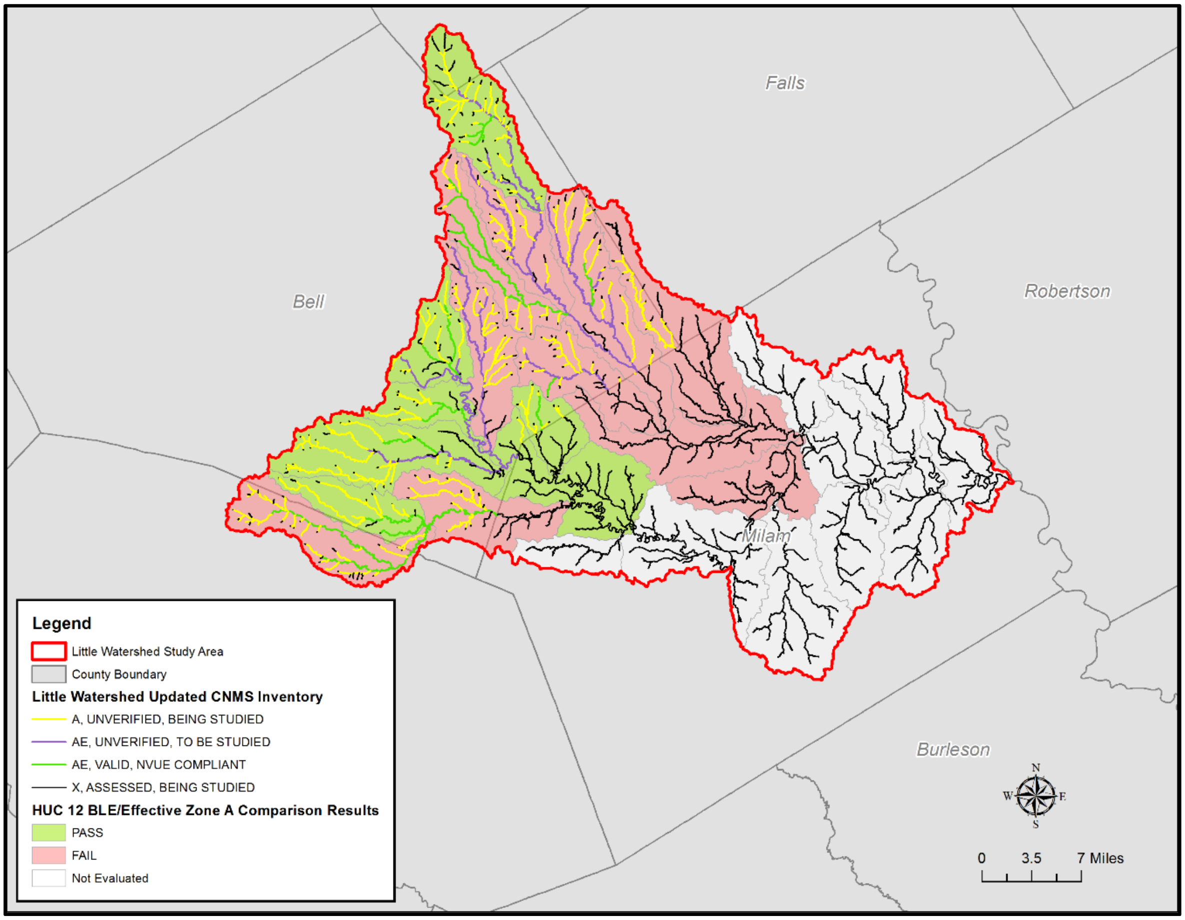


**Figure 6: Little Watershed CNMS Validation Results**

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.

North Elm Creek HUC-12 was determined to have the highest priority score and the most need while Boggy Creek-Little River HUC-12 had the lowest scores.

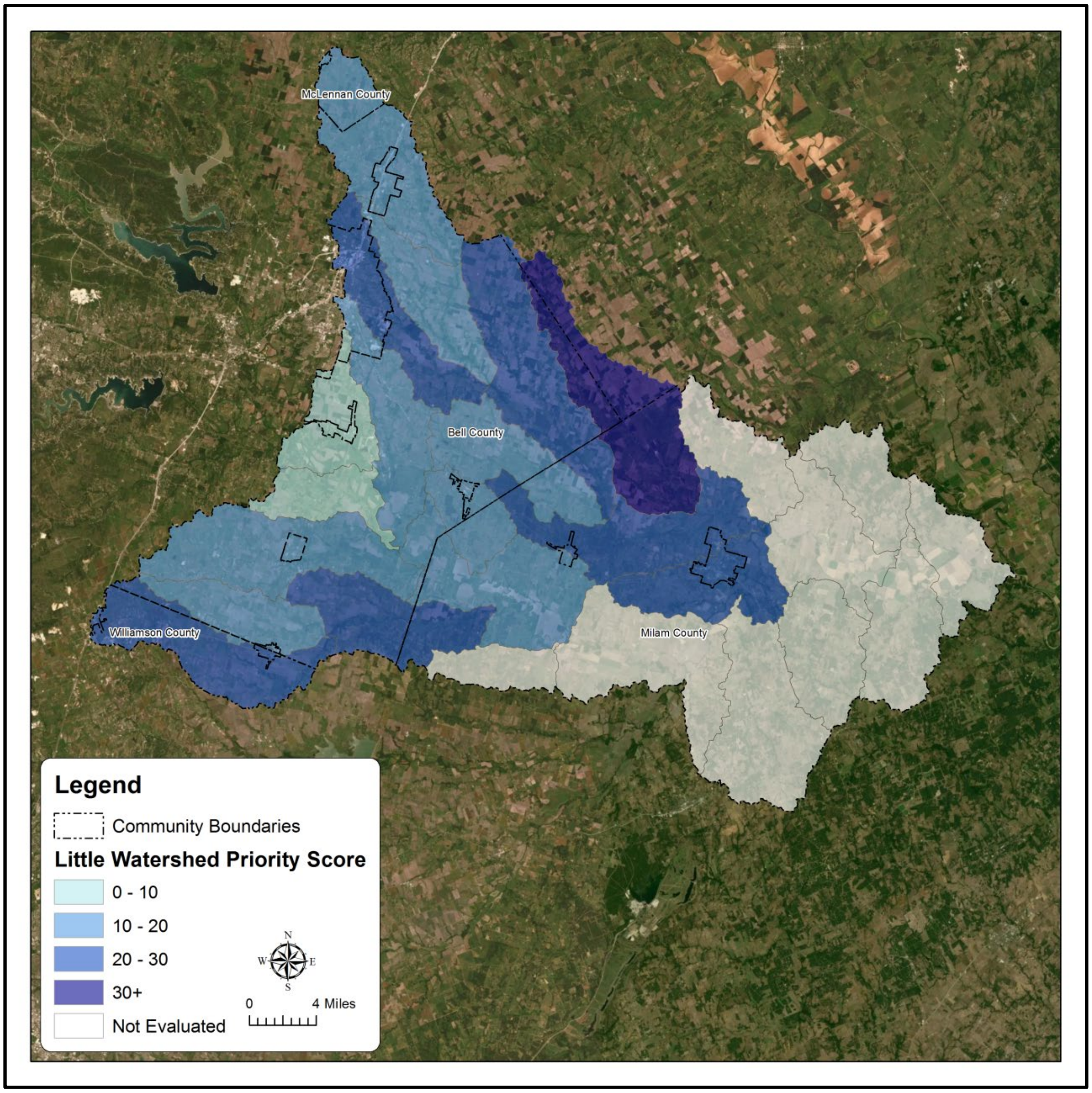


Figure 7: Ranking of Little Watershed HUC-12s

## 3.2 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 reporting 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.

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# Appendix A BLE Map