Amite Watershed, Louisiana: 2D Base Level Engineering Methods and Results

Contract #HSFE60-15-D-0003
Task Order #HSFE60-16-J-0201
May 2018

DHS/FEMA (Federal Emergency Management Agency)
FEMA Region VI
FRC 800 North Loop 288
Denton, TX 76209-3698

Submitted by:

Compass PTS JV
3101 Wilson Boulevard, Suite 900
Arlington, VA 22201

DOCUMENT HISTORY

DOCUMENT LOCATION

K:/R06/LOUISIANA_22/EAST_BATON_ROUGE_22033/EAST_BATON_ROUGE_033C/16-06-3601S/SubmissionRepository/Hydraulics/2186737

REVISION HISTORY

Version Number	Version Date	Summary Changes	Team/Author
1.0	March 2017	Deliverable to FEMA Region VI	Compass
2.0	May 2018	Addressed minor comments received from the Region	Compass

APPROVALS

This document requires the approval of the following persons:

Role	Name	Phone	Title (CLIN/RMC)	Review Date	Approved Date
Project Manager	April Smith	512.457.7818	Project Manager	March 13, 2017	March 15, 2017

CLIENT DISTRIBUTION

Name	Title/Organization	Location
Shona Gibson	FEMA Region VI	Denton, Texas
FEMA's MIP	Region VI	See path above

Table of Contents

List of Figures

List of Tables

01 Introduction

Recent innovations and efficiencies in floodplain mapping have allowed the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop a process formerly known as First Order Approximation (FOA), now labeled Base Level Engineering (BLE), which can be used to address 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 automated techniques to produce estimates of flood hazard boundaries for multiple recurrence intervals. Although the cost for developing the data and estimates resulting from the BLE process should be lower than standard flood production costs, the Amite BLE documented here was designed to use 2-dimensional (2D) modeling efforts with enhancements and calibration to develop products intended to be transitioned into regulatory data development workflows.

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 Identification (SID) #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping which may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an 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 should not only be used for CNMS evaluations of Zone A studies, but can also be leveraged throughout the Risk MAP program. The large volume of data resulting from a BLE can be updated as needed and used for the eventual production of regulatory and non-regulatory products, outreach and risk communication, and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

In an effort to increase and enhance the flood risk products in Louisiana, FEMA Region VI contracted the Compass PTS JV to perform BLE for the Amite Watershed. This report documents the BLE process, products, and results for this watershed. Figure 1 depicts the Amite Watershed footprint. Figure 2 depicts the Amite Watershed HEC-RAS 2D model areas.

Figure 1: Amite Watershed BLE

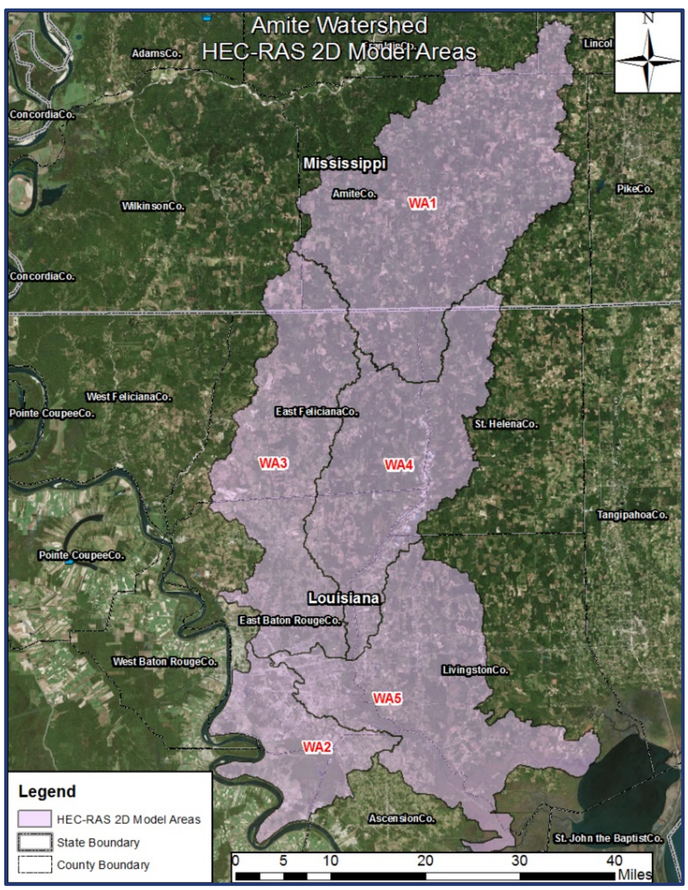

Figure 2: Amite Watershed HEC-RAS 2D Model Areas

02 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2-dimensional (2D) hydraulic engineering analysis for the Amite Watershed. Inputs such as elevation data, hydrology from rain-on-grid and inflow hydrographs, and hydraulic analyses and variables are defined herein.

2.1 Topographic Data

A high resolution Digital Elevation Model (DEM) is a fundamental component for two-dimensional engineering analyses by providing a detailed representation of the surface for hydraulic routing through the model area. As such, DEMs were developed for the Amite BLE project by leveraging available high resolution gridded elevation data derived from Light Detection and Ranging (LiDAR) collections throughout the entire State of Louisiana. The 10 foot DEM developed to support the 2D BLE modeling and analysis, within the Amite Watershed, was executed using the following steps:

1. Available elevation data for the project area were inventoried and collected.
2. Leverage elevation data were evaluated and prioritized based on source vertical accuracy, year of collection, and resolution.
3. Seamless DEMs were processed using GIS.
4. Quality was assured using quantitative and qualitative assessment.

Documentation regarding leverage data including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables and text within Section 2.1. All vertical accuracy specifications were obtained from the metadata or survey reports provided with the leverage datasets. All available metadata, survey reports, and other leverage documentation are included in the FEMA Data Capture Technical Reference compliant submittal content for the Amite Watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the Amite BLE project footprint. Figure 3 depicts the datasets identified for leveraged across the project area. FEMA, NOAA, USGS, and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

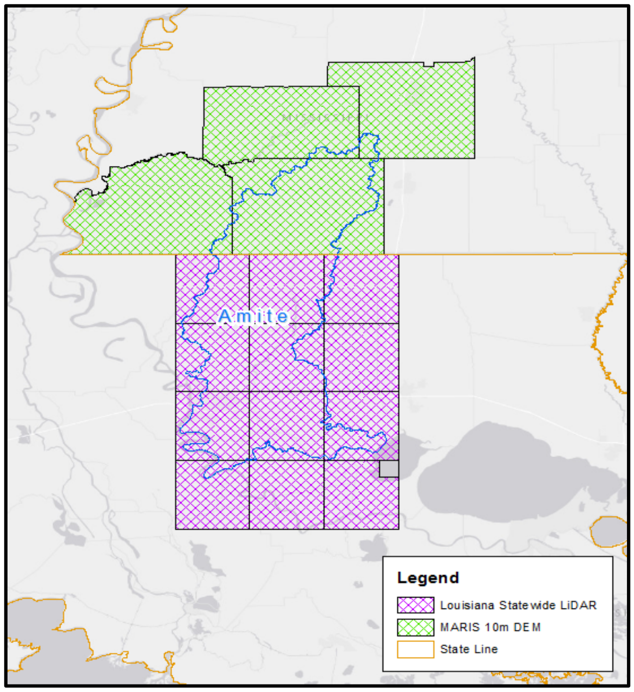

Figure 3: Amite Watershed BLE Source Terrain

2.1.2 Evaluation

A data coverage assessment was conducted to check for data gaps, extent, accuracy, and completeness. A review of related documentation, reports, indexes, and metadata associated with the leverage datasets ensured each dataset meets FEMA accuracy requirements for topographic data. Decisions to leverage or exclude a dataset (or portion of it), were based generally on the following criteria coupled with engineering judgment:

- Data meet FEMA vertical accuracy standards (Table 1)
- Date of origination
- Data density and coverage

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

Table 1: FEMA Vertical Accuracy Requirements for Leveraged Data

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

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

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

Table 2: Source Topographic Data Available for the Amite Watershed

Year	Description	Data Type	RMSE	Source/Owner
2006	Louisiana Statewide LiDAR	Airborne LiDAR	15-30 cm	LSU/USGS
2007	MARIS 10 meter DEM	DEM from Contours	≤ 30 cm	MARIS/USGS

2.1.2.1 Amite Watershed Source Terrain Data

The primary source elevation data for the Amite Watershed are DEMs derived from the Louisiana Statewide LiDAR collection. Only points classified as "ground" points (i.e., bare earth) were imported from the LiDAR and used for development of the project DEMs. Bare-earth LIDAR data are typically made by filtering non-ground returns (e.g. buildings, vegetation, etc.) from the raw laser returns. Table 3 lists the source data used to compile the engineering DEM for the Amite Watershed. Figure 4 depicts the extent of the data defined in Table 3.

Table 3: Amite Watershed Source Terrain Data

Year	Description	Data Type	RMSE	Source/Owner
2006	Louisiana Statewide LiDAR	Airborne LiDAR	15-30 cm	LSU/USGS
2007	MARIS 10 meter DEM	DEM from Contours	≤ 30 cm	MARIS/USGS

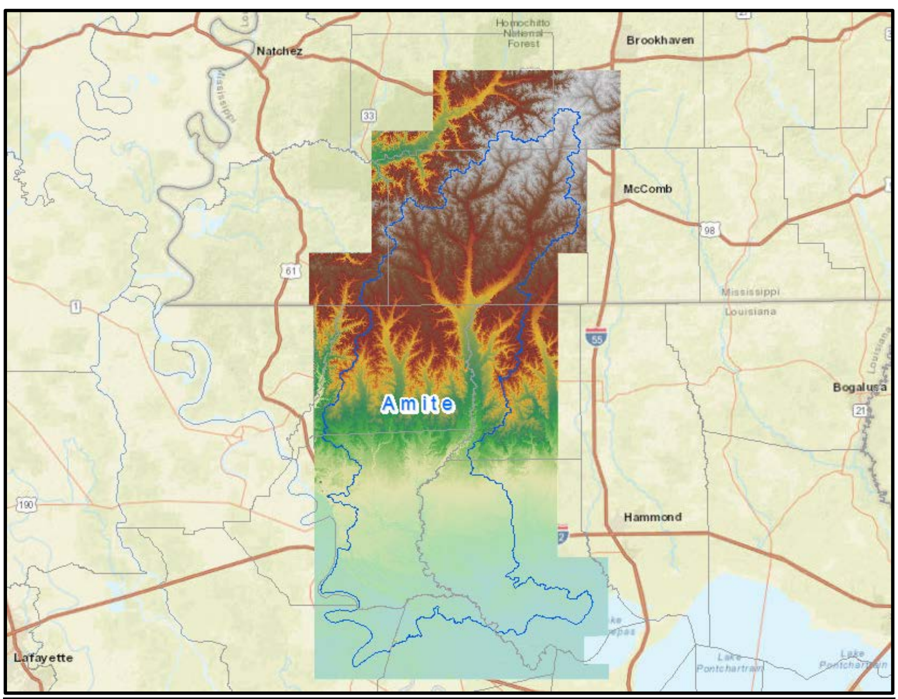

Figure 4: Amite Watershed Source Terrain Data

2.1.2.1.1 2006 Louisiana Statewide LiDAR

Louisiana's statewide LIDAR project began in 2000, through 2006, largely in response to the high per capita and repetitive flood loss rates experienced by the FEMA, National Flood Insurance Program and the private insurance industry in the state. The LIDAR systems being used in the Louisiana project are accurate to 15-30 cm RMSE, depending upon land cover, and will support contours of 1-2 foot vertical map accuracy standards. These accuracies meet FEMA standards for floodplain reevaluation studies and map modernization programs designed to update the Flood Insurance Rate Maps (FIRM).

2.1.2.1.2 2007 MARIS 10m DEM

MARIS 10m DEMS were created from existing 1:24,000 contour quadrangle vector coverages converted into vector shapefiles. The contours for a county were appended. A 400 meter county border buffer was created. The contours for a county were clipped on this 400 meter buffer to ensure a smooth model at the border. Using the 3D Analyst Topo-to-Raster command, a 10 meter DEM was generated. The resulting DEM was inspected for anomalies using a visual inspection in ArcMap of the grey-scaled image. Both the DEM and the contour vector file were sent to USGS/NGTOC III for inspection. Their staff performed a QA review of the data for completeness and accuracy in topographic characterization. In addition, a statistical sampling of vertical accuracy was performed by USGS/NGTOC III to ensure the vertical accuracy was met.

2.1.3 Data Development Methodology

The source topographic data were processed for an area covering the Amite Watershed and contributing drainage areas for the Amite BLE modeling efforts. The topographic data for Amite was projected horizontally, as needed, to North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS) Louisiana South in feet (1702-SPC83). All topographic data were adjusted vertically, as needed, to NAVD88 in feet. Compass used a combination of ArcGIS and other software tools to apply any vertical datum shifts and\or any horizontal projection transformations to the topographic data.

2.1.4 DEM QA/QC

DEMs developed for use in the Amite BLE analysis were developed and independent assured to meet quality standards of the project. The data were developed using a controlled process, were evaluated and assured by a topographic data development team, and were evaluated and assured by the engineering team. Quality assurance during the data development process includes, but is not limited to the following QC checks:

- Horizontal Projection Check
- Vertical Datum Check
- Resolution Check
- Format Check
- Seamless Data Check to ensure the DEM files are consistent and seamless along source data edges

The quality control after the development process by the DEM development team included visual observations using hillshade, contouring, color rendering, and/or other visual aids to review and identify potential impactful anomalies within the DEM surface. This QC step included, but were not limited to the following QC checks:

- Seamless Data Check to ensure no voids along the edges and between the prioritized datasets
- NoData Value Check to ensure no null values
- Manual Elevation Check using hillshade rasters to find erroneous elevation issues
- Unit Consistency Check
- Legacy Cell Value Anomalies

Quality assurance conducted after the seamless DEM development conducted by the engineering team included visual or automated assessments to identify potentially impactful anomalies or slope changes that may adversely impact hydraulic.

The final DEM data developed for Amite are assured to meet FEMA standards and present a representative surface developed from leverage elevation data for the purposes of this BLE project.

2.2 2D BLE Methods

The following sections describe the 2D computational mesh and program setting considerations, followed by discussion and tabulation of hydrologic and hydraulic engineering methods and model inputs. For this study, HEC-RAS 5.0.3 (RAS 5) was used for hydraulic calculations.

2.2.1 2D Computational Mesh and Settings

The RAS 5 2D computational mesh was created for the Amite Watershed using ArcGIS toolsets, such as smoothing and simplification routines, ultimately significantly reducing the need for manual edits to mesh cells within RAS 5 that happen to generate errors. The 2D mesh for the Amite Watershed was divided into five work areas totaling 1,051,950 cells, 939 internal breakline connects, and a 200 foot nominal mesh cell size. Computational time steps ranged from 15-seconds to 1-minute in the RAS 5 model, applying the Diffusion Wave (simplified Full Momentum) equations.

2.2.2 Model and Boundary Condition Setup

Using RAS 5 rain-on-grid modeling requires establishing a 2D computational mesh boundary, and often requires defining inflow boundary conditions in addition to excess precipitation applied to the mesh. For the Amite Watershed, three inflow hydrographs along Beaver Creek, West Fork Amite River, and East Fork Amite River were used for model area WA1. See Figure 5. The inflow hydrographs were derived for the portion of the watershed in Mississippi due to lower quality terrain. Only the higher quality terrain was used in the RAS 5 2D model. Along with the inflow hydrographs (where applicable), excess precipitation is applied to the 2D mesh for each RAS 5 model area. Figure 6 below shows the 2D computational mesh for this project, along with inflow boundary condition locations for the mesh and USGS peak streamflow gages pertinent to the study.

Figure 5: Locations of Upstream Inflow Hydrographs Applied to Model Area WA1

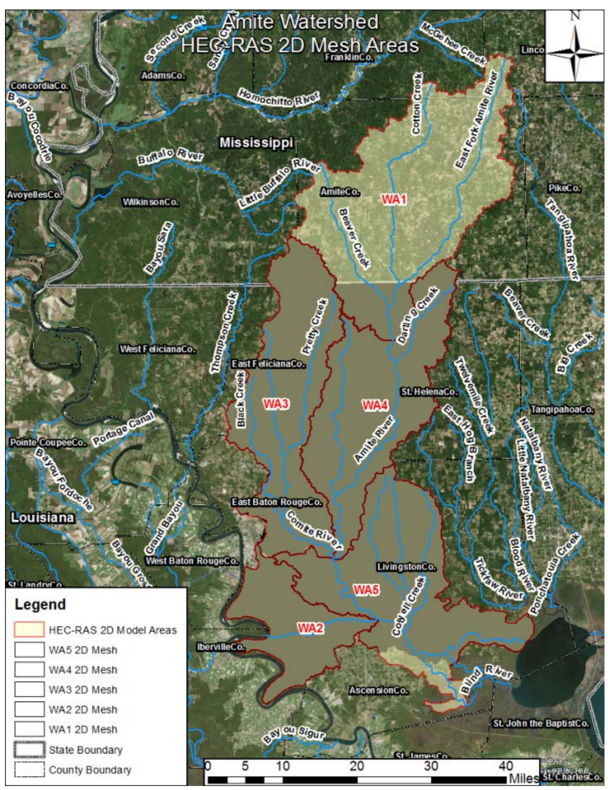

Figure 6: RAS 5 2D Computational Mesh and Boundary Conditions and USGS Peak Streamflow Gages

The development of inflow hydrographs and excess precipitation hyetographs for the 2D mesh are described in Section 2.2.3.

Outflow boundary conditions (from the computational 2D mesh) were utilized along work area boundaries without an inflow boundary condition. Unique outflow boundaries were established for obvious riverine outflows, while the remaining boundaries were defined as continuous boundaries to allow drainage from adjacent basins to leave the model area freely. Normal depth was used for all outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain data.

2.2.3 Hydrology

Precipitation data for this study were referenced from NOAA's Precipitation Frequency Data Server using the NOAA Atlas 14 Frequency Estimates for Louisiana. See Table 7 for a summary of the precipitation values for each RAS 5 model area. Regionally appropriate temporal distributions provided by NOAA for the Southeast, Region 1 have been utilized (see Figure 7). Per guidance from NOAA, for a 24-Hour duration the majority of storms for this region occur in the first quartile. The 50% cumulative total precipitation will be used for the Region 1 since it represents the median temporal distribution. See Table 4.

Table 4: Total Number of Precipitation Cases and Number (and Percent) of cases in each Quartile for Selected Durations

Duration	Region	All Cases	1st Quartile Cases	2nd Quartile Cases	3rd Quartile Cases	4th Quartile Cases
6-hour	1	9,142	3050 (33%)	2,829 (31%)	2,087 (23%)	1,176 (13%)
	2	1,231	748 (35%)	698 (33%)	426 (20%)	259 (12%)
12-hour	1	9,631	3,519 (37%)	2,476 (26%)	2,203 (23%)	1,433 (15%)
	2	2,189	826 (38%)	550 (25%)	463 (21%)	350 (16%)
24-hour	1	9,325	3316 (36%)	2,278 (24%)	2,171 (23%)	1,560 (17%)
	2	2,218	764 (34%)	476 (21%)	505 (23%)	473 (21%)
96-hour	1	8,908	3696 (41%)	1,962 (22%)	1,653 (19%)	1,597 (18%)
	2	2,113	747 (35%)	504 (24%)	414 (20%)	448 (21%)

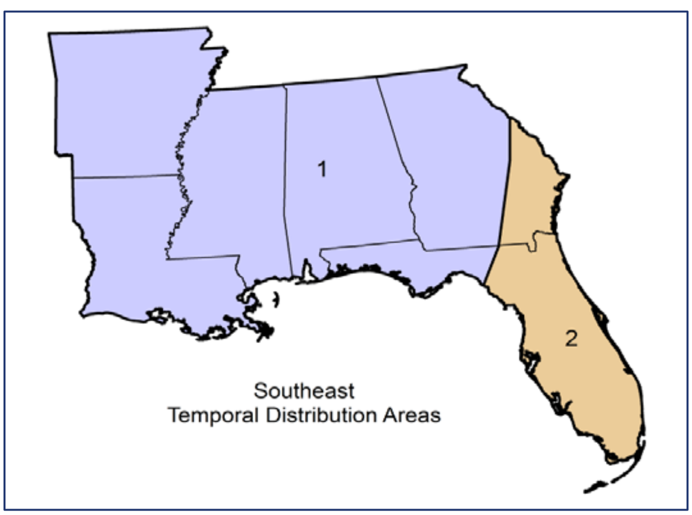

Figure 7: NOAA Atlas 14 Volume 9 - Southeast Temporal Distribution Areas

2.2.3.1 Excess Precipitation for 2D Computational Mesh

HEC-HMS version 4.1 was used to apply the SCS Curve Number method to calculate losses and define excess precipitation for each model work area. Regionally appropriate temporal distributions defined by NOAA Atlas 14, Volume 9, Region 1 were defined using a 24-hour duration. The 1% plus and minus storm event precipitation values were found by using a 68% confidence interval on the baseline 1% event.

Initial Curve Numbers (i.e., prior to calibration) were computed by intersecting the National Land Cover Dataset (NLCD) 2011 coverage and NRCS soils data based on the matrix presented in Table 5.

Table 5: Landuse-Soils-CN Matrix for Computing Initial Curve Numbers

Land Use (LU) GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	99	99	99	99
21	Developed Open Space	49	69	79	84
22	Developed Low Intensity	61	75	83	87
23	Developed Medium Intensity	81	88	91	93
24	Developed High Intensity	89	92	94	95
31	Barren Land	39	61	74	80
41	Deciduous Forest	30	55	70	77
42	Evergreen Forest	30	55	70	77
43	Mixed Forest	30	55	70	77
52	Shrub Scrub	30	48	65	73
71	Herbaceous	49	62	74	85
81	Hay Pasture	39	61	74	84
82	Cultivated Crops	51	67	76	80
90	Woody Wetlands	72	80	87	93
95	Emergent Herbaceous Wetlands	72	80	87	93

Antecedent Runoff Condition (ARC) II Curve Numbers (CN's) were used for all baseline recurrence interval storm events, while ARC III CN's were used for the 1% plus event and ARC 1.5 CN's were used for the 1% minus event. Table 6 provides the initial CNs used for determining excess precipitation.

Table 6: Curve Numbers Input into HMS Models

Model Area	Initial CN's ARC II	1% Plus CN's ARC III	1% Minus CN's ARC 1.5
WA1	68.4	76.0	84.0
WA2	86.9	91.0	95.0
WA3	79.6	85.6	91.0
WA4	74.8	81.5	88.0
WA5	75.0	81.5	88.0

The following figures shows the final excess precipitation hyetographs applied to the 2D computational mesh. Note that Curve Numbers were modified during the calibration process and the excess precipitation hyetographs were recalculated, as discussed in Section 2.2.5.1.

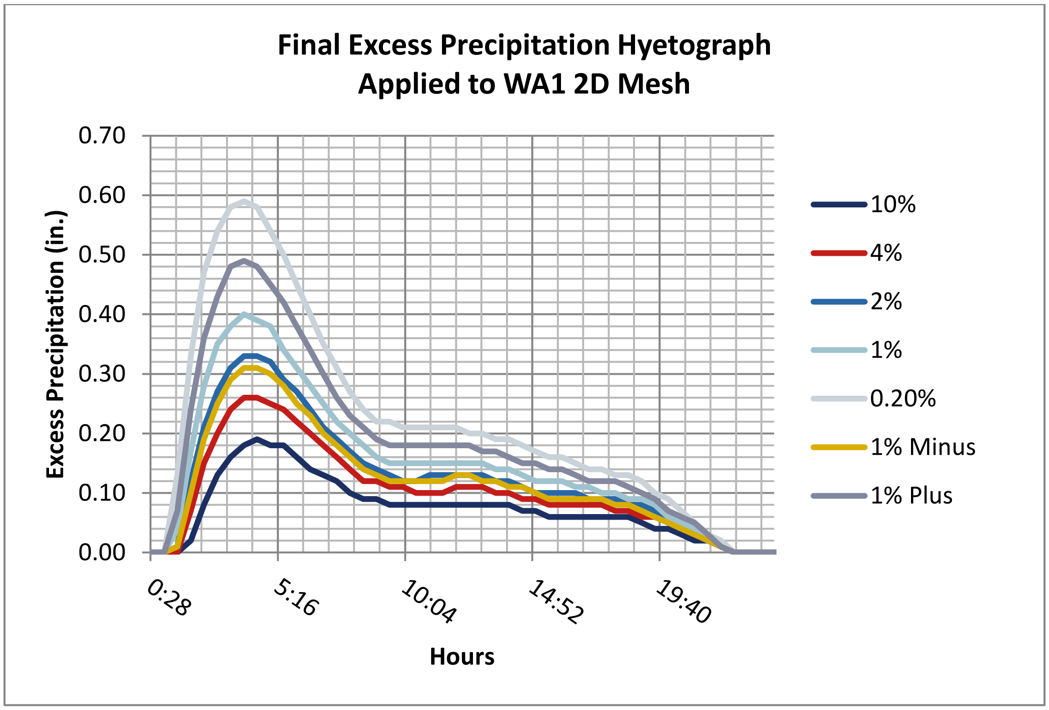

Figure 8: Excess Precipitation Hyetographs (post ARF) Applied to the Computational Mesh

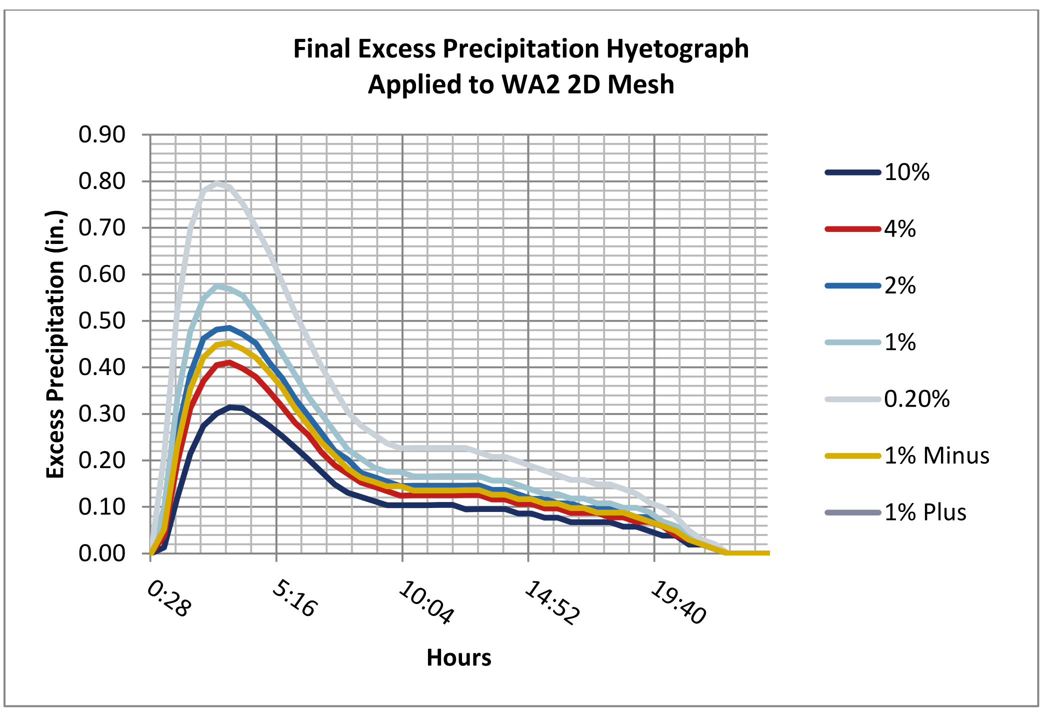

Figure 9: WA2 Excess Precipitation Hyetographs (post ARF) Applied to the Computational Mesh

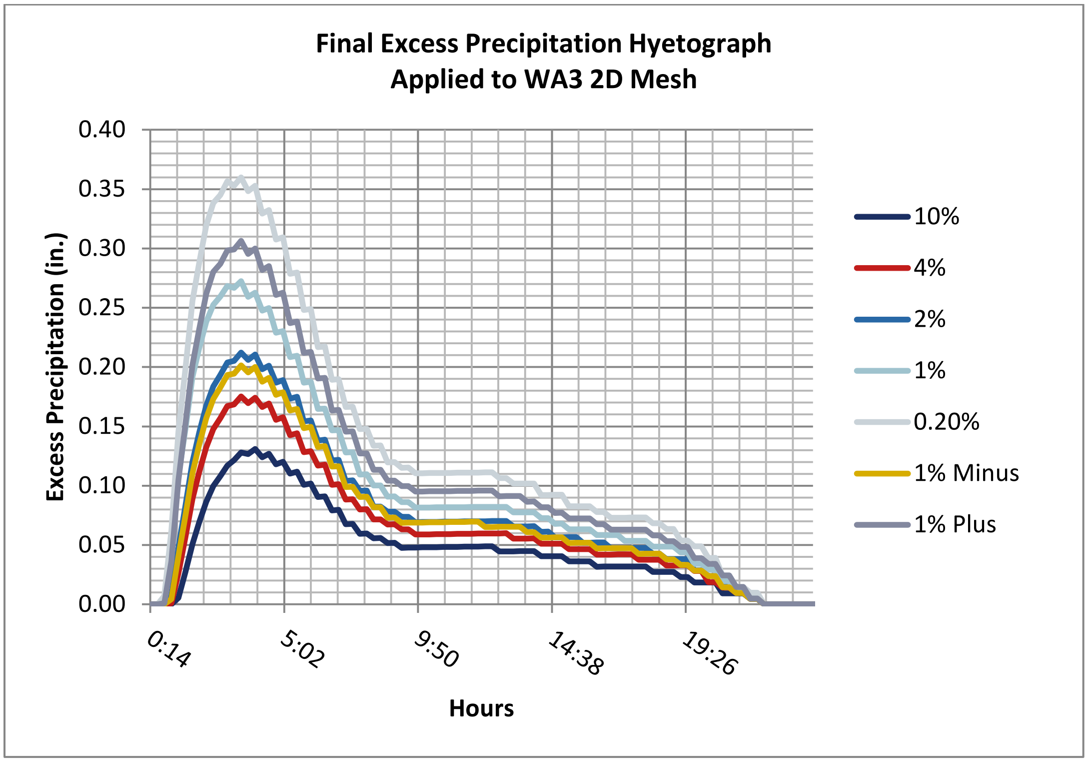

Figure 10: WA3 Excess Precipitation Hyetographs (post ARF) Applied to the Computational Mesh

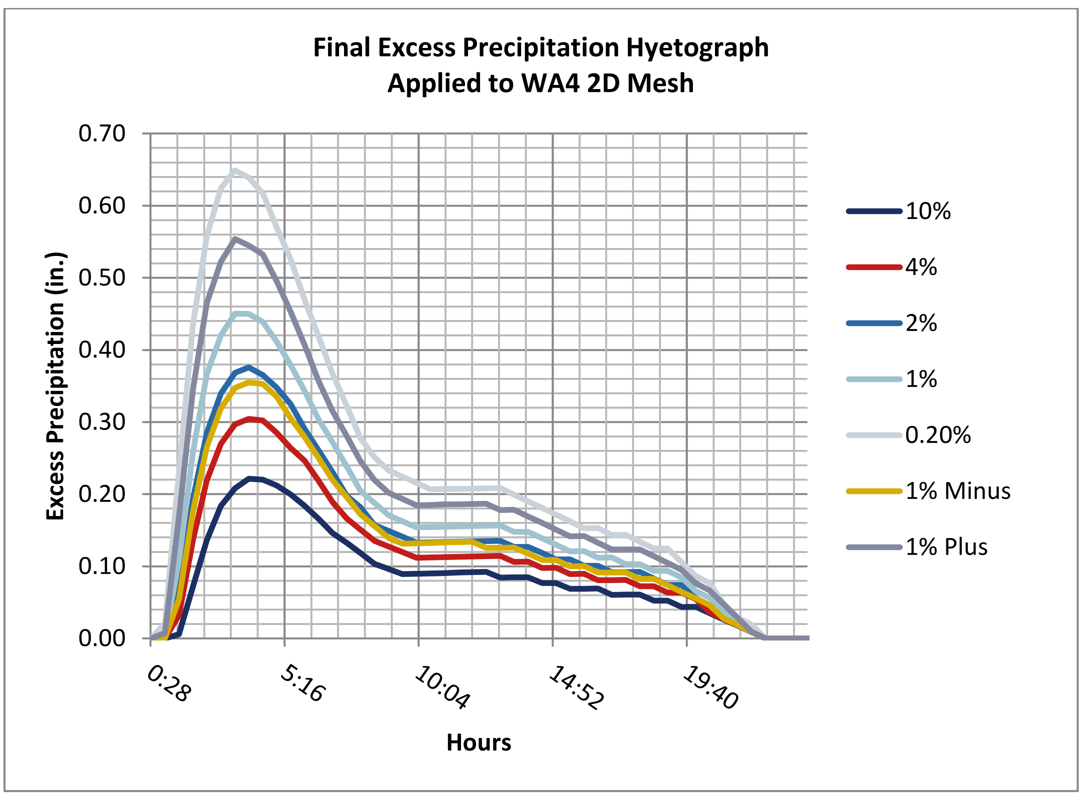

Figure 11: WA4 Excess Precipitation Hyetographs (post ARF) Applied to the Computational Mesh

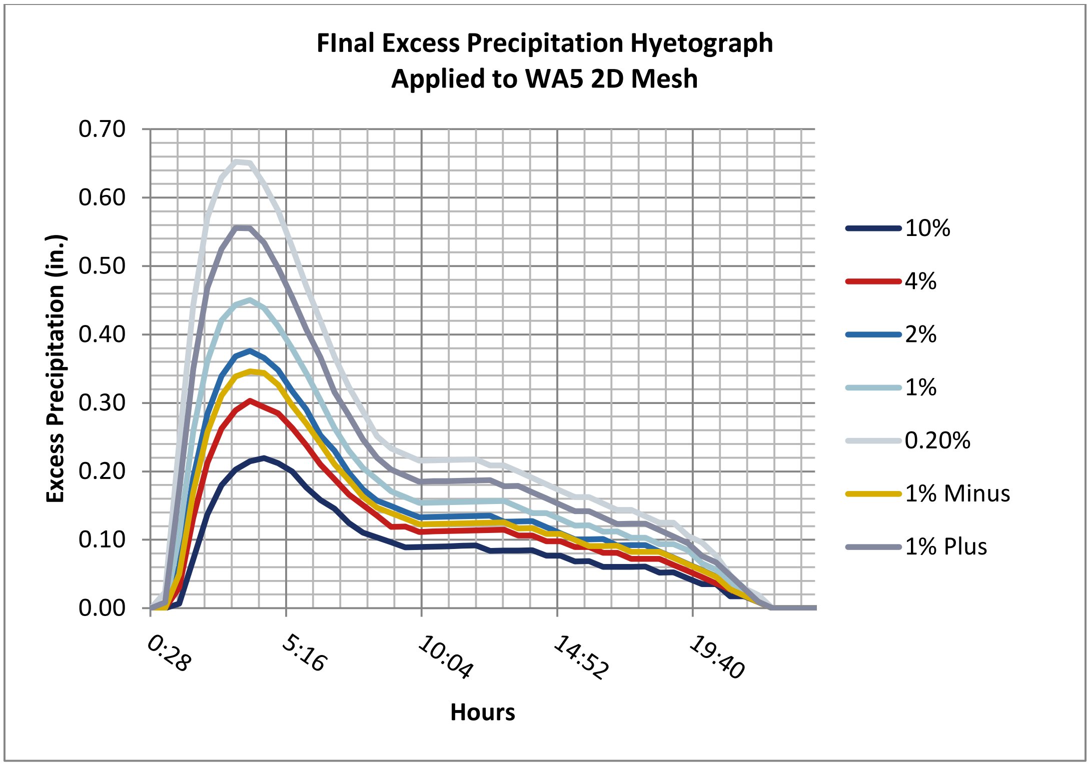

Figure 12: WA5 Excess Precipitation Hyetographs (post ARF) Applied to the Computational Mesh

2.2.3.2 Rainfall-Runoff Hydrograph Boundary Conditions

This section discusses the drainage areas for which inflow hydrographs, developed from rainfall-runoff modeling, were used as boundary conditions to the 2D computational mesh. Table 7 shows the precipitation total depths (before an areal reduction factor (ARF) was applied) for the sub-basin elements representing drainage areas to (and within) the 2D computational mesh. An areal reduction factor (ARF) is generally defined as the ration of the mean precipitation depth over a watershed resulting from a storm to the maximum point depth of the storm. ARF's range from 0.0 to 1.0, and vary according to storm characteristics such as watershed size, shape, and geographic location. Table 8 summarizes the ARFs applied to each modeled area within the Amite Watershed.

Table 7: Precipitation Totals (in) for Sub-basin Elements of Inflow Drainage Areas to the 2D Mesh (no ARF)

Model Area	Percent Annual Chance Precipitation Total (in)						
	10	4	2	1	0.2	1% Minus	1% Plus
WA1	7.50	9.16	10.50	11.90	15.60	10.11	13.69
WA2	7.48	9.22	10.70	12.20	16.20	10.11	14.29
WA3	7.59	9.35	10.80	12.30	16.30	10.38	14.22
WA4	7.63	9.36	10.80	12.30	16.00	10.42	14.18
WA5	7.52	9.24	10.70	12.20	16.10	10.17	14.23

Table 8: Summary of Areal Reduction Factors

Model Area	Area (mi^2)	Areal Reduction Factor (ARF)
WA1*	61.95	0.9459
WA2	168.80	0.9216
WA3	451.00	0.9098
WA4	366.94	0.9103
WA5	414.06	0.9098
*Louisiana portion only		

The following figure shows the 1% annual chance inflow hydrographs applied to model area WA1 for each contributing flooding source applied to the 2D computational mesh in Louisiana. Similar approaches were applied to model area WA1 for the other modeled recurrence intervals.

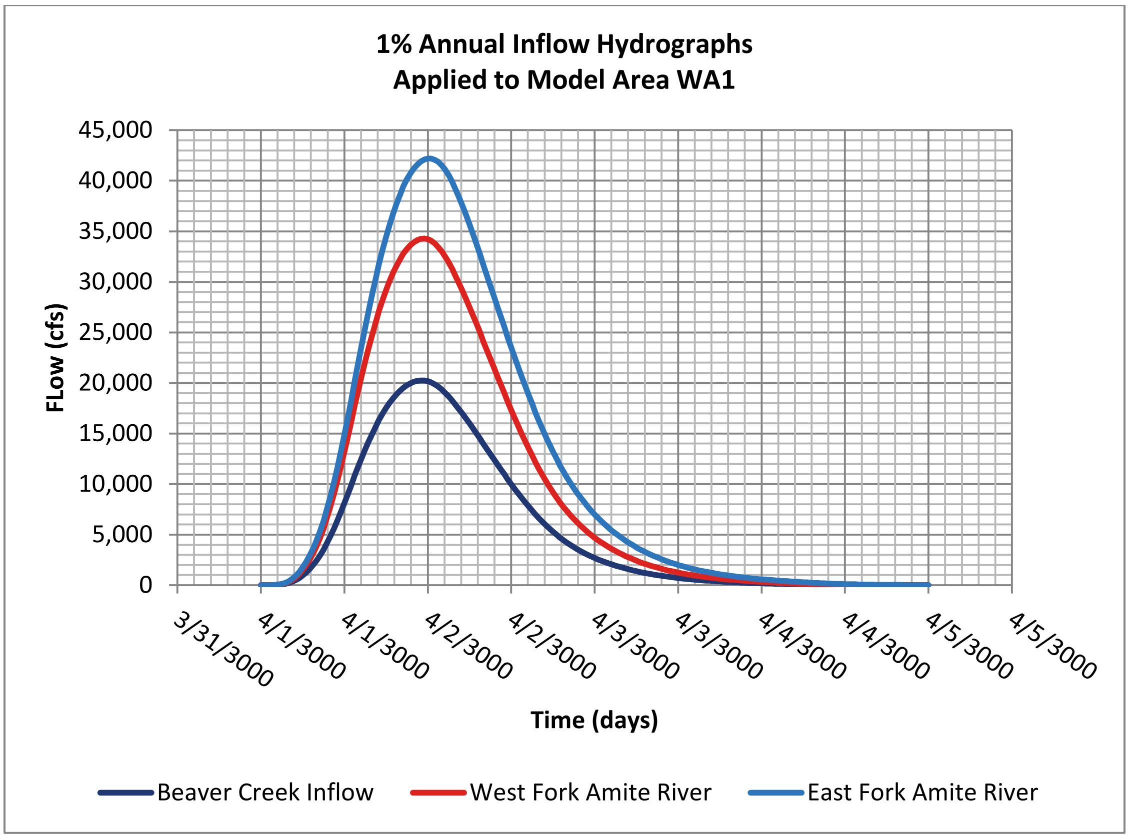

Figure 13: 1% Annual Chance Contributing Drainage Area Inflow Hydrographs applied to Model Area WA1

2.2.4 Hydraulics

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

2.2.4.1 Roughness Coefficients

Manning's n roughness coverage was developed for the 2D computational mesh using typical values for roughness for given NLCD land classifications. The table below shows a typical landuse-roughness matrix used in defining the roughness coverage for the study area.

Table 9: NLCD 2011-Manning's N Roughness Matrix

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

2.2.4.2 Breaklines

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including, road embankments and hydraulic structures. Road embankments were defined in GIS and imported into RAS 5 as breaklines to ensure that water was not routed past roads without passing through a structure until it was deep enough to overtop the road. Similarly, bridge/culvert crossings that were not processed out of the terrain data were modeled by offsetting breaklines adjacent to the road embankment to align grid cells around the embankment and allow water to be routed across the embankment without creating artificial backwater. This approach was used for most hydraulic structures because it could be implemented in GIS on a large scale with much less effort than alternative methods. An example of the offset breakline approach is shown below.

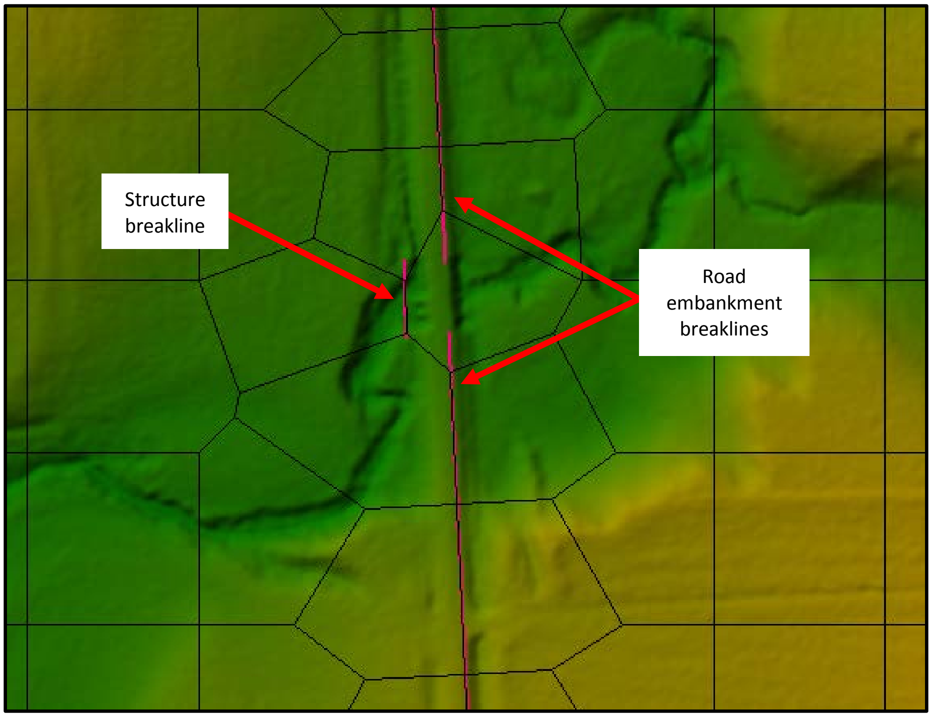

Figure 14: Offset Breakline Approach at Bridge Crossing

2.2.4.3 Internal Hydraulic Structures

Internal structures where utilized to define some prominent hydraulic structures and at locations where flow hydrographs needed to be extracted for calibration or flow transfer to an adjacent model. Internal structures at bridge or culvert crossings were input based on estimated parameters measured from aerial imagery (e.g., culvert diameter, culvert length, weir width, etc.). To extract flow hydrographs "dummy" weirs were input with a profile equivalent to the underlying terrain and a width one foot and a weir coefficient of 0.2 to minimize impacts to the hydraulics.

2.2.5 Model Results

The 2D BLE results for the study produced a Special Flood Hazard Area (SFHA) that compared reasonably well with the effective SFHA in most cases, and provides additional estimated SFHA in areas that do not currently have an SFHA mapped. While the results provide context for flood risk communication as part of the Discovery process, and are scalable, the results require further analysis to be used for regulatory purposes. The validity of the 2D BLE results should be verified through community work map meetings before being applied to a regulatory product. Figure 6 shows the USGS gage locations used for model calibration.

2.2.5.1 Calibration

Known USGS gages within the model area with rating curves were used for calibration of the 1% annual chance event.

Annual chance peak flows were calculated at each gage using USGS Bulletin 17B methodology. The 68% confidence interval was used to determine the 1%-plus and minus chance events. Calculated discharges for the 1%, 1%-plus, and 1%-minus events are presented in Table 10 for each gage utilized in this study.

Model calibration was achieved by calibrating to the gage elevation. The discharges used in the HEC-RAS 5.0 model may be lower than those determined using the Bulletin 17B Analysis however, this method represents a more accurate comparison because the ground surface may not have captured the entire channel and does not account for base flow in the channel. Results of the calibration are presented below in Table 10.

Table 10: USGS Gage Calibration Location Results

RAS 5 Model Area	Flooding Source	USGS Gages used for Verification	Bulletin 17B Flow Frequency Results			HEC-RAS 5.0 (2D)		USGS Gage
			1% (cfs)	1% Minus (cfs)	1% Plus (cfs)	1% Peak Q (cfs)	1% WSEL (ft)	WSEL (ft)
WA1	Amite River near Darlington, LA	07377000	106,000	89,550	128,700	112,396	167.1	167.7
WA2	Ward Creek at Siegens Lane near Baton Rouge, LA*	07380000	10,930	7,228	21,340	4,164		
	Ward Creek at Government Street, at Baton Rouge, LA*	07379000	2,936	2,502	3,678	293		
WA3	Comite River near Olive Branch, LA	07377500	36,610	31,520	43,490	34,065	134.7	133.4
	Little Redwood Creek Trib at JH PD, Wilson LA*	07377650	1,557	1,190	2,292	319		
	Redwood Creek near Slaughter, LA*	07377700	7,647	6,193	10,130	7,479		
	Comite River near Zachary, LA*	07377750	40,320	29,600	62,630	45,925		
	White Bayou E.DIV. Canal near Baton Rouge, LA*	07377755	2,032	1,728	2,555	1,558		
	White Bayou SE of Zachary, LA**	07377782	5,481	4,984	6,144	6,448		
	White Bayou near Baker, LA*	07377842	1,072	910	1,352	2,594		
	Comite River near Comite, LA**	07378000	36,690	32,800	41,710	28,055		
WA4	Amite River at Grangeville, LA *	07377150	101,800	71,290	169,200	104,144		
	Little Sandy Creek at Peairs Rd SE of Milldale, LA*	07377230	6,392	4,544	10,150	436		
	Little Sandy Creek near Greenwell Springs, LA*	07377240	22,710	13,840	47,570	6,643		
	Amite River at Magnolia, LA**	07377300	84,550	75,870	96,060	108,537		
WA5	Amite River near Denham Springs, LA	07378500	124,800	109,500	144,900	113,400	37.2	40.3
	Amite River at Port Vincent, LA **	07380120	75,850	65,530	90,970	28,028		

* Low number of gage records available for Bulletin 17B analysis
**No rating curves available

2.3 Challenges

Major challenges included a lack peak streamflow record, though sufficient data was available to provide confidence in the results. A majority of the gages in the Amite Watershed only have stage records and not flow records.

2.4 Recommendations

This study provides significant information useful for flood identification and communication among those affected. The study is highly scalable, and stakeholder input and further analysis could enhance end products and the transformation to regulatory flood hazard areas. Additionally, the results presented in this report and the accompanying FEMA data capture technical reference format flood hazard results should be presented and further evaluated through Flood Risk Review meetings before being mapped as special flood hazard area.

03 Floodplain Mapping and Effective Zone A Validation

The following sections provide a synopsis of how raw modeled depths were translated into SFHAs. In addition to developing a new SFHA, the BLE model data was leveraged to validate the effective zone A studies within the project footprint. The results of the validation effort can be found below in section 3.2.

3.1 Special Flood Hazard Area

3.1.1 Model Outputs

The floodplains are derived from the raw modeled depth grids using the maximum value. These depth grids are exported from HEC-RAS as TIFF format rasters with an interpolated rendering that slope values at the center and along the faces/edges of the computational mesh cells. Using GIS, the TIFF rasters are post processed into 1% SFHA and 0.2% shaded X polygons.

3.1.2 Methodology

The use of 2D modeling methods results in water surface elevation values at every cell in the model's computational mesh. In order to represent the desired model results and eliminate extraneous disconnected cells, post processing of the depth grids is required. For the purposes of the Amite BLE project, floodplain mapping delineation was completed using connected raster cells at the extent of the CNMS mapped and unmapped features in the project footprint. Converting the raster data to polygon features enabled an intersection of modeled results to the CNMS and effective zones to create the SFHA and 0.2% shaded X features. Because the new mapping, based on gridded engineering, retains the blocky shape of a raster, a simplification process was applied using GIS to smooth the boundaries. These processes remove unnecessary points, bends, and angles while preserving the natural shape of the polygon. Furthermore, small voids, or "holes" inside of the floodplain were aggregated with the larger surrounding polygons to merge them and make the floodplain complete. These edits adhere to traditional and approved floodplain mapping approaches.

In addition to the SFHA, all other flooding associated with the 1% and 0.2% raw results were retained as "on the shelf" data that may be leveraged for future needs and analysis.

3.1.3 Flood Hazard Area Layer

Special Flood Hazard Areas, as noted above, were developed to the extent of the CNMS features or up to 1 square mile drainage area and effective zone A study locations. The Regional CNMS database, National Flood Hazard Layer, and paper inventory were used as reference data to ensure extent of the BLE results represents appropriate flooding extent.

The 0.2% flood areas were produced using the same methods as the 1% SFHA. After both layers were developed, a union of the two products was performed to develop the deliverable format EBFE_FLD_HAZ_AR.

3.2 Validation of Effective Zone A SFHA

The following summarizes the results of the CNMS validation assessments for the effective Zone A studies in Amite Watershed.

3.2.1 Initial Assessment A1 – Significant Topography Update Check

The significant topography update check determines whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. For the study area in Amite, LA the effective Zone A topographic data source is unknown, but most likely would have leveraged contours from USGS 24K map products. The topographic data source for the BLE was derived from LiDAR flown for the state of Louisiana in 2006. This elevation data leveraged in the BLE represents a significant improvement from the assumed effective Zone A topographic source.

3.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

The significant hydrology changes check determines whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent-annual-chance flow. The significant hydrology changes check determines whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent-annual-chance flow. The latest published regression equation is The National Flood-Frequency Program-Methods For Estimating Flood Magnitude And Frequency In Rural Areas In Louisiana, 2001. It has been determined that the updated regression equations would significantly affect the 1-percent-annual-chance flow. Studies with a date of effective analysis prior to 2001 will fail this check.

3.2.3 Initial Assessment A3 – Check for Significant Development

The significant development check, using the National Urban Change Indicator (NUCI) dataset, assesses increased urbanization in the watershed of the BLE. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15 percent or more, and has increased by 50 percent or more since the effective analysis, the study would fail this check. 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 the Amite study area was completed by evaluating percentage of urban change at the HUC-12 level. None of the HUC-12 polygons within the study area met the threshold of 15% or more urban cover.

Table 11 presents the summarized results of checks A1 through A3.

Table 11: A1-A3 Validation Results

Assessment Checks	Pass / Fail	Notes
A1 – Topography	Fail	2006 LiDAR significantly better than assumed effective USGS topo source.
A2 – Hydrology	Fail	Updated Regression Equations from 2001 exist in LA from the time of assumed effective studies
A3- Development	Pass	Less than 15% of study area is under urban cover

3.2.4 Validation Check A4 – Check of Studies Backed by Technical Data

Zone A studies that pass all initial assessment checks described above may be categorized as “Valid” in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If the effective Zone A study passes all initial assessment checks, but is not supported by modeling, or if the original engineering method used is unsupported or undocumented, a comparison of the BLE results and effective Zone A’s is performed.

Due to lack of documentation of the original engineering methods in the Amite Watershed, check A4 has been marked as Fail in CNMS with the exception of Ascension Parish. Zone A areas in Ascension Parish were documented as being studied by detailed methods in the FIS Report.

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

The effective Zone A comparison was performed at the full extent of Amite Watershed. The validation of the effective Zone A boundaries using 2D flood hazard products differ from the standard 1D methods due to the lack of cross sections and their use with standard FBS methodology. For this 2D study, the effective A zone boundaries were compiled using a combination of data from the National Flood Hazard Layer and the CoreLogic digital uplift product. These data were dissolved to one continuous A-zone layer, which then had points placed along its perimeter every 250 feet.

For each test point, a 75-foot buffer was created. Using this buffer, the minimum and maximum values of the DEM were extracted, as a proxy for the effective base flood elevation. The minimum value of the 1% minus raster, and the maximum value of the 1% plus raster are also extracted. These 1% plus maximum and 1% minus minimum values act as the vertical tolerance. The point passes if the DEM minimum value is less than or equal to the 1% plus maximum value and the DEM maximum value is greater than or equal to the 1% minus minimum value. This can be visualized as a short 75-foot radius cylinder, with a height of 1% plus maximum – 1% minus minimum. This test verifies that there is at least one point from the ground surface (i.e. proxy BFE) falls both vertically and horizontally within this range.

3.2.6 Validation Results

Based on 619 total miles of available CNMS features representing the effective zone A studies, 101.6 stream miles were categorized as UNVERIFIED – TO BE STUDIED, and 517.4 miles categorized as VALID – NVUE COMPLIANT. Total miles in each of these categories are summarized in Table 12 and illustrated in Figure 15 below.

Table 13 summarizes the validation results based on the individual HUC 12 watersheds within Amite.

Table 12: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	NVUE COMPLIANT	517.4
UNVERIFIED	TO BE STUDIED	101.6

Table 13: HUC 12 Zone A Validation Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Amite	All Streams	77,332	6,711	70,621	0.91	Pass	
Cars Creek-East Fork Amite River	080702020106	44	3	41	0.93	Pass	6.1
Lower Beaver Creek	080702020303	787	28	759	0.96	Pass	3.2
Clear Creek-Amite River	080702020401	1,041	59	982	0.94	Pass	5.1
Sandy Run-Darling Creek	080702020402	730	17	713	0.98	Pass	2.1

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Sandy Creek-Darling Creek	080702020403	1,096	93	1,003	0.92	Pass	7.6
Bluff Creek-Amite River	080702020404	733	74	659	0.90	Pass	9.1
Pigeon Creek-Amite River	080702020405	1,101	150	951	0.86	Pass	12.3
Kidds Creek-Amite River	080702020406	2,359	150	2,209	0.94	Pass	5.7
Hunter Bayou-Sandy Creek	080702020501	2,041	35	2,006	0.98	Pass	1.5
Mill Creek-Sandy Creek	080702020502	613	41	572	0.93	Pass	6.0
Little Sandy Creek-Sandy Creek	080702020503	1,990	274	1,716	0.86	Pass	12.4
Beaver Creek-Sandy Creek	080702020504	1,606	145	1,461	0.91	Pass	8.1
Little Comite Creek-Comite River	080702020601	378	3	375	0.99	Pass	0.5
Richland Creek-Comite Creek	080702020602	230	16	214	0.93	Pass	5.9
Pretty Creek-Comite River	080702020603	1,435	71	1,364	0.95	Pass	3.9
Knighton Bayou-Comite River	080702020604	2,326	304	2,022	0.87	Pass	11.8
Doyle Bayou-Redwood Creek	080702020605	3,242	348	2,894	0.89	Pass	8.4
White Bayou-Comite River	080702020606	3,315	309	3,006	0.91	Pass	6.9
Blackwater Bayou-Comite River	080702020607	1,858	132	1,726	0.93	Pass	6.6
Hurricane Creek-Comite River	080702020608	6,223	453	5,770	0.93	Pass	7.0
Hornsby Creek-Colyell Creek	080702020701	1,187	151	1,036	0.87	Pass	11.5
West Colyell Creek-Middle Colyell Creek	080702020702	4,124	283	3,841	0.93	Pass	6.5
Middle Colyell Creek-Colyell Creek	080702020703	3,560	179	3,381	0.95	Pass	4.6
Little Colyell Creek-Colyell Creek	080702020704	3,092	227	2,865	0.93	Pass	6.6
Bayou Braud	080702020801	1,947	515	1,432	0.74	Fail	22.0
Bayou Braud-Bayou Manchac	080702020802	3,346	429	2,917	0.87	Pass	11.3
Ward Creek-Bayou Manchac	080702020803	4,245	157	4,088	0.96	Pass	3.6
Bayou Fountain-Bayou Manchac	080702020804	6,213	531	5,682	0.91	Pass	7.9

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Jones Creek-Amite River	080702020901	3,266	278	2,988	0.91	Pass	8.3
Beaver Creek-Amite River	080702020902	2,974	291	2,683	0.90	Pass	9.3
Grays Creek-Amite River	080702020903	2,062	151	1,911	0.93	Pass	7.0
Clay Cut Bayou-Amite River	080702020904	3,135	343	2,792	0.89	Pass	10.6
King George Bayou-Amite River	080702020905	1,643	48	1,595	0.97	Pass	2.7
Bayou Barbary-Amite River	080702020906	3,390	423	2,967	0.88	Pass	11.0

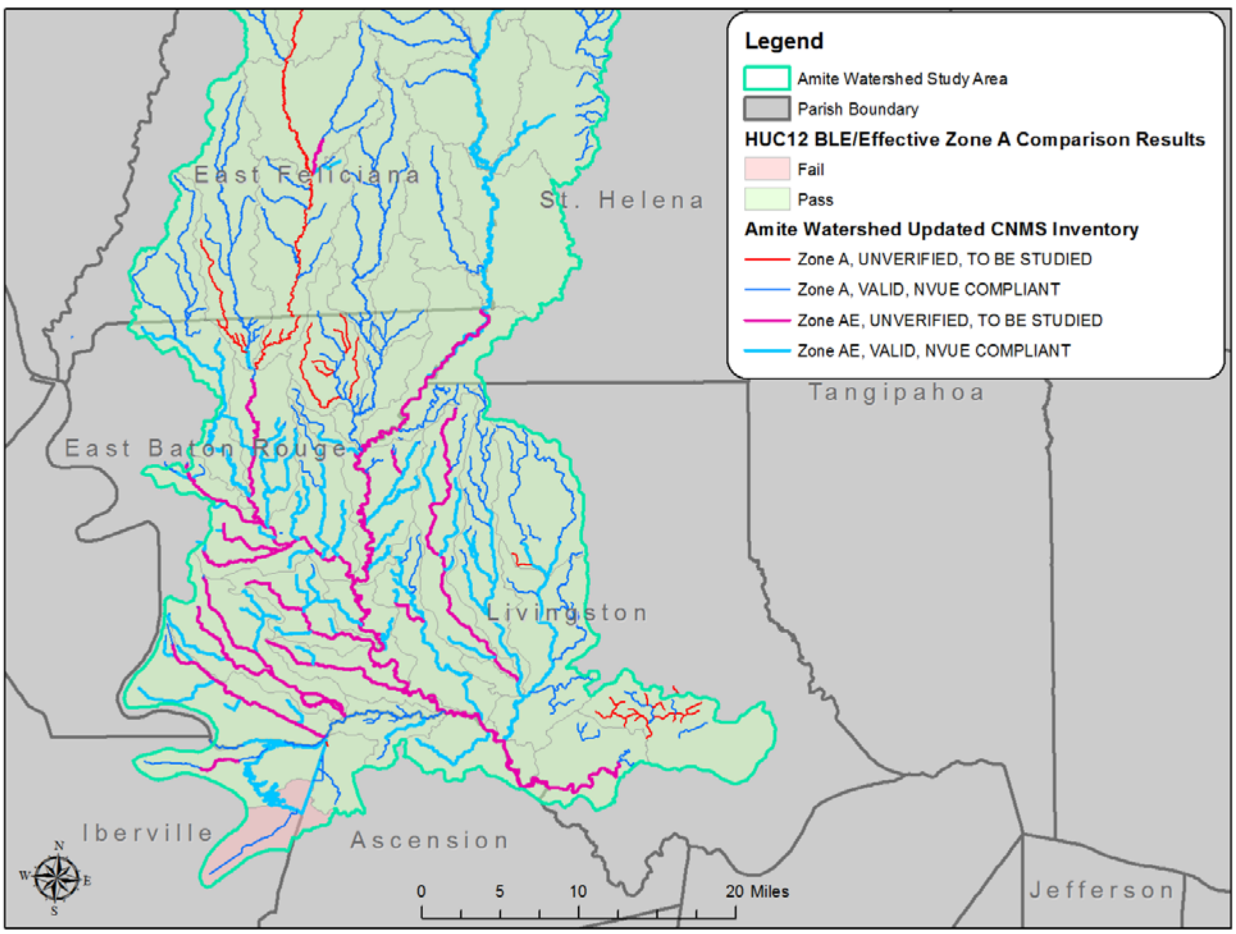

Figure 15: Amite Watershed CNMS Validation Results

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 16 below shows the range of the Amite HUC-8 priority scores which can be used to initiate discussions during the Discovery phase. Bayou Braud HUC-12 was determined to have the highest priority score and the most need while Little Comite Creek – Comite River HUC-12 has the lowest score.

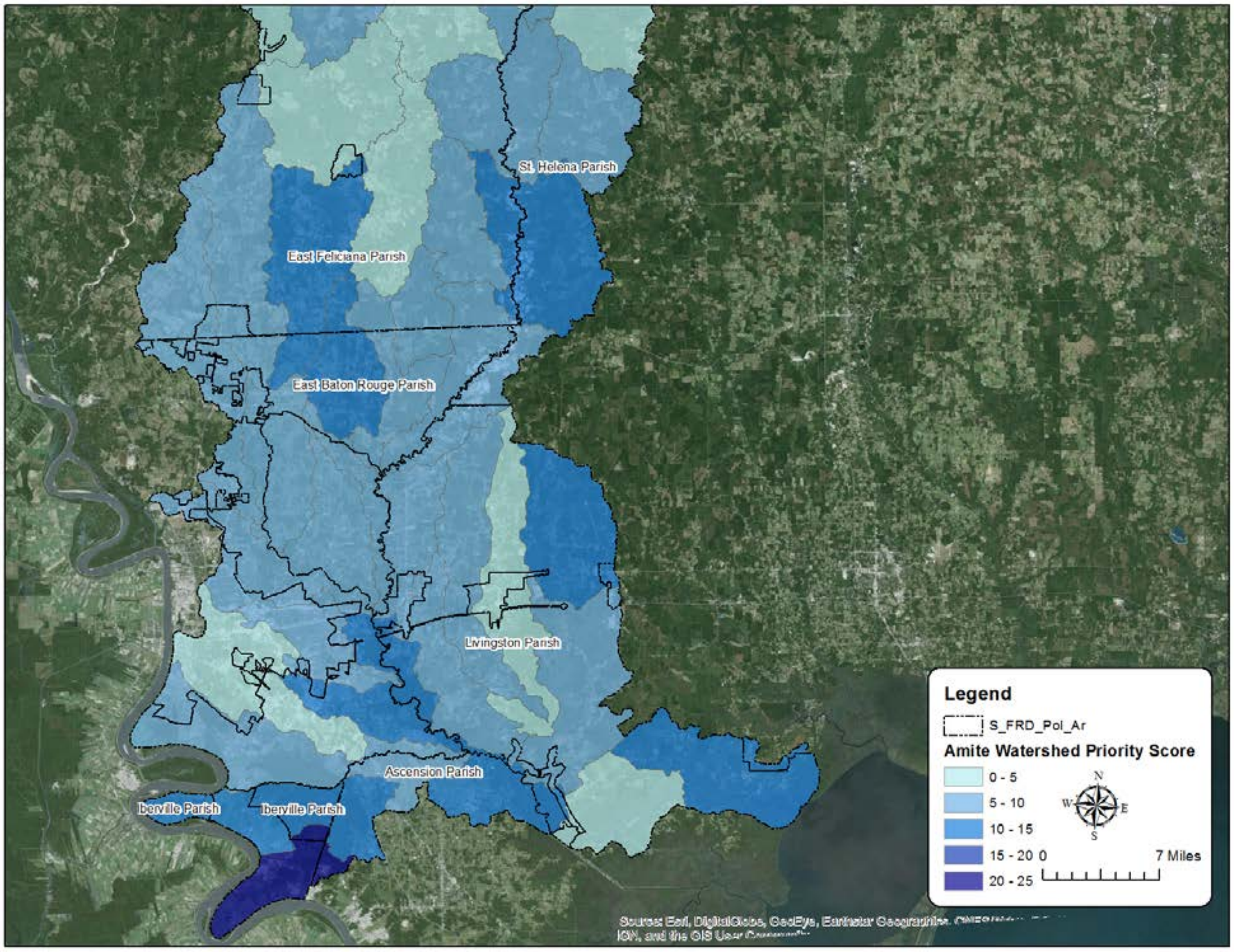

Figure 16: Ranking of Amite Watershed HUC-12s

3.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The initial 2010 AAL study was based upon 2000 census data, for this project a new Basic Hazus analysis was performed to establish a base level of flood losses. Those results are stored in the L_RA_AAL table. The updated 1-percent annual chance grid (known as 'refined' grid) was used to update the flood losses. The refined grid loss results are stored in the L_RA_Refined table. Both tables are combined to populate the L_RA_Composite table.

Hazus version 3.2 was used for the basic and refined loss analysis.

The losses are reported via census blocks. It is important to note that Hazus version 3.2 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

04 References

1. USGS, “Estimating Magnitude and Frequency of Floods Using PeakFQ Program: USGS Fact Sheet”, 2006.
2. USGS, “Methods For Estimating Flood Magnitude and Frequency in Rural Areas in Louisiana: USGS Fact Sheet”, 2001.
3. USGS, “Flood Characteristics of Mississippi Streams; Water-Resources Investigations Report 91-4037”, 1991.
4. USGS, “Water Resources Technical Report No. 75: Regionalized Regression Equations for Estimating Low-Flow Characteristics for Selected Louisiana Streams”, 2004.
5. USGS. Multi-Resolution Land Characteristics Consortium. *National Land Cover Database 2011*. (http://www.mrlc.gov/nlcd2011.php).
6. Chow, Ven T. "Development of Uniform Flow and It Formulas." *Open Channel Hydraulics*. Caldwell, NJ: Blackburn, 1959. 109-113. Print.
7. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (September 2016). HEC-RAS River Analysis System, Version 5.0.3 Davis, California.
8. FEMA, “Guidance for Flood Risk Analysis and Mapping – Automated Engineering”, May 2016. (https://www.fema.gov/media-library-data/1469144112748-f3c4ecd90cb927cd200b6a3e9da80d8a/Automated_Engineering_Guidance_May_2016.pdf).

Appendix A BLE Map