Cedar Watershed, TX
Base Level Engineering (BLE) Results

September 2017

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DOCUMENT HISTORY

CEDAR WATERSHED

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APPROVALS

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Project Manager	April Smith	512.457.7818	Project Manager	September 24, 2017	September 24, 2017

CLIENT DISTRIBUTION

Name	Title/Organization	Location
Halff Associates	Prime Consultant	Via FTP

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Executive Summary

North Central Texas Council of Government (NCTCOG) contracted AECOM, through Halff Associates' prime contract, to complete a Base Level Engineering (BLE) analysis for the Cedar HUC-8 watershed in North Central Texas, to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). The BLE process involves using best available data and incorporating automated techniques with 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 United States Geological Survey (USGS) regression equations and gage analyses, where stream gages with sufficient records 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) were used. PeakFQ version 7.1 was used to perform Flood Frequency Analysis (FFA) for the two gages along Cedar Creek.

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 4.1 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 stream miles associated with this validation analysis.

Table ES - 1: Summary of Stream Miles

Source	Cedar Stream Miles
CNMS	1,345.6
Total	**1,345.6**

The full inventory of Zone A studies in Cedar Watershed was 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	Cedar (miles)
VALID	BEING STUDIED	78.1
UNVERIFIED	BEING STUDIED	321.1
	TO BE STUDIED	384.6
UNKNOWN	TO BE ASSESSED	266.3
Total		1,050.1

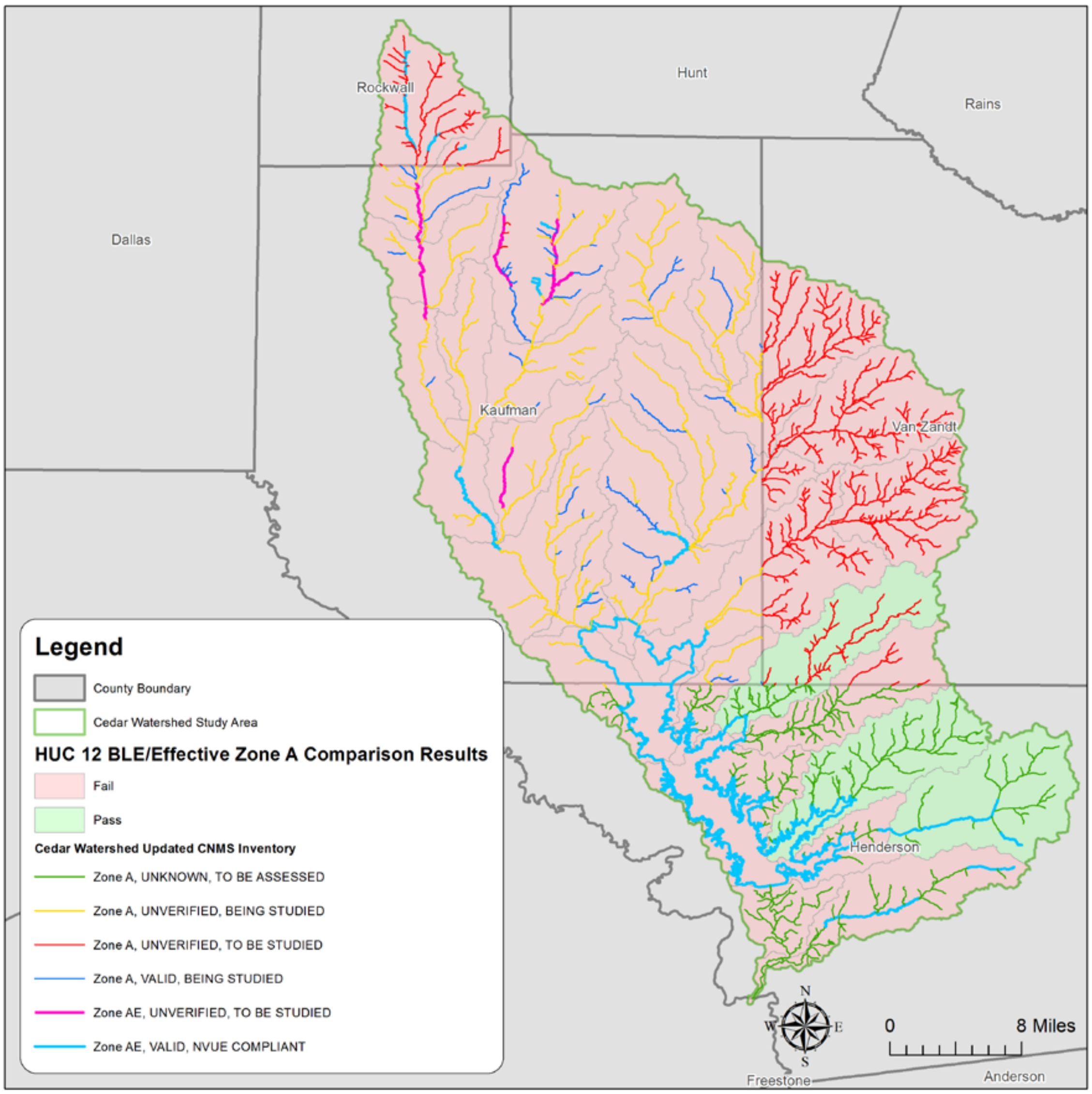

Figure ES - 1: Cedar Watershed CNMS Validation Results

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

For Cedar Watershed, Big Cottonwood Creek – Kings Creek HUC-12 was determined to have the highest priority score and the most need while Headwaters Caney Creek HUC-12 has the lowest score.

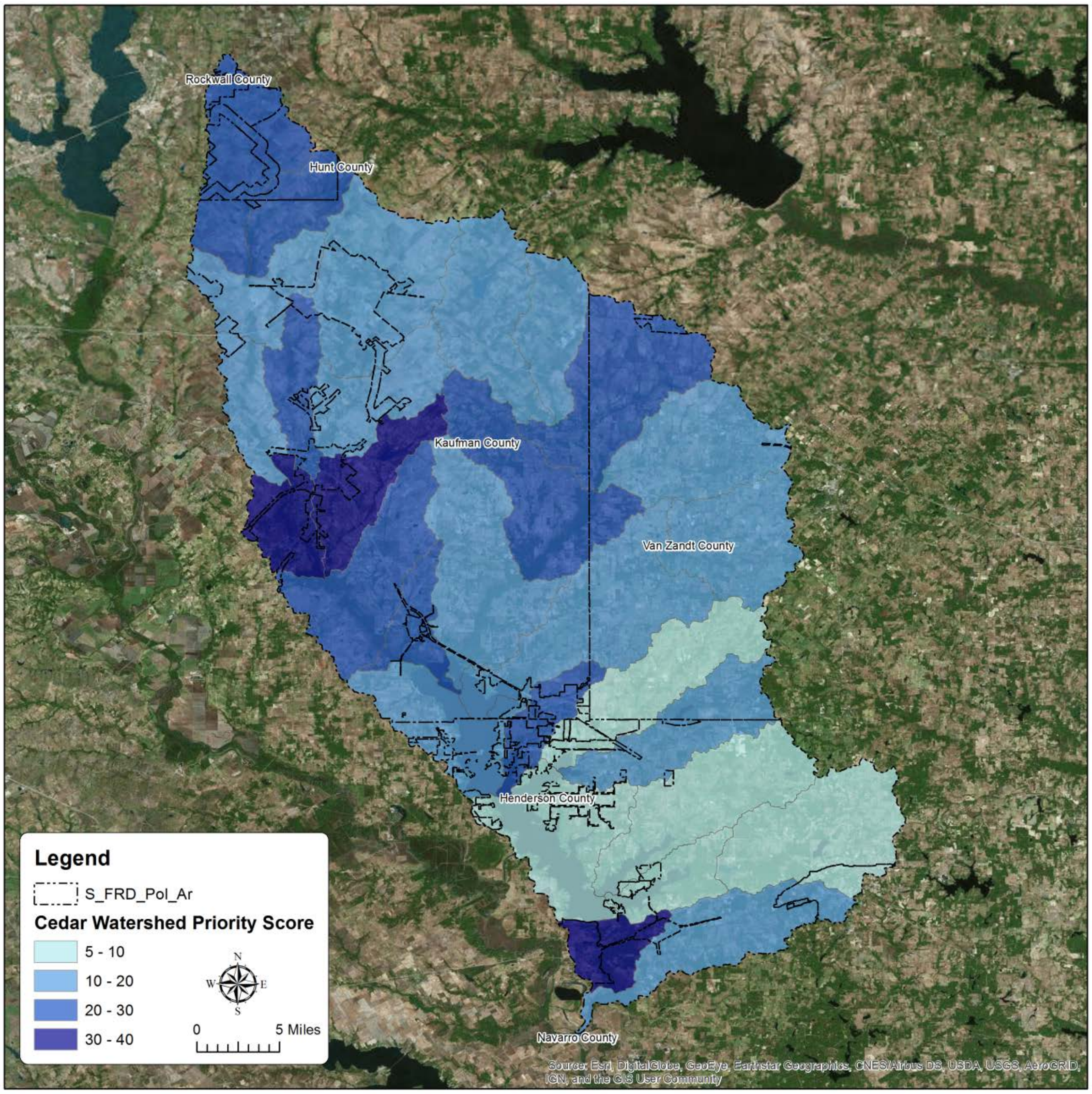

Figure ES - 2: Ranking of Cedar Watershed HUC-12s

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 floodprone 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.

North Central Texas Council of Governments (NCTCOG) contracted AECOM, through Halff Associates' prime contract, to complete a Base Level Engineering (BLE) analysis for the Cedar HUC-8 watershed in North Central Texas, to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs).

Study extents for Cedar Watershed include portions of Henderson County, Hunt County, Kaufman County, Rockwall County, Van Zandt County and include the following communities: Cities of Athens, Caney City, Canton, Eustace, Fate, Forney, Grays Prairie, Gun Barrel City, Kaufman, Kemp, Log Cabin, Mabank, Malakoff, Mclendon-chisholm, Payne Springs, Post Oak Bend, Rockwall, Scurry, Seven Points, Star Harbor, Talty, Terrell, Tool, Trinidad, and Willis Point; the Towns of Enchanted Oaks, Oak Grove and Oak Ridge. The study area consisted of three HUC-10 basins: Kings Creek – Cedar Creek Reservoir, Cedar Creek – Cedar Creek Reservoir and Cedar Creek Reservoir – Cedar Creek. Figure 1 shows the orientation of the Cedar HUC-10 basins with respect to the counties.

Figure 1: Cedar Watershed HUC-10 Basins

AECOM studied approximately 2,022 miles of stream reaches within the Cedar Watershed with a minimum drainage area tolerance of one square mile outside of population centers and one half square mile inside of population centers. Population centers were identified as having a population of greater than 1,000 people. The selection and extent of stream reaches studied was based upon the number of stream miles with minimum drainage area of one square mile (or one half 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 floodplain received an updated analysis. Topographic data used was from multiple sources was used to determine the hydrologic and hydraulic characteristics of the watershed. Topographic data used was obtained from the North Texas Council of Governments (NCTCOG), Texas Natural Resources Information System (TNRIS), and the United States Geological Survey (USGS). The following sections will summarize the BLE process and will discuss the results along with their recommended use.

1.1 Topographic Data

Documentation regarding leverage data and process including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables and text within this section. 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 available with the source dataset. Figure 2 shows the extents of the Digital Terrain Model (DTM) data used for the HUC-8 watershed studied.

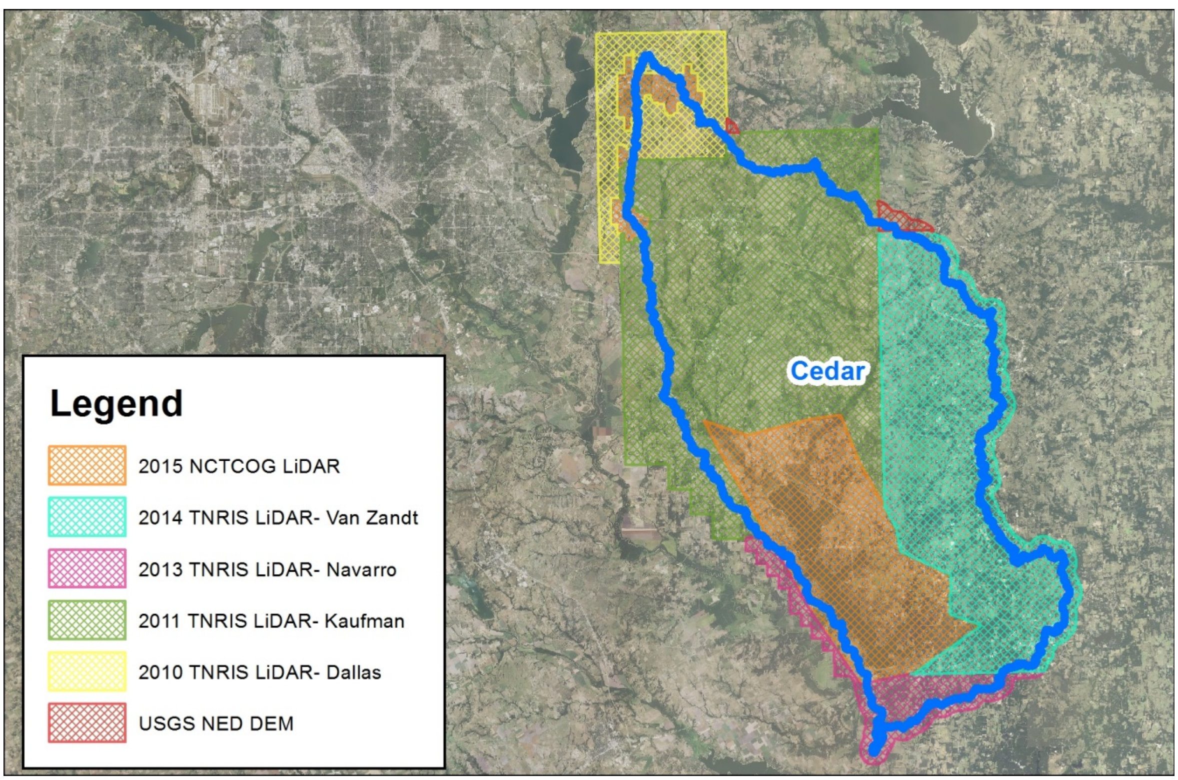

Figure 2: Extent of LiDAR Data for Cedar Watershed

1.1.1 Source Terrain Data

1.1.1.1 Cedar Watershed

1.1.1.1.1 2015 NCTCOG LiDAR

The NCTCOG Light Detection and Ranging (LiDAR) was acquired in 2015 by Woolpert Inc. The data density is 1 point per square meter (PPSM) with a 0.5 meter nominal point spacing (NPS). The data was compiled to meet 0.07 meters vertical accuracy at 95 percent confidence level which meets project accuracy specifications of the National Standard for Spatial Data Accuracy (NSSDA). This data was available as LiDAR point clouds in the American Society of Photogrammetry and Remote Sensing (ASPRS) common LiDAR Data Exchange Format (LAS 1.2).

1.1.1.1.2 2014 TNRIS LiDAR (Van Zandt County)

The TNRIS LiDAR data for Van Zandt County was acquired in 2014 by the Atkins North America team (Atkins, McKim & Creed, and Williams Aerial and Mapping Inc.). The data density is ranged from 4 PPSM to 8 PPSM with a 0.5 meter NPS. The data was compiled to meet 0.07 meters vertical accuracy at 95 percent confidence level which meets project accuracy specifications of the NSSDA. This data was available as LiDAR point clouds in the ASPRS common LiDAR Data Exchange Format (LAS 1.2).

1.1.1.1.3 2013 TNRIS LiDAR (Navarro County)

The TNRIS LiDAR data for Navarro County was acquired in 2013 by Gorrondona and Associates, Inc., Williams Aerial and Mapping, Inc., and McKim and Creed. The data density is 4 PPSM with a 0.5 meter NPS. The data was compiled to meet 0.07 meters vertical accuracy at 95 percent confidence level which meets project accuracy specifications of the NSSDA. This data was available as LiDAR point clouds in the ASPRS common LiDAR Data Exchange Format (LAS 1.2).

1.1.1.1.4 2011 TNRIS LiDAR (Kaufman County)

The TNRIS LiDAR data for Kaufman County was acquired in 2011 by Merrick & Company. The data density is 4 PPSM with a 0.5 meter NPS. The data was compiled to meet 18.5 cm vertical accuracy at 95 percent confidence level which meets project accuracy specifications of the NSSDA. This data was available as LiDAR point clouds in the ASPRS common LiDAR Data Exchange Format (LAS 1.2).

1.1.1.1.5 2010 TNRIS LiDAR (Dallas County)

The TNRIS LiDAR data for Dallas County was acquired in 2010 by Sanborn Map Company. The data density is 1 PPSM with a 1 meter NPS. The data was compiled to meet 0.07 meters vertical accuracy at 95 percent confidence level which meets project accuracy specifications of the NSSDA. This data was available as LiDAR point clouds in the ASPRS common LiDAR Data Exchange Format (LAS 1.2).

1.1.1.1.6 USGS NED DEM

The National Elevation Dataset (NED), a product of the USGS, is a seamless gridded dataset representing the best available raster elevation data available to the USGS for the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. The NED serves the Cedar Watershed topographic data development by filling in as best available data where there are gaps in the data sets listed above. This data was used to keep the project on schedule and was only used for a very small area in comparison to the overall HUC-8 watershed.

1.1.1.2 Terrain Data Processing

The Watershed Information System (WISE) software platform was utilized in order to create a digital surface model for each watershed's 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 Cedar Watershed, the 2015 NCTCOG LiDAR LiDAR was highest priority with the 2014 TNRIS LiDAR for Van Zandt County prioritized second and 2013 TNRIS LiDAR for Navarro County, 2011 TNRIS LiDAR for Kaufman County and 2010 TNRIS LiDAR for Dallas County prioritized third, fourth and fifth. Lastly the USGS NED DEM data was used as the sixth data source for areas where LiDAR did not exist.

The DEMs created from the LiDAR datasets mentioned 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 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.

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 streams. This gave the stream 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 streams file is then "burned" into the 50-foot DEMs to force flow through structures while preventing it from jumping out of the channel banks.

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 flows downstream correctly and is routed to outside of the HUC-8 basin.

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 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 USGS regression equations and gage analysis, where stream gages with sufficient records exist. 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) contains the most recent regression equations for Texas and was used as the basis for regression discharge calculations.

Table 1 shows the published equations used for 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, P represents mean annual precipitation in inches, S represents dimensionless main-channel slope, Ω represents the OmegaEM parameter, and A is cumulative drainage area in square miles.

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

Recurrence Interval	Equation[1]
$Q_{10\%}$	$P^{1.203}S^{0.403}$ x $10^{[0.918\ \Omega\ +13.62-11.97A\char`^(-0.0289)]}$
$Q_{4\%}$	$P^{1.140}S^{0.446}$ x $10^{[0.945\ \Omega\ +11.79-9.819A\char`^(-0.0374)]}$
$Q_{2\%}$	$P^{1.105}S^{0.476}$ x $10^{[0.961\ \Omega\ +11.17-8.997A\char`^(-0.0424)]}$
$Q_{1\%}$	$P^{1.071}S^{0.507}$ x $10^{[0.969\ \Omega\ +10.82-8.448A\char`^(-0.0467)]}$
$Q_{0.2\%}$	$P^{0.988}S^{0.569}$ x $10^{[0.976\ \Omega\ +10.40-7.605A\char`^(-0.0554)]}$

[1] Variables:
Q_i peak flow for i recurrence interval (a.c.e.), in cubic feet per second;
P, Mean Annual Precipitation in Inches;
S, Main-channel slope (dimensionless);
Ω, OmegaEM parameter;
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 by multiplying the $Q_{1\%}$ discharges by 0.30*log10, which is the mean residual standard error for the $Q_{1\%}$ equation.

The WISE computer program was used to delineate drainage basins in shapefile format using the 50-foot resolution DEM. Basin break points were set by the user with a sub-basin target area of one square mile in size. This criterion was adjusted for streams with larger drainage areas in order to avoid excessive and unnecessary discharge breaks. Break points were also set just 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.

WISE was used to calculate the main-channel slope for each basin. An automated routine was used to determine the longest flowpath from the headwaters of a watershed to the outlet of the point of interest based on flowpaths developed from the 50-foot DEM. Using the longest flowpath, elevations for the endpoints were determined based on the 50-foot DEM. The slope was calculated by dividing the difference in elevation with the flowpath length. The result was expressed in unit less form.

In order determine mean annual precipitation and OmegaEM values for each sub-basin, a Python script was created and run in ESRI's ArcCatalog. The script batch processed the geoprocessing needed to assign mean annual precipitation values in inches and OmegaEM values to each sub-basin.

The mean annual precipitation values were determined based on a shapefile coverage obtained from the Texas Water Development Board and available for download from the following location: http://www.twdb.texas.gov/mapping/gisdata/doc/Precipitation_Shapefile.zip

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

From USGS 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 streams that crossed multiple OmegaEM values, a weighted OmegaEM parameter was calculated and then applied on a sub-basin basis.

Additionally, the Python script used all inputs from each sub-basin and calculated the appropriate discharge values using the regression equations. The resulting discharge values were appended to the sub-basin shapefile attribute table.

Flood Frequency Analyses (FFA) were performed following Bulletin 17B guidelines, using PeakFQ version 7.1, for two gages on Cedar Creek. All gages evaluated are listed in Table 2.

Table 2: USGS Stream Gages Used in Analyses

Gage ID	Flooding Source and Location	Computed Drainage Area (mi^2)	Published Drainage Area (mi^2)	Period of Record
08062650	Cedar Creek Reservoir Spillway Outflow near Trinidad, TX	1,007.3	1,007.0	1966-1982
08062800	Cedar Creek near Kemp, TX	189.2	189.0	1963-2015

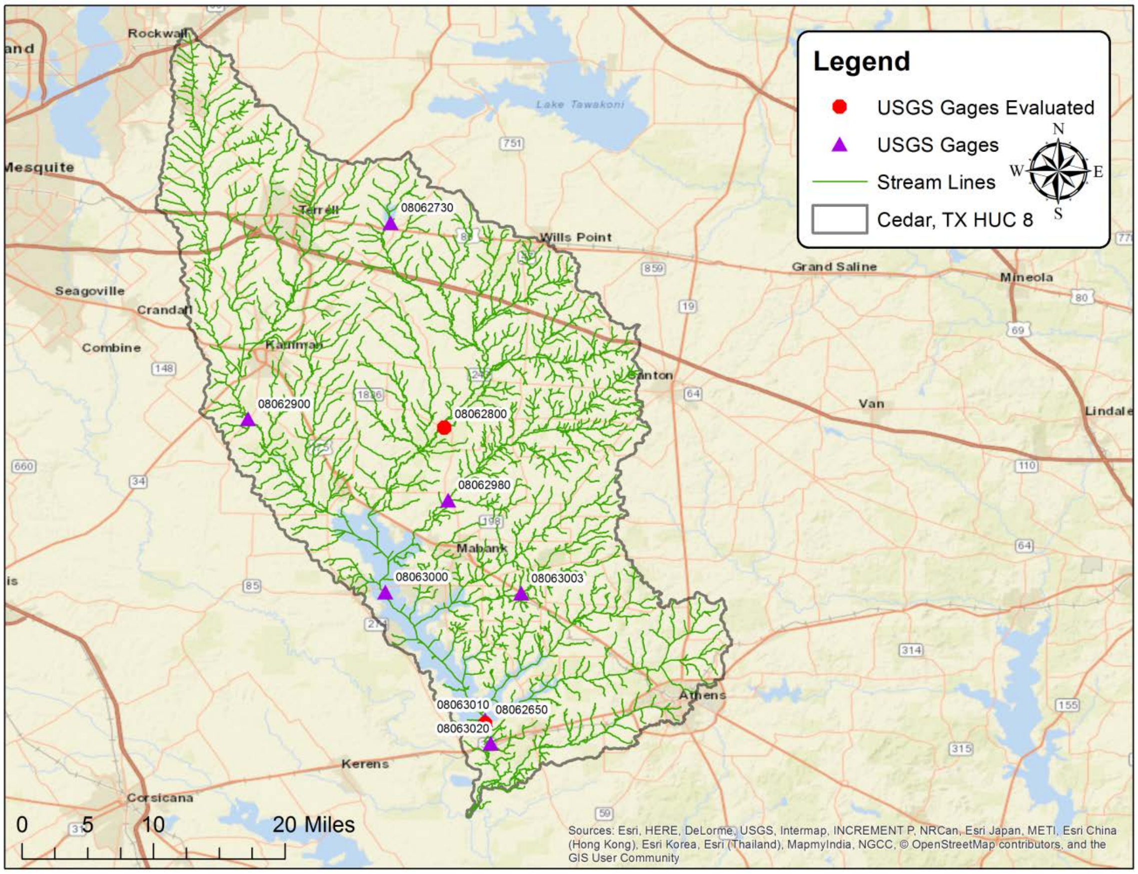

Figure 3: USGS Gage Stations within Cedar Watershed

No gage analyses were performed for Gage IDs 08063000 (Cedar Creek near Mabank, TX), 08062730 (New Terrell City Lake near Terrell, TX), 08062980 (Lacey Fork near Mabank, TX), 08063003 (South Twin Creek near Eustace, TX) or 08063020 (Cedar Creek at Trinidad, TX). The gage near Mabank was in use before the flood control structure was built in 1965 while Gage ID 08063020, and 08063003 have insignificant periods of record for peak streamflow. Gage ID 08063010, 08062980, and 08062730 are stage only gages and therefore, weren't used for discharge validation.

1.3 Hydraulics

The hydraulic approach used for this BLE analysis for the Cedar Watershed consisted of using the terrain model described in Section 1.1 in combination with hydrology input computed as described in 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 4.1 was chosen as the computer model to compute water surface elevations on a stream by stream basis. The WISE computer program was used to establish model stream orientation, initial hydraulic cross section layout and stationing, assign n-values to cross sections, and to 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 based on the 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. At this stage, a second pass inspection for cross section placement 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 as well as at locations deemed by the engineer to be ineffective at conveying flow downstream.

Cross sections were drawn on dam tops for flood control identified dams in order to better represent ponded water upstream of the structures. It was assumed in doing this 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 known elevations from past flooding events and effective Zone A boundaries and the results were determined reasonable.

Significant effort was made to start all tributaries below the receiving water surface elevations but this was not always achieved, particularly in wide, flat floodplains where small tributaries ran parallel to large streams or where road crossings or dams interfered with cross section alignments.

The relationship between drainage area and assigned channel geometry is shown in Table 3. These default values for dimensions and spacing are subject to change based on the details noted above as well as the judgment of the responsible engineer.

Table 3: Cross Section Default Parameters

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
1.0	500	4	3.5	0.5
2.0	500	6	4	0.5
4.0	500	11	8	0.5
8.0	500	14	10	0.5
10.0	500	17	13	0.5
15.0	600	20	16	0.5
20.0	600	25	20	0.5
25.0	600	25	20	0.5
30.0	600	25	20	0.5
40.0	600	31	25	0.5
50.0	600	31	25	1
75.0	750	40	30	1
100.0	750	50	42	1
150.0	1000	50	42	1
250.0	1000	50	42	2

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
500.0	1500	120	100	2
1000.0	2500	351	346	3
2000.0	4000	657	652	3
5000.0	4000	1575	1565	3

Manning's roughness coefficients (n-values) were determined using the 2011 National Land Cover Data (NLCD) dataset in combination with n-values from Chow (1959) and Calenda, et al. (2005). The association between the n-values and the NLCD Classification is shown in Table 4. Manning's n-value takeoffs were performed by WISE and the n-values were adjusted in some locations based on engineering judgment. N-values within channel banks were limited by the automated routine to a range of 0.030 to 0.070.

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

NLCD Classification	Minimum	Normal	Maximum	Source
Open Water	0.025	0.03	0.033	Chow 1959
Developed, Open Space	0.01	0.013	0.016	Calenda, et al. 2005
Developed, Low Intensity	0.038	0.05	0.063	Calenda, et al. 2005
Developed, Medium Intensity	0.056	0.075	0.094	Calenda, et al. 2005
Developed, High Intensity	0.075	0.1	0.125	Calenda, et al. 2005
Barren Land	0.025	0.03	0.035	Chow 1959
Deciduous Forest	0.1	0.12	0.16	Chow 1959
Evergreen Forest	0.1	0.12	0.16	Chow 1959
Mixed Forest	0.1	0.12	0.16	Chow 1959
Scrub/Shrub	0.035	0.05	0.07	Chow 1959
Grassland/Herbaceous	0.025	0.03	0.035	Chow 1959
Pasture/Hay	0.03	0.04	0.05	Chow 1959
Cultivated Crops	0.025	0.035	0.045	Chow 1959
Woody Wetlands	0.08	0.1	0.12	Chow 1959
Emergent Herbaceous Wetland	0.075	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 names in the National Flood Hazard Layer (NFHL) and streams with large drainage areas (generally greater than 8 square miles), the normal depth slope was calculated based on the HEC-RAS profile invert.

1.4 Quality Control

Following the initial BLE analysis in each watershed, the flood hazard area delineations created by the BLE process 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 SFHA data.

Typical manual editing 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 50 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 adding cross-sections at confluence areas (see Figure 5 below), modification to improve perpendicular orientation at the channel, adjustment of discharge breaks to better represent flow addition points, revisions to dam spillways and dam tops, 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 another frequency or by the 1-percent plus or 1-percent minus 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.

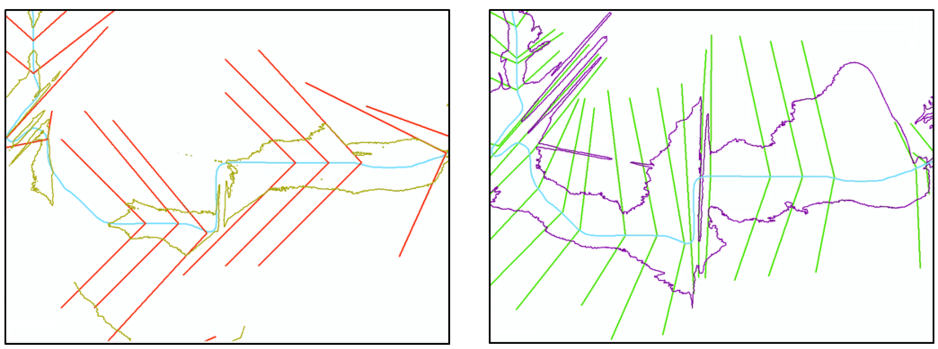

Figure 4: Default "V" angle cross-sections automated by WISE (left). Manually edited cross-sections to more accurately capture terrain (right). Resulting flood boundaries shown in gold (left) or purple (right) for clarity.

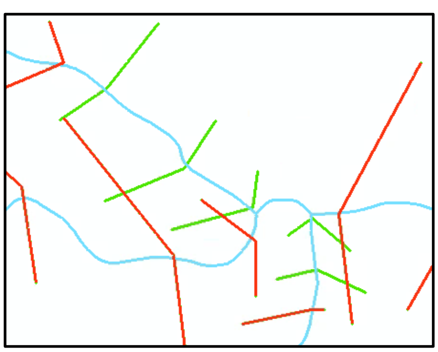

Figure 5: Manually added cross-sections (green) to improve accuracy of tie-ins at confluences.

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, areas with a size of less than 5,000 square feet were removed and all others were investigated to determine whether they should be considered as potentially part of the SFHA. 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. Islands with a size between roughly 5,000 and 30,000 square feet were inspected and, in general, islands that were less than 10,000 square feet were 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

Challenges encountered during BLE analyses will vary based on available data on which to run the analysis. The watershed analyses presented challenges as summarized in the following paragraphs.

As noted in Section 1.2 above, there are a significant number of dams on tributaries to Cedar Creek. Hydrologic results from regression calculations were not adjusted to take into account the impact of these structures. Further investigation should be conducted when upgrading these models.

As noted in Section 1.3 above, significant effort was made to start all tributaries below the receiving water surface elevations but this was not always achieved, particularly in wide, flat floodplains where small tributaries ran parallel to large streams or where road crossings or dams interfered with cross section alignments.

Parallel streams with shared floodplains were modeled by moving the combined discharge upstream to the cross section that begins the shared floodplain.

Results and Recommendations

The BLE results for this study produced a SFHA that compares reasonably well with the effective SFHA in some cases and narrower in other cases. These boundaries provide an additional estimated SFHA in areas that 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.

Maps showing the BLE results are included as Appendix A.

3.1 CNMS Validation of Effective Zone A SFHA

The inventory of Zone A studies (1,050.17 miles) in the Cedar watershed were classified in CNMS with validation status of "UNKNOWN", "UNVERIFIED", "VALID" miles, and with status type of "TO BE ASSESSED" and "TO BE 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 Cedar Watershed TX, the effective Zone A topographic data leveraged a variety of sources, but primarily based upon USGS 24K map products. The topography listed in Section 1.1 above represents a significant improvement from the effective Zone A topographic source.

INITIAL ASSESSMENT A2 – CHECK FOR SIGNIFICANT HYDROLOGY CHANGES

This check involves first determining 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.

The source for the effective Zone A study areas located in Henderson, Kaufman, and Van Zandt Counties in TX is unknown due to the lack of effective data. It is known that the study analyses for these counties were performed prior to the most recent publication 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)

Rockwall County effective Zone As were developed using the publication WRIR 96-4307, *Regional Equations for Estimation of Peak-Streamflow Frequency for Natural Basins in Texas* (1997).

Due to the lack of study data, the significant impact that the updated regression equations would have on the 1-percent annual chance flow in Cedar Watershed TX is unknown.

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. Of the 29 HUC-12 polygons within the study area, none show a percentage of 15% or more urban area, thus none have applicable significant development.

Table 5: Zone A Initial Assessment Results

Assessment Check	Pass / Fail	Notes
A1 – Topography	Fail	Topographic described in Section 1.1 is significantly better than effective topographic source.
A2 – Hydrology	Pass	Newer Regression Equations published in 2009 are available for studies located in Henderson, Kaufman, Rockwall, and Van Zandt Counties, TX. The significant impact the newer regression equations would have on the 1-percent annual chance flow is unknown.
A3- Development	Pass	0 of the 29 HUC-12s fail.

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. Streams located in Henderson, Kaufman, Rockwall, and Van Zandt Counties have been marked as fail in the A4 check due to lack of evidence in the FIS report and on FEMA's Mapping Information Platform (MIP) detailing study methods.

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).

Of the 856 modeled BLE streams in the study area, 811 were found to correspond (within the tolerance limits) with effective Zone A flood zones. Comparison results are summarized to the individual reach 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".

VALIDATION RESULTS

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Cedar Watershed study area has been updated, with 384.6 miles categorized as UNVERIFIED – TO BE STUDIED, 321.1 miles categorized as UNVERIFIED – BEING STUDIED, 266.3 miles categorized as UNKNOWN – TO BE ASSESSED and 78.1 miles categorized as VALID – BEING STUDIED. Total miles in each of these categories are summarized in Table 6 and illustrated in Figure 6 below. It should be noted that due to the lack of effective digital data in this watershed approximately 17% of the HUC-12s have no data to evaluate.

Table 6: Zone A Validation Results

Validation Status	Status Type	Cedar (miles)
VALID	BEING STUDIED	78.1
UNVERIFIED	BEING STUDIED	321.1
	TO BE STUDIED	384.6
UNKNOWN	TO BE ASSESSED	266.3
Total Miles		1,050.1

Table 7: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Cedar	All Streams	53,971	13,146	40,825	76%	Fail	
Allen Creek-Cedar Creek	120301070203	4,423	1,526	2,897	65%	Fail	27.1
Big Cottonwood Creek-Kings Creek	120301070108	468	225	243	52%	Fail	39.9
Caney Creek	120301070204	3,299	706	2,593	79%	Fail	17.1
Caney Creek-Cedar Creek	120301070310	1,258	196	1,062	84%	Fail	10
Caney Creek-Cedar Creek Reservoir	120301070309	431	73	358	83%	Fail	8.5
Clear Creek-Cedar Creek Reservoir	120301070307	2,847	384	2,463	87%	Pass	6.5
Dry Lacy Fork	120301070301	4,053	735	3,318	82%	Fail	14.2
Headwaters Big Cottonwood Creek	120301070109	1,229	477	752	61%	Fail	31
Eagans Branch-Kings Creek	120301070106	1,236	220	1,016	82%	Fail	14.1
Headwaters Caney Creek	120301070308	1,244	108	1,136	91%	Pass	5.1
Headwaters Kings Creek	120301070105	2,332	508	1,824	78%	Fail	15.5
High Point Creek	120301070102	1,060	270	790	75%	Fail	22.9
Kemp Lake-Cedar Creek Reservoir	120301070206	2,251	549	1,702	76%	Fail	19
Lacy Fork-Cedar Creek Reservoir	120301070302	3,829	844	2,985	78%	Fail	15.7
Little Brushy Creek-Kings Creek	120301070107	909	296	613	67%	Fail	26.3

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Little Cottonwood Creek-Kings Creek	120301070110	2,021	575	1,446	72%	Fail	22.8
Lower Big Brushy Creek	120301070104	636	154	482	76%	Fail	19.8
McAllister Slough-Cedar Creek	120301070311	1,338	652	686	51%	Fail	33.3
Middle Big Brushy Creek	120301070103	871	186	685	79%	Fail	17.9
Muddy Cedar Creek	120301070201	1,916	568	1,348	70%	Fail	16.9
North Twin Creek-Cedar Creek Reservoir	120301070305	2,303	272	2,031	88%	Pass	6.9
Persimmon Branch-Cedar Creek Reservoir	120301070303	608	113	495	81%	Fail	12.6
Prairie Creek-Cedar Creek Reservoir	120301070304	1,085	355	730	67%	Fail	22.4
Rocky Cedar Creek	120301070202	1,338	407	931	70%	Fail	19.3
South Twin Creek-Cedar Creek Reservoir	120301070306	2,607	480	2,127	82%	Fail	10.5
Town of Kemp-Cedar Creek Reservoir	120301070111	948	269	679	72%	Fail	21.6
Upper Big Brushy Creek	120301070101	3,266	859	2,407	74%	Fail	23.7
Walnut Creek-Cedar Creek	120301070312	1,462	332	1,130	77%	Fail	13.7
Williams Creek-Cedar Creek	120301070205	2,703	807	1,896	70%	Fail	23.9

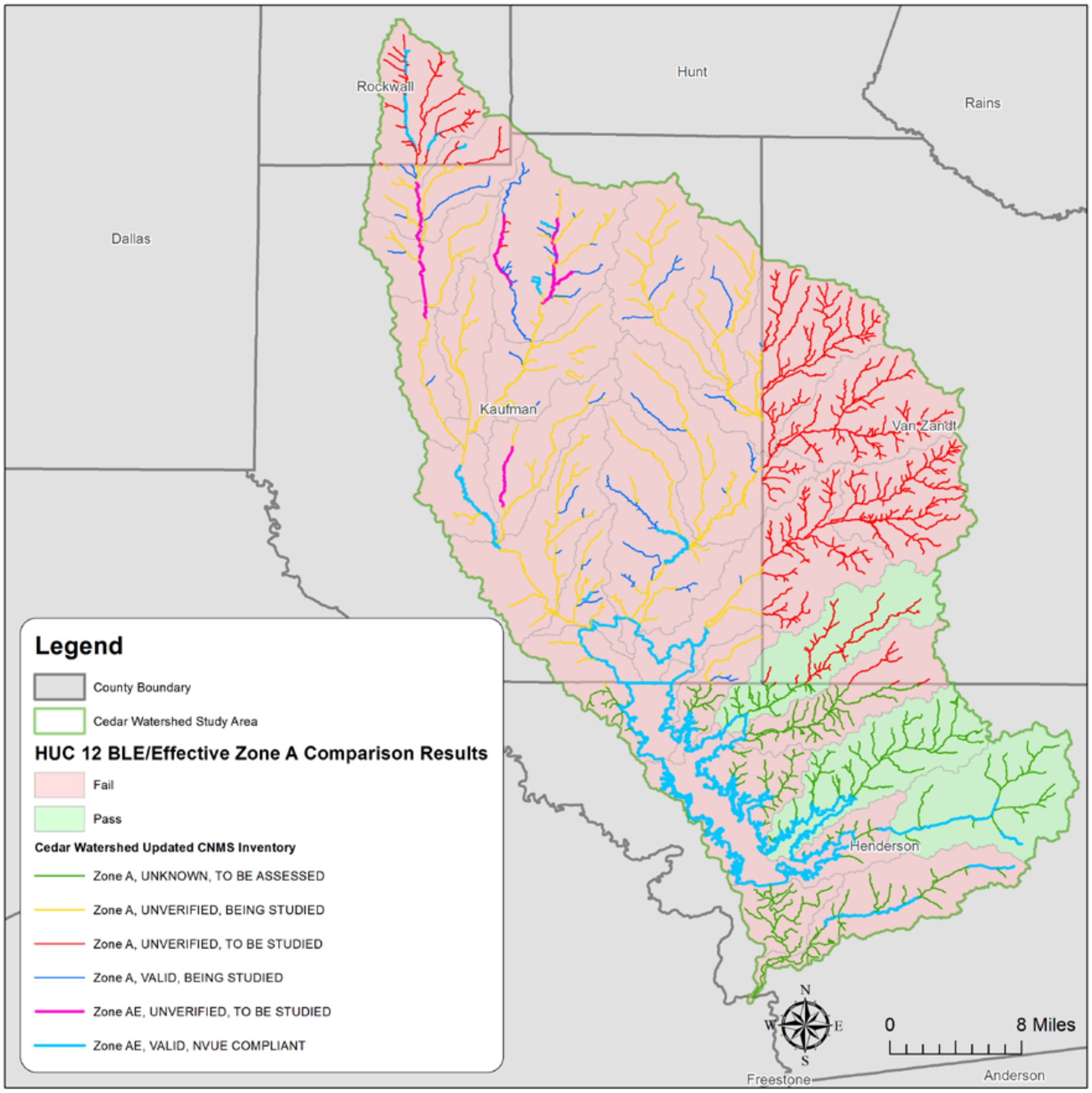

Figure 6: Cedar Watershed CNMS Validation Results

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

For Cedar Watershed, Big Cottonwood Creek – Kings Creek HUC-12 was determined to have the highest priority score and the most need while Headwaters Caney Creek HUC-12 has the lowest score.

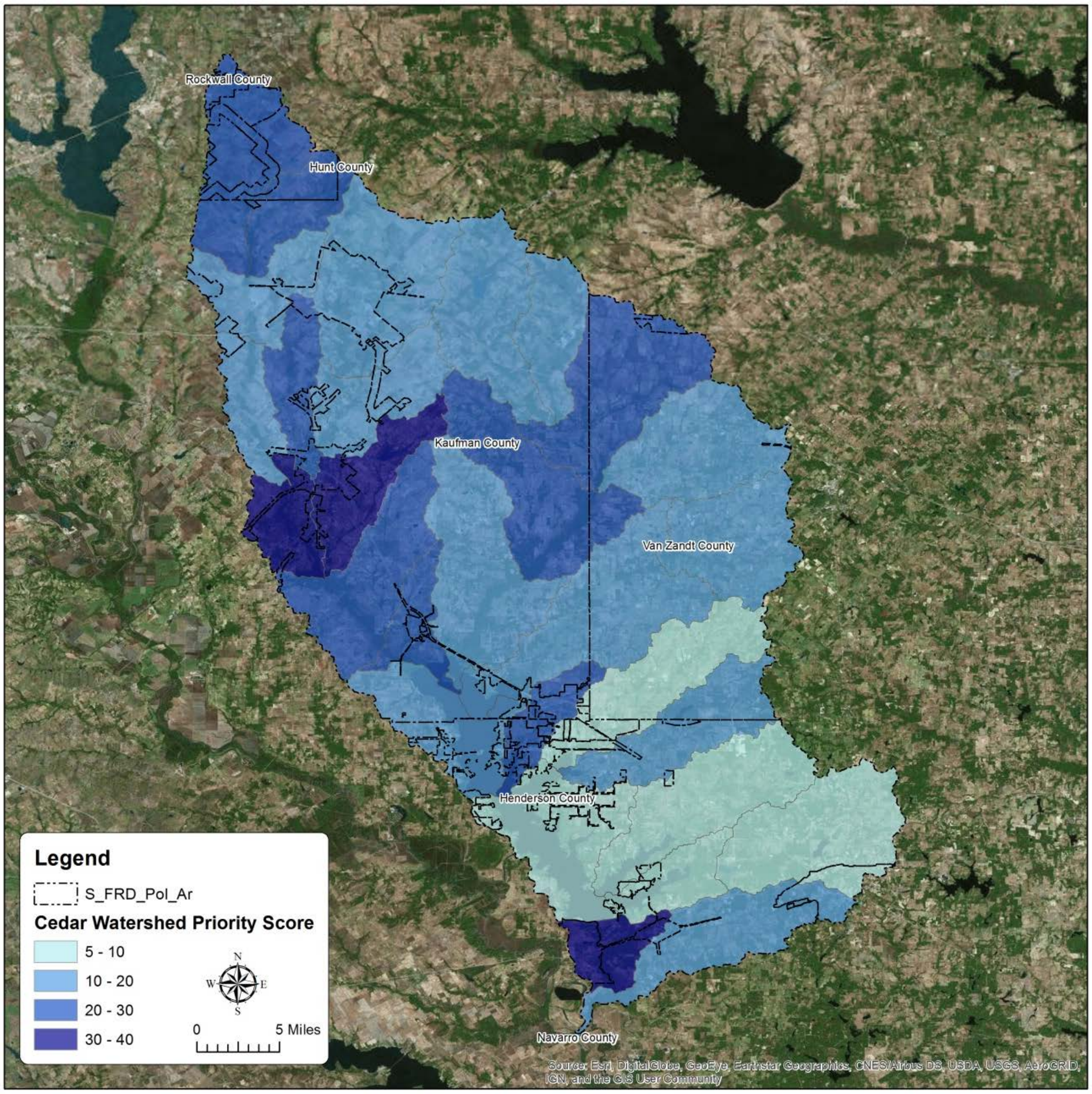

Figure 7: Ranking of Cedar Watershed HUC-12s

3.2 Flood Risk Analysis

An advanced flood risk analysis was performed using the updated 1-percent-annual-chance grid (known as 'refined' grid) created for this project. The loss analysis uses 2010 census data and the subsequent results are stored in the L_RA_Results table.

Hazus version 4.0 was used for the loss analysis.

The losses are reported via census blocks. It is important to note that Hazus version 4.0 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 Maps