Huxtable Pumping Station Photo Courtesy: US Army corps of Engineers

Lower St. Francis Watershed, AR Base Level Engineering (BLE) Results

Lower St. Francis Watershed, HUC - 08020303

Clay*, Craighead*, Crittenden *, Cross*, Greene*, Lee*, Mississippi*, Phillips*, Poinsett*, St. Francis* Counties, Arkansas and, Bollinger*, Butler*, Dunklin*, Stoddard*, and Wayne* Counties, Missouri

**Spans more than one watershed. This report covers only the area within the studied watershed.*

June 2017

Project Area Community List

Community Name	CID
Arkansas	
Clay County Communities	
Clay County[1]	050423
Greenway, City of	050031
Nimmons, Town of	050332
Piggott, City of[1]	050035
Rector, City of	050366
St. Francis, City of	050037
Craighead County Communities	
Bay, City of	050045
Black Oak, Town of	050389
Brookland, City of	050047
Craighead County[1]	050427
Jonesboro, City of[1]	050048
Lake City, City of	050049
Monette, City of	050350
Crittenden County Communities	
Anthonyville, Town of	050512
Clarkedale, Town of	050513
Crawfordsville, City of	050317
Crittenden County[1]	050429
Earle, City of	050054
Edmondson, Town of	050409
Gilmore, Town of	050245
Horseshoe Lake, Town of	055057
Jennette, Town of	050514
Jericho, Town of	050515
Marion, City of	050345
Sunset, Town of	050476
Turrell, City of	050370
West Memphis, City of	050055
Cross County Communities	
Cross County[1]	050056
Parkin, City of	050059
Wynne, City of[1]	050060
Greene County Communities	
Greene County[1]	050435
Oak Grove Heights, City of	050510
Paragould, City of	050085

Lee County Communities	
Lee County[1]	050444
Mississippi County Communities	
Bassett, Town of	050489
Birdsong, Town of	050516
Blytheville, City of[1]	050140
Burdette, Town of	050602
Dell, Town of	050490
Dyess, Town of	050143
Joiner, City of	050145
Keiser, City of	050146
Luxora, City of	050148
Marie, Town of	050150
Mississippi County[1]	050452
Osceola, City of	050151
Victoria, Town of	050491
Wilson, City of	050153
Phillips County Communities	
Phillips County[1]	050166
Poinsett County Communities	
Lepanto, City of[1]	050174
Marked Tree, City of	050175
Poinsett County[1]	050172
Trumann, City of	050176
Tyronza, City of	050371
St. Francis County Communities	
Forrest City, City of[1]	050187
Hughes, City of	050188
Madison, City of	050189
St. Francis County[1]	050184
Widener, Town of	055023
Missouri	
Bollinger County Communities	
Bollinger County[1]	290787
Butler County Communities	
Butler County[1]	290044
Fisk, City of[1]	290045
Dunklin County Communities	
Cardwell, City of	290125
Dunklin County[1]	290122
Holcomb, City of[1]	290127
Kennett, City of[1]	290129

Stoddard County Communities	
Bloomfield, City of	290423
Dexter, City of[1]	290424
Dudley, City of	290615
Puxico, City of	290428
Stoddard County[1]	290845
Wayne County Communities	
Wayne County[1]	290449

[1] Community is located within more than one HUC8 watershed.

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BLE Workmaps (Digital Format Only)

1. Executive Summary

The U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) is currently implementing the Risk Mapping, Assessment, and Planning (Risk MAP) Program across the Nation. The vision and intent of the Risk MAP program is to, through collaboration with State and Local entities, deliver quality data that increases public awareness and leads to mitigation actions that reduce risk to life and property. To achieve this vision, FEMA has transformed its traditional flood identification and mapping efforts into a more integrated process of more accurately identifying, assessing, communicating, planning and mitigating flood risks. Risk MAP attempts to address gaps in flood hazard data and form a solid foundation for risk assessment, floodplain management, and provide State and Local entities with information needed to mitigate flood related risks.

The FEMA Region 6 office and the Arkansas Natural Resources Commission (ANRC) entered into a Cooperating Technical Partners (CTP) partnership agreement for implementation of Risk MAP in the State of Arkansas. As part of this partnership, the ANRC and its contractor, FTN Associates, Ltd. (FTN), began work on a Base Level Engineering (BLE) analysis in the Lower St. Francis Watershed in October 2016 to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Area (SFHA).

The BLE process involves using best available data and incorporating automated techniques with existing hydrologic and hydraulic (H&H) model development procedures to produce quality flood hazard boundaries and secondary products (Water Surface Elevation grids, Depth grids, etc.) for multiple recurrence intervals. The purpose and intent of the BLE process is to validate existing Zone A flood boundaries within the existing Coordinate Needs Management Strategy (CNMS) dataset and provide updated flood risk data in the early stages of a Flood Risk Project (Discovery). An important goal of the BLE process developed by FEMA is the scalability of the results. Scalability means that the results of an BLE cannot only be used for CNMS evaluations of Zone A studies but also leveraged throughout the Risk MAP program.

The source digital terrain data used for surface model development in support of H&H analysis, as well as mapping activities were leveraged from existing Light Detection and Ranging (LIDAR) data collected by the Natural Resource Conservation Service (2012 L'Anguille and Lower St. Francis Watershed Area), the U.S. Army Corps of Engineers (2014 AR-MO LIDAR Project, 2014 Cape Girardeau-Stoddard Co., 2014 Stoddard-Mississippi Co., 2016 USACE_MVS_MO [Butler_Ripley], 2009 Duck Creek LiDAR datasets), and the United States Geological Survey (2012 Upper Black, 2013 Lower St. Francis, 2012 Dunklin County, 2012 Wappapello datasets, USGS 1/3 arc-second DEMs). The LiDAR datasets were 1-meter gridded DEM data that were reprojected to a 15 ft cell size for hydrologic processing and a 5 ft cell size for hydraulic and mapping processing in 1D areas and 15 ft cell size for 2D areas.

Flood discharges for this analysis were calculated using the National Oceanic and Atmospheric Administration's National Weather Service, Precipitation Frequency Data Server (PFDS) for Atlas 14, ESRI's ArcGIS software, the HEC-Hydrologic Modeling System (HEC-HMS) computer program, and the HEC - River Analysis System (HEC-RAS) program (versions 4.1 or 5.0.3). Initial precipitation values were obtained, based on a watershed level, from NOAA's Precipitation Frequency Data Server (PFDS) for Atlas 14, which was then processed in ESRI's ArcGIS 10.x software into a usable format. The obtained preceipitation values and resulting GIS parameters for the watershed, were then input into HEC-HMS to determine the excess rainfall that would result based on the applied conditions. For 2-D study areas, this excess rainfall was then applied to a 2-D HEC-RAS model in the form of a rain on grid scenario, which was then used compute the water surface elevations for the 10-, 4-, 2-, 1-, 0.2-percent-events and the 1-percent-minus and 1-percent plus flood events. For 1-D study areas, a traditional HEC-HMS model was produced. In areas of were then inserted in HEC-RAS to model water surface elevations.

The modeled stream mile network for the Lower Saint Francis Watershed to include streams that extended upstream to a contributing drainage area of approximately 1 sq. mile.

2. Base Level Engineering (BLE) Methodology

This section provides guidance for the hydrologic, hydraulic and floodplain mapping steps required to create a BLE. The BLE process involves using best available data and incorporating automated techniques with existing H&H model development procedures to produce quality flood hazard boundaries and secondary products (Water Surface Elevation grids, Depth grids, etc.) for multiple recurrence intervals. The purpose and intent of the BLE process is to validate existing Zone A flood boundaries within the existing CNMS dataset and provide updated flood risk data in the early stages of a Flood Risk Project (Discovery).

The cost and effort for developing the data and estimates resulting from the BLE process are lower than standard flood production tasks. An important goal of the BLE process developed by FEMA is the scalability of the results. Scalability means that the results of an BLE cannot only be used for CNMS evaluations of Zone A studies but also leveraged throughout the Risk MAP program. The large volume of data resulting from an BLE can be 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.

Per the the Code of Federal Regulations, once every five years, FEMA must evaluate whether the information on Flood Insurance Rate Maps (FIRMs) reflects the current risks. This evaluation is done by examining the existing flood boundaries for changes in study attributes and physical characteristics, as specified in the CNMS Technical Reference. Additionally, this evaluation occurs using a series of critical and secondary checks to determine the validity of the existing flood hazard areas. In addition to the need for evaluating the accuracy of Zone A mapping, newer FEMA standards also require that flood risk data be provided in the early stages of a Flood Risk Project. Particularly, 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.

Therefore, based on these requirements, the results of the BLE process are being provided to the local Floodplain Administrators (FPAs), which allows for users to have access to a model backed Zone A study that is suitable to replace the effective Zone A products. The following sections are being supplied to document the hydrologic, hydraulic, and floodplain mapping techniques used. Regardless of the individual techniques used to perform these steps, the goal of a scalable product should be adhered to throughout the entire BLE process.

2.1. Terrain

To determine the parameters for the hydrologic and hydraulic analyses, FTN obtained Digital Elevation Model (DEM) data developed from LIDAR information that was collected by the Natural Resource Conservation Service (2011 L'Anguille and Lower St. Francis Watershed Area), the U.S. Army Corps of Engineers (Crittenden_Cross, Game-Fish, Mississippi-Lauderdale, Monroe_Lee-

Phillips, Phillips_Desha, Poinsett_Craighead_Greene, and St. Francis_Lee, Cape Girardeau-Stoddard Co., Stoddard-Mississippi Co., USACE_MVS_MO [Butler_Ripley], Duck Creek, LiDAR datasets), The United States Geological Survey (FEMA_VI_Upper_Black_Watershed, FEMA_VI_Lower_St._Francis Watershed, Dunklin_MO, Wappapello datasets, and 1/3 arc-second elevation data). The bare earth DEM data was provided as 1-meter, 1/3 arc-second, or 1/9 arc-second DEMs with varying horizontal and vertical coordinate systems. Prior to use, the DEM data was resampled to a 5- and 15-foot cell size, where possible, with a horizontal coordinate system of NAD 1983 State Plane Arkansas North (feet) with a vertical datum of NAVD 88 in feet. DEMs were then mosaicked into a single DEM that covered the entire watershed. The single DEM was then processed using Environmental Systems Research Institute's (ESRI) ArcMap Geographic Information System (GIS) 10.2.2 software and the ArcHydro toolset to develop the hydrologic parameters needed for the time of concentration and longest flow path lengths required for developing flow estimates.

A terrain and workmap index has been prepared and is attached to the end of this report and included in Appendix A – Workmaps.

2.2. Hydrology

Excess runoff for the 10-, 4-, 2-, 1-, 0.2-percent-events and the 1-percent-minus and 1-percent plus flood events were calculated using NOAA's Precipitation Frequency Data Server (PFDS) for Atlas 14. This task was completed by processing raster data for the study events based on a HUC-10 level. The excess rainfall values were spatially averaged from raster data using the zonal statistics toolset in ESRI's ArcGIS. The maximum rainfall values, based on a HUC 10 level were selected as input for the resulting HEC-HMS model.

In addition to the Atlas 14 precipitation values, ESRI's ArcGIS software and supporting toolsets were used to process the initial terrain data, delineate drainage basins, and develop basin parameters for the study area. In addition, drainage points were obtained around the basin in such a way that there is a point upstream of the confluences in each of the stream and also at the downstream. In addition, drainage points were also created on the top of structures. Drainage basins for each of these drainage points were then established.

For this BLE analysis, the SCS Cuver Number Method was used for the Loss Method due to varying landuses. For the curve number calculations, the weighted Curve Numbers were developed using the 2011 National Land Cover Database, NRCS's SSURGO Soil Surveys, TR-55 runoff curve numbers, and ESRI's ArcGIS software. The watershed was assumed to be at Antecedent Moisture Condition II (average moisture condition).

The SCS Lag Method was used for the Transform Method. As this is not considered a detailed analysis, this method uses imperical methods to develop representative parameters for each subwatershed. Additionally, the SCS Type II rainfall distribution was used to distribute the rainfall across the basin. Table 1, shown below, lists the initial and excess rainfall used for the hydrologic analysis.

As this analysis uses both 1-D and 2-D analyses, additional details regarding the hydrologic modeling are described below:

1-D: Upon completion of the base hydrologic data, a complete hydrologic model was developed based on HUC-10 boundaries using the parameters discussed above and reach routing techniques. The routing method used for this project is the Modified Puls Routing Method. Storage-discharge relationships for each reach were developed by establishing an initial HEC-RAS model. The HEC-RAS model consisted of a reach for each drainage basin, and each reach was represented by 2 - 4 cross sections with flows ranging from 5 cfs to 400,000 cfs (upper limit varies based on size of stream). Cross sections were drawn initially using an automated routine based on the stream sinuosity. However, these cross sections were then refined manually to account for structures and other obstructions that might impact the flow of water downstream. Additionally, the hydraulic routing model used normal depth slope methods for the downstream boundary condition.

Once all parameters were developed, a final HUC 10 basin HEC-HMS model was produced, with the resulting flows being reviewed and then incorporated into the hydraulic modeling.

2-D: Upon completion of the base hydrologic data, the hydrologic model was run to determine the excess rainfall that would be translated to runoff. As the SCS Curve Number method was used, some of the initial rainfall is determined to remain. This is referred to as initial abstraction. Initial abstraction is the fraction of the storm depth after which runoff begins. After determining the excess runoff in HEC-HMS for the watershed, this information was then applied to the 2-D hydraulic model as a rain on grid scenario.

Tables 1 - 5, shown below, lists the initial and excess rainfall used for the various model extents shown in the hydrologic analysis.

Table 1: List of rainfall and peak runoff volume at different recurrence interval (Missouri 2-D Area)

Recurrence Interval (% chance)	Missouri 2D area	
	NOAA Atlas 14 Rainfall (in)	Excess Volume (in)
10	5.44	3.18
4	6.66	4.24
2	7.66	5.14
1	8.71	6.12
0.2	11.42	8.71
1-plus	11.27	8.57
1-minus	6.53	4.13

Table 2: List of rainfall and peak runoff volume at different recurrence interval (West 2-D Area)

Recurrence Interval (% chance)	West 2D Area	
	NOAA Atlas 14 Rainfall (in)	Excess Volume (in)
10	5.39	3.24
4	6.39	4.15
2	7.17	4.85
1	7.97	5.6
0.2	9.96	7.53
1-plus	9.97	7.55
1-minus	6.23	4.03

Table 3: List of rainfall and peak runoff volume at different recurrence interval (Northeast 2-D Area)

Recurrence Interval (% chance)	Northeast 2D Area	
	NOAA Atlas 14 Rainfall (in)	Excess Volume (in)
10	5.46	3.32
4	6.49	4.23
2	7.27	5.0
1	8.11	5.76
0.2	10.09	7.63
1-plus	10.2	7.72
1-minus	6.27	4.05

Table 4: List of rainfall and peak runoff volume at different recurrence interval (Southeast 2-D Area)

Recurrence Interval (% chance)	Southeast 2D Area	
	NOAA Atlas 14 Rainfall (in)	Excess Volume (in)
10	5.44	3.62
4	6.45	4.53
2	7.23	5.28
1	7.98	6.02
0.2	9.95	7.89
1-plus	9.93	7.85
1-minus	6.29	4.37

Table 5: List of rainfall at different recurrence interval (1-D Study sreams)

Recurrence Interval (% chance)	1D Area
	NOAA Atlas 14 Rainfall (in)
10	5.51
4	6.48
2	7.25
1	8.04
0.2	9.98
1-plus	9.76
1-minus	6.48

2.3. Hydraulics

For 1D and 2D areas, all streams identified in the Lower St. Francis Watershed, the BLE process uses ESRI ArcGIS software and toolsets to create the HEC-RAS layers used for geometric data development and extraction. Additionally, the hydraulic modeling and mapping for this BLE process was conducted using the USACE's HEC-RAS software package, versions 4.1 (1D) and 5.0.3 (2D). Figure 1. Study Areas provides additional details as to the location of each of the study zones.

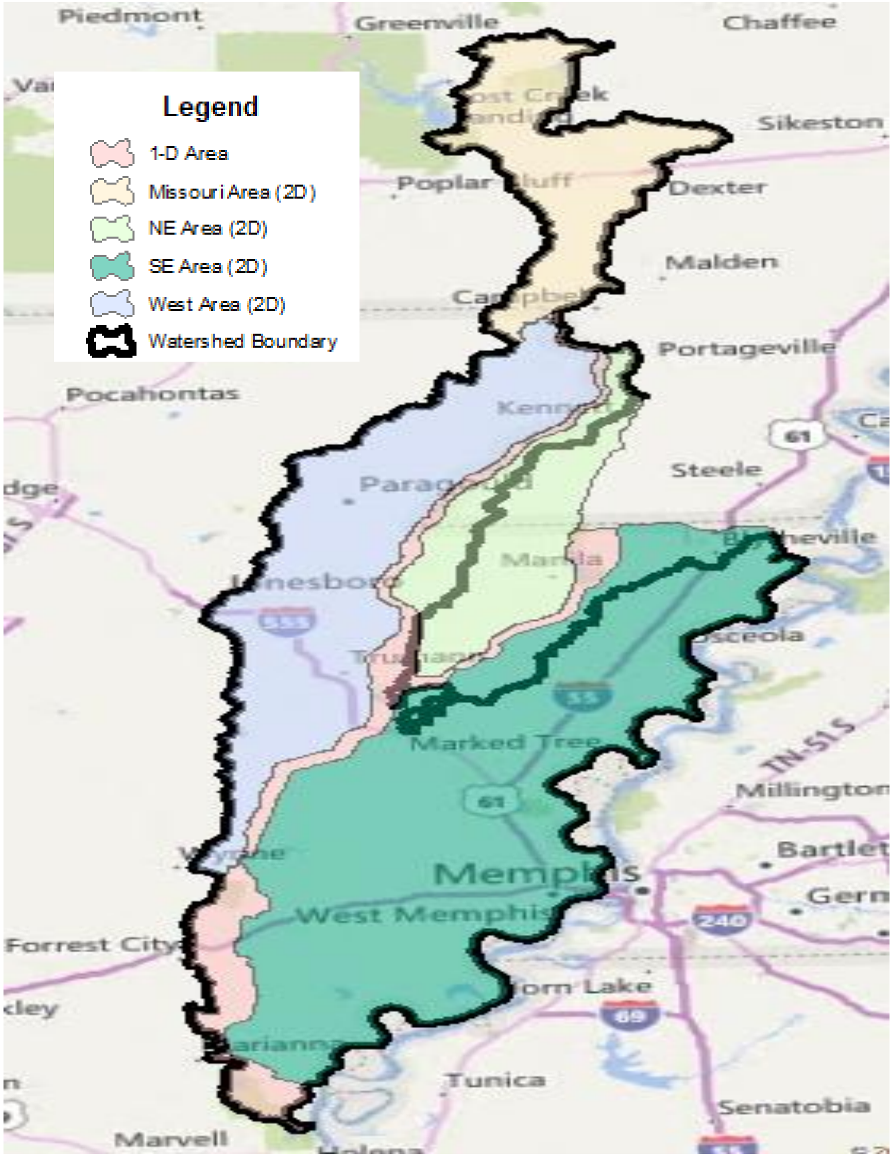

Figure 1. Study Areas

Streams

The streamlines used for determining what areas needed to be modeled were taken from the CNMS dataset. They were then expanded to include streams that extended up to a contributing drainage area of approximately 1 sq. mile. These streams were then reviewed and updated to match aerial imagery and detailed topographic data, as needed.

Cross Sections (1-D analysis)

1-D: For the remaining streams, the hydraulic approach for BLE analysis for the Dardanelle Reservoir watershed consisted of using the terrain data described in Section 2.1, in combination with the hydrology discharges computed Section 2.2, to establish water surface elevations using 1-D steady state analysis. HEC-RAS 4.1.0 was chosen to compute water surface elevations on a stream by stream basis within the watershed. ESRI's ArcGIS computer program and supporting HEC-GeoRAS toolset were also used to establish streams, cross section layouts and stationing, assign Manning's "n" values to cross sections, and to develop all input files for the HEC-RAS program.

Initial cross section layouts were developed using an automated routine based on the stream sinuosity. These cross sections were then edited manually, as needed, and additional cross sections were placed upstream and downstream or structures and along the top of the structure, considering bridges or culverts will impact the flow of water downstream. Cross sections were also placed across easily identifiable watershed dams, as the number of dams located on a stream was minimal. Additionally, attempts were made to ensure that cross sections contained all flows modeled (particularly the 0.2- and 1%-plus-annual-chance events); however, due to the possibility of basin overflows or common floodplains, there are some cross sections that may have vertical extensions.

The channel banks used in the hydraulic models were based on offsetting the main channel stream centerline by a 30-ft interval. After testing sensitivity of the bank station locations, it was determined that the manual adjustment of the bank stations to more realistic locations was not warranted at this time. Likewise, the reach lengths were determined by offsetting the stream centerline by a 150-ft interval. This approach was again used to allow for more automated processes to be conducted to more efficiently develop the hydraulic modeling.

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.

2-D: Hydraulic modeling for the Cache Watershed BLE Analysis was computed using 2-D analyses to better reflect the large, flat, and interconnected floodplains. To perform this modeling, 2-D capabilities of the HEC-RAS 5.0.3 was utilized. With a 2-D model, the area is modeled using a topographic mesh rather than a series of cross sections down the longitudinal axis of the stream reach, as is done in a 1-D model. The HEC-RAS mesh consists of computational cells that are assigned elevations and roughness values along the cell faces that represent the topographic surface and frictional characteristics of the area and and volumetric relationships for the cell area, respectively. The use of the 2-D model allows for more detailed resolution in water surface elevations, velocities, and flows than is possible with a 1-D model that is only capable of computing the average water surface elevations, velocities, and flows for three general regions at a cross section. Based on engineering judgement, breaklines were defined along the levees, dams, roads, culverts and elevated berms as seen on the topography. It is necessary to draw breaklines as it makes sure that the flow across the cell faces is blocked by the elevation of the structure along the break line.

Parameter Estimation

The Manning's "n" values used were based on engineering judgment and using the 2011 National Land Cover Data (NLCD) dataset. Table 6 lists the landuse and roughness coefficients used in this analysis.

Table 6: Manning's "n" Coefficients

Material Type	Manning's "n"
Open Water	0.01
Developed, Open Space	0.04
Barren Land (Rock/Sand/Clay)	
Grassland/Herbaceous	0.05
Pasture/Hay	
Emergent Herbaceous Wetlands	
Developed, Low Intensity	0.06
Shrub/Scrub	
Cultivated Crops	
Developed, Medium Intensity	0.08
Developed High Intensity	0.10
Deciduous Forest	
Evergreen Forest	
Mixed Forest	
Woody Wetlands	

Boundary Conditions

For this BLE analysis, the downstream boundary conditions are set to be normal depth slope. The computed slope is based on topographic data from the downstream limits of the modeling.

Model Calibrations

No calibration was performed on these streams, although streams with gages were reviewed for consistency with respect to estimated and observed discharges and gage heights.

2.4. Quality Control

Throughout the BLE analysis, quality checks were performed. These checks included review of topographic data processing, hydrologic parameters being applied, checking for complete model coverage, adjusting the mesh cell sizes, adjusting mesh boundaries, adding breaklines along structures, as required, and review of the final mapping results.

2.5. Mapping

Following the hydraulic analysis, the model results were then imported into the HEC-RAS RAS Mapper tool to map floodplain boundaries for the model extent. This tool uses a routine that develops water surface elevation grids based on the elevation datasource. For this BLE analysis, mapping results were developed for seven (7) events. These events were the 10-, 4-, 2-, 1-, 0.2-percent-events and the 1-percent-minus and 1-percent plus boundaries.

Once the floodplain boundaries were created, the resulting floodplain data were smoothed and small polygons (less than 0.25 acres) and small disconnected fragments were removed. After the initial boundary edits, the resulting floodplain boundaries were merged into a single watershed based map boundary. For this BLE process, only the 1-percent-annual-chance floodplain is reported on the workmaps. Workmaps were generated to provide a graphical comparison of the effective floodplain boundaries to that of the BLE processed streams. These workmaps are provided in Appendix A – Workmaps.

Once the map boundaries were cleaned, the resulting rasters (Water Surface Elevation, Depth, etc.) were developed with the raster set to correspond in extent to the cleaned polygon boundary. This ensures that the water surface raster and the floodplain boundary are consistent with each other. The depth raster product was created by performing a raster subtraction with the water surface elevation raster and the ground DEM. Once complete, the resultant depth grids were used to perform an updated Flood Loss Analysis for the watershed using the HAZUS program.

3. Submittal

All information, data, and files for the Lower St. Francis Watershed BLE process are uploaded to the FEMA MIP and provided digitally in electronic format in a directory structure provided below.

08020303\Lower St. Francis Watershed BLE

\General

- Project Narrative (PDF)

\Hydraulic_Models

\<HUC-8>\<Stream Name> *(St. Francis River and 2D models)*

- HEC-RAS models

\<HUC-10>\<Stream Name>

- HEC-RAS models

\Spatial_Files

- Lower St. Francis_Watershed (file geodatabase format)

\Supplemental_Data

\CNMS_Update

- CNMS database update (file geodatabase format)

\HAZUS

- Loss Analysis project

\Mapping

- BLE Mapping files (multiple events)

\Workmaps

- Terrain and Workmap Index (PDF)
- Workmaps (PDF)
- Workmap Index (SHP format)
- Community Map Index (if needed)

4. References

1. USGS. Multi-Resolution Land Characteristics Consortium. *National Land Cover Database 2011*. (http://www.mrlc.gov/nlcd2011.php).

2. NOAA. Precipitation-Frequency Atlas of the United States, Atlas 14. (http://hdsc.nws.noaa.gov/hdsc/pfds/).

3. Chow, Ven T. *Open Channel Hydraulics*. Caldwell, NJ: Blackburn, 1959. Print.

4. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (January 2010). HEC-RAS River Analysis System, Version 4.1.0. Davis, California.

5. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (September 2016). HEC-RAS River Analysis System, Version 5.0.3. Davis, California.

6. FEMA, “Guidance for Automated Engineering”, May 2016.(http://www.fema.gov/media-library-data/1469144112748-3c4ecd90cb927cd200b6a3e9da80d8a/Automated_Engineering_Guidance_May_2016.pdf).