
# Base Level Engineering

## Region 6 Submittal Guidance

Version 6

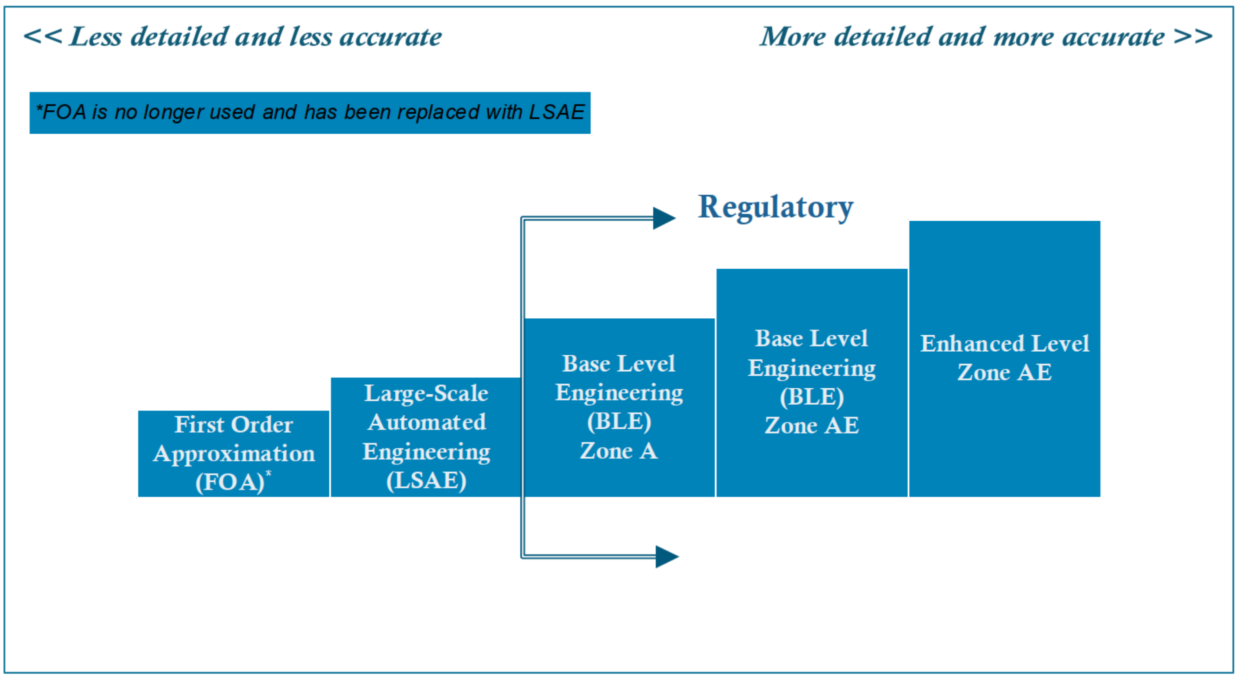
***July 2021***

FEMA

## Preface

FEMA Region 6 is funding Base Level Engineering (BLE) in watersheds throughout the Region. The investment in producing broad flood hazard information through the BLE methodology will provide regulatory-ready flood hazard data in the form of engineering models, floodplain extents and other visualization tools that will assist communities to better determine their flood risk with Estimated Base Flood Elevations (EBFEs). The intent of this document is to provide information to all Mapping Partners within the Region that are delivering Base Level Engineering throughout Region 6.

This guidance document supports effective preparation of BLE analysis, including compilation of the minimum deliverables and datasets consistent with Risk MAP Program and Regional development and deliverable requirements. As emphasized in FEMA's BLE Analyses and Mapping Guidance (2018), Region 6 requires engineering models created during a BLE assessment to produce information that meets the mapping Standards for Flood Risk Projects (FEMA Policy Memo FP 204-078-1) to produce Zone A (1-percent-annual-chance flood) information.




Data from the BLE assessment shall be delivered to meet both MIP (FEMA Data Capture Technical Reference) and Regional (Estimated Base Flood Elevation Viewer) requirements.

BLE data will be developed for viewing and download with the use of an interactive mapping platform named the Estimated Base Flood Elevation Viewer (https://webapps.usgs.gov/infrm/estBFE/) where users can interact with datasets, point and click to estimate Base Flood Elevations and download models, spatial data and reports. This centralized distribution requires a standardized set of deliverables be produced and made available. This guidance document provides overview and insight into the required delivery of Base Level Engineering datasets to allow the data prepared to allow data transfer between Mapping Partners, and delivery of all required information to support broader data sharing with communities through the Estimated Base Flood Elevation Viewer. Following the guidance document will promote the timely release and availability of Base Level Engineering data through the interactive viewer.

BLE data will also be delivered to the MIP through respective data capture purchases and tasks to establish a basis for a future regulatory update. Completeness and validation checklists for BLE MIP deliveries are contained within this submittal guidance document. Mapping Partners should also refer to respective MIP workflow guidance and data capture technical references for additional information and requirements to complete MIP delivery.

This guidance document supports effective and efficient implementation of flood risk analysis and mapping standards codified in the Federal Insurance and Mitigation Administration Policy FP 204-07801.

For more information on the Estimated BFE viewer and Federal Emergency Management Agency (FEMA) Guidelines and Standards for Flood Risk Analysis and Mapping, please review respective webpages https://webapps.usgs.gov/infrm/ and (https://www.fema.gov/flood-maps/guidance-reports/guidelines-standards). Information is available regarding access to the BLE data and which policies, guidance, technical references, standards govern BLE development and expectations.

## Document History

| Affected Section or Sub-Section | Date | Description |
|---|---|---|
| First Tabular Release | February 2016 | BLE database tables prepared to support development of geodatabase template. |
| First Narrative Publication | June 2017 | Narrative report prepared and tabular guidance previously prepared was expanded upon for use by all active Mapping Partners preparing Base Level Engineering within Region 6. |
| Submittal Guidance (Spatial Delivery) | November 2017 | Updated existing guidance to include additional information to spatial delivery including 2-D BLE delivery. Also included minor updates to folder structure requirements for MIP upload, XS backwater data inclusion and addition of BFE layer for 2-D BLE delivery. |
| Addition of Appendix A | November 2017 | Appendix A was added to the document to provide Mapping Partners information for the preparation of 2-D BLE engineering analysis and spatial datasets. |
| General Document Update | October 2018 | Updated to reflect February 2018 guidance and standards update including CNMS, Flood Risk Products, Hazus and the new MIP structure. Also includes new procedure for loading to the new EBFE viewer. |
| Submittal Guidance (Modeling) | January 2019 | Updated guidance to provide outlines and templates to support 2-D model delivery. |
| Tips and Tricks | January 2019 | Additional guidance based on delivery reviews and troubleshooting. |
| Update to Database files – Hazus Results | April 2019 | Update to Spatial Template (Mitigation Layers) to match updates to National Flood Risk Database/Dataset modifications outlined in Flood Risk Database (FRD) Technical Reference, dated February 2018. Updates include:<br>• Remove FRD_Pol_AR<br>• Replace with S_Pol_AR<br>• Remove S_CenBlk_Ar dataset<br>• Replace with S_FRAC_AR dataset<br>• Remove L_RA_Results table<br>• Renamed XS to XS_1D<br>• Renamed BFE to BFE_2D<br>• Added L_Source_Cit table (REQUIRED) for all BLE submittals<br>• Section – Base Level Engineering Data Delivery – updated detail<br>• Section – S_AOMI_PT updated detail<br>• Section – S_AOMI_AR updated detail |

| | | |
|---|---|---|
| | | • Section – Tips and Tricks updated detail |
| General Document Update and Addition of Appendix B | July 2021 | Updates to emphasize delivery expectations for regulatory-ready BLE, regional review of BLE data, MIP data capture delivery with validation checklists (Appendix B), and general maintenance from previous version. |

## Table of Contents

## Introduction

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every 5 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 (fema.gov). 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 needed to address Zone A study miles in the CNMS inventory that are currently “unknown” or that are approaching their 5-year expiration and require revalidation. Assessing and evaluating these miles places increased demands on the Regions in a resource-constrained environment.

At the start of this effort, the FEMA Region 6 inventory was comprised of more than 70% of Zone A study miles and approximately 75% of the Region’s flood hazard inventory was currently unknown or unverified. Base Level Engineering will produce floodplains and modeling allowing the Region to assess its current effective flood hazard information on FIRMs through the CNMS assessment process. Furthermore, should the assessment identify an issue with the flooding currently shown on the FIRMs, Base Level Engineering will provide the data necessary to update FIRMs through the Regulatory Update process, producing and releasing a preliminary FIRM in the future.

## Base Level Engineering

Base Level Engineering is an engineering assessment completed for a county, watershed, or river basin. FEMA’s Base Level Engineering (BLE) analysis prepares digital engineering models to determine the potential flood extents for streams throughout the Nation. Base Level Engineering data offers local community officials responsible for floodplain management and permitting an advantage by making the calculated water surface elevation (WSEL) more readily available and more reflective of current conditions.

Base Level Engineering may be produced utilizing one-dimensional (1-D) or two-dimensional (2-D) engineering analysis. A good portion of the United States is made up of well-defined stream channels that convey storm water runoff where flood risk is appropriately modeled using a 1-D modeling approach. The presence of complex, flat, low-lying, and interconnected drainage areas (like the flat and delta areas within the Region) may benefit from an initial assessment using a 2-D modeling approach. FEMA Region 6 works with its State Partners to identify watershed areas that would benefit from 1-D, 2-D or a composite assessment using both 1-D and 2-D engineering modeling methodology.

Consistent with FEMA’s BLE Analyses and Mapping Guidance, Region 6 BLE should be developed with such quality that meets the mapping Standards for Flood Risk Projects to produce Zone A information. BLE data is intended to represent the base level of investment needed for all flood study efforts FEMA will undertake.

## Sharing data publicly through the Estimated Base Flood Elevation Viewer

To provide homeowners, businesses and community officials with the best available information on flood risk outside of GIS, FEMA Region 6 created the Estimated Base Flood Elevation Viewer (https://webapps.usgs.gov/infrm/estbfe/). This tool provides the opportunity to identify property-specific flood elevations with a 1% annual chance of occurring any calendar year in areas where new flood risk data is available.

To deliver consistent information across all watersheds and with the assistance of various Mapping Partners, the Region has developed this guidance document to centralize the delivery of datasets for each Base Level Engineering assessment effort. A database and XML template are also available for use on FEMA Region 6's SharePoint Site (BLE Guidance and Tools).

## Ground Elevation Data Requirements

Base Level engineering shall only be prepared and produced where 90% or greater high-resolution ground elevation data is available for use. Existing topographic data leveraged by FEMA must have documentation that it meets the vertical accuracy requirements detailed in SID43, reproduced in the table below for reference:

Table 1: Vertical Accuracy Requirements

| Vertical Accuracy Requirements based on Flood Risk and Terrain Slope within the Floodplain being Mapped | | | | |
|---|---|---|---|---|
| Level of Flood Risk | Typical Slopes | Specification Level | Vertical Accuracy: 95% Confidence Level (FVA or NVA) / (CVA or VVA) | 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 1, 2, 3) | 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 or Hilly | 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 |

## Base Level Engineering Assessment – Minimum Deliverables

Mapping Partners preparing Base Level Engineering datasets within FEMA Region 6 shall prepare and deliver the following minimum deliverables:

- The Terrain surface that was utilized for the development and validation of the BLE models shall be delivered to the MIP, along with all accompanying data and materials, in accordance with the current Data Capture Technical Reference.
- Hydrologic modeling utilizing regression equations to prepare flow volumes for the 10%, 4%, 2%, 1%, 1%+, 1%-, and 0.2% frequency events.
  - Mapping Partners shall review results to assure regression equations are not used outside of the parameters outlined in the equations (i.e. for drainage areas more than the upper limit for the drainage area)
  - Rain-on grids may also be prepared/produced, if deemed appropriate.
  - If a 2-D approach is selected, Mapping Partners shall refer to Appendix A for additional guidance related to developing the hydrologic assessment within a project area.
- HEC-RAS modeling shall be prepared for each of the seven flood frequencies listed above. In addition, the following manual reviews shall be completed during the HEC-RAS modeling preparation.
  - If BLE is produced for a county or parish-wide assessment, model streams and cross-sections shall be extended to a point where the assessment will produce a complete flood risk assessment for the county/parish area.
  - All hydraulic cross-sections shall be **reviewed for orientation** (assuring left to right)
  - Where **floodplains expand or contract** at a large rate, additional cross-sections shall be added to the cross-section file to better describe the natural stream channel

- At locations **where in-line reservoirs exist**, the mapping partner shall include an upstream and downstream face cross-section, as well as describe the Top of Structure location (typically with a cross-section on top of structure).
  - At locations **where culverts and bridges** cross the floodplain, the mapping partner shall include an upstream and downstream face cross-section near the structure. Major structures can be identified by using a roadway geospatial file.
  - A polygon file (S_AOMI_AR) shall be compiled to indicate the location of dams, culverts, bridges, and other crossings may benefit from locally available structure information to refine the analysis in the future.
  - Model files shall be compiled by stream name/number and organized into HUC10 folders for delivery
  - If a 2-D approach is selected, Mapping Partners shall refer to Appendix A for additional guidance related to developing the hydraulic modeling within a project area.
- The following spatial layers are required to be delivered to the Spatial Files folder within the Hydraulics task on the MIP: S_Fld_Haz_Ar, S_BFE, S_Gen_Struct (if applicable), S_Levee (if applicable), S_Nodes (if applicable), S_Profil_Basln (if applicable), S_Stn_Start (if S_Profil_Basln was provided), S_Submittal_Info, S_XS (if applicable).
- The following tables are required to be delivered to the Spatial Files folder within the Hydraulics task on the MIP: L_Source_Cit, L_ManningsN (if applicable), L_Summary_Elevations (if applicable), L_XS_Elev (If applicable), L_XS_Struct (if applicable).
- The Mapping Partner shall prepare a Hazus analysis, using the Base Level Engineering results for the flood extent. The results of this analysis must be delivered within the Flood Risk Products data capture task, in accordance with the current Data Capture Technical Reference.
- An Engineering Report shall also be compiled to include a description and summary of the methodologies used to compile the terrain and Base Level Engineering assessment, a comparison of the effective mapping to the BLE results, a summary of the CNMS validation rate within the study area, compilation of the Flood Risk Assessment Results table, and a list of model refinement suggestions for evaluation.
- A Project Narrative must be created and delivered for each Data Capture task type.
- Certificates of Compliance and Completeness must be prepared and delivered if applicable, as noted in the following sections.
- CNMS Scoping and Production phase updates.
  - CNMS Scoping Phase delivery within 30 days of project start to update BLE tracking and BEING STUDIED fields in CNMS including incorporation of unmapped miles. Updated CNMS database is submitted to the RSC once completed.
  - CNMS Production Phase Update for validation assessment shall be completed using the Base Level Engineering results for all streams existing in the current flood hazard inventory. The updated CNMS database and supplemental information should be submitted to the Regional Service Center (email the Region 6 CNMS Coordinator) once completed. The study team must provide a link to location of the data within the Mapping Information Platform for inclusion in the Regional roll up, performed quarterly.
- The following **minimum flood hazard datasets** shall be prepared and delivered as part of the EBFE geodatabase for all Base Level Engineering assessment areas:

| Category | File Name | File Type | Description | Est BFE Viewer? | FRD (GDB or SHP) |
|---|---|---|---|---|---|
| **BLE Vector Layers/Tables** | | | | | |
| Base Dataset | S_Pol_AR | Polygon | Political/Community Layer | No | No |
| | S_HUC_AR | Polygon | HUC8 Basin | Yes | Yes |
| EBFE Dataset | SUB-BASINS | Polygon | Hydrologic sub-basin delineations | No | No |
| | XS | Line | 1-D Hydraulic Cross-Sections | Yes | No |
| | BFE | Line | 2-D Base Flood Elevations | Yes | No |
| | WTR_LN | Line | Stream Centerline | Yes | No |
| | WTR_AR | Polygon | Water Bodies | No | No |
| | DTL_STUD_LN | Line | Stream Centerline – Detailed Study on FIRM | Yes | No |
| | DTL_STUD_AR | Polygon | Bounding Area – Detailed Study on FIRM | Yes | No |
| | FLD_HAZ_AR | Polygon | Seamless 1% and 0.2% floodplains included | Yes | No |
| | TENPCT_FP | Polygon | Seamless 10% floodplain | No | No |
| Mit_Haz Datasets | S_AOMI_AR | Polygon | Areas of mitigation that provide targets for future mitigation action | No | Yes |
| | S_FRAC_AR | Polygon | Census Blocks within HUC8 with loss analysis results | No | Yes |
| | S_FRAS_Pt | Point | Census points with loss analysis info | No | Yes |
| CNMS Dataset | S_Studies_Ln | Line | CNMS validation status for streams included on current FIRMs | No | No |

| | | | | | |
|---|---|---|---|---|---|
| | S_UnMapped_Ln | Line | CNMS stream centerlines for streams not currently included on the FIRM | No | No |
| Grids | BLE_WSE01PCT | Raster | Water Surface Elevation Grid – 1% annual chance | Yes | Yes |
| | BLE_WSE0_2PCT | Raster | Water Surface Elevation Grid – 0.2% annual chance | No | Yes |
| | BLE_DEP01PCT | Raster | Flood Depth Grid – 1% annual chance | Yes | Yes |
| | BLE_DEP0_2PCT | Raster | Flood Depth Grid – 0.2% annual chance | No | Yes |

Additional information is available for each feature class for the compilation of these datasets. Hyperlinks are available in the table above to allow the user of this guidance to navigate the guidance document more efficiently. A template geodatabase schema is available along with this guidance to assist mapping partners.

## Setting Up a Base Level Engineering Project in the MIP

The Mapping Partner and FEMA Project Monitor shall coordinate with the Region 6 MIP Champion to establish the MIP project set up and determine the units of delivery for each Base Level Engineering project. MIP project enrollment information is required to be provided to the MIP Champion via the Region 6 Quantities and Baseline Schedule (QBS) form. If modifications to the MIP setup are needed after the initial enrollment, a revised QBS form that contains the changes must be created and submitted before the MIP can be modified.

The following MIP purchases should generally be created for all Region 6 BLE studies; General (management), Terrain, Hydrology (1-D only), Hydraulics, and Flood Risk Products. The delivery of final materials to the MIP through these respective tasks must include the required components and align to the folder structure that is defined in the latest version of the FEMA Risk MAP Data Capture Technical Reference. Additional guidance is included in this document.

## BLE Delivery for Regional Review

The following process should be followed by all mapping partners delivering BLE in Region 6.

1. Mapping Partner completes BLE analysis, compiles eBFE Viewer Deliverable products consistent with Region 6 submittal guidance and has performed all QA/QC and self-checks.
2. Mapping Partner submits eBFE Viewer Deliverable products for Regional review.
    - If BLE data is being shipped by USB hard drive:
        - Provider should send an email to diane.howe@fema.dhs.gov that includes – name of Sender, Mapping Partner, BLE project name, return address for USB hard drive, how many files (number

count) are included in the model files for review, and attach Word and PDF versions of the BLE Report.

  - Provider should send USB hard drive and include transmittal form with contact and project description information to

    BLE Data Delivery
    ATTN: Diane Howe
    FEMA Region 6, Risk Analysis Branch
    800 North Loop 288
    Denton, Texas 76209

- If BLE data is being sent by eFTP:
  - Provider should send to diane.howe@fema.dhs.gov and steven.sharp@fema.dhs.gov through the FEMA FFX site: Floodmaps File eXchange | Floodmaps | FEMA.gov
  - Provider should also send an email to diane.howe@fema.dhs.gov and steven.sharp@fema.dhs.gov that includes – notice that BLE is being transferred by FFX and how many files (number count) are included in the model files for review.

3. Region 6 performs Regional review and either approves or provides comments to Mapping Partner.

- If Region has comments, Mapping Partner addresses comments and resubmits.
- If Region approves, **Mapping Partner compiles, formats, and submits MIP Deliverable Products** from approved eBFE Viewer Deliverable products. Concurrently, the **Region will submit the approved eBFE Viewer Deliverable Products** to the USGS for visualization.

4. Mapping Partner completes MIP tasks and requests validation from Region 6 Project Monitor

After Regional review and approval, all MIP deliverables and supporting data must be uploaded to the MIP for respective tasks. If any of these data are modified after the initial MIP delivery, the revised data (along with all applicable revised supporting documentation or materials) must be uploaded to the MIP before the task can be validated and approved. If a data capture task has been validated and approved, and then any part of the data or deliverable is subsequently revised, the task(s) must be re-opened and updated materials must be re-delivered to the MIP and the task must go through the validation workflow once again before it can be considered complete.

## MIP Delivery

Generally, Base Level Engineering is prepared for one or multiple HUC8 watersheds. If one or more HUC8 watersheds are included in a Mapping Partner's project area, the instructions below should be followed for each HUC8 area.

MIP deliverables must follow the Data Capture Technical Reference, this document is refreshed regularly, study teams are responsible for accessing and following the latest version when compiling MIP deliverables for BLE studies in Region 6. The following Data Capture task types are required to be delivered for BLE studies in Region 6: Terrain, Hydraulics, Flood Risk Products, General (project management cost tracking only), Hydrology is also required to be delivered if the study employs a 1D BLE modeling approach. If the BLE study utilizes a 2D approach, all relevant Hydrology components shall be delivered within the Hydraulics Data Capture task, as noted below.

**Relevant Guidelines and Standards:**

Mapping Information Platform Guidance (Dec 2020), BLE considerations: BLE data should be submitted to the MIP under the applicable Hydrology, Hydraulics, and Floodplain Mapping purchases [floodplain mapping not applicable to Region 6 MIP purchase recommendation] and tagged with the appropriate Large Scale Automated Engineering or Base Level Engineering purchase type indicator. If LSAE or BLE data is subsequently revised or refined as part of another MIP purchase, the refined data should be submitted under the appropriate MIP Data Capture task(s) (e.g. hydrology, hydraulics, or floodplain mapping) of the subsequent MIP purchase.

SID 161: All deliverables and supporting data must be uploaded to the MIP as each workflow step is completed for each project task. If any of these data are modified subsequently, the revised data must be uploaded to the MIP before the effective date of the FIRMs or the completion of the project, if no regulatory products are produced.

SID 180: All regulatory product deliverables, non-regulatory flood risk product deliverables, and relevant supporting data must be submitted in one of the acceptable file format(s) and in the directory structure outlined in the Data Capture Technical Reference. If data are collected that are not specifically mentioned in the Data Capture Technical Reference but are relevant to the project, or data is obtained from existing flood hazard analyses, those data must be submitted, but do not have to follow the file format and directory structure requirements.

SID 181: A metadata file in XML format must be submitted that complies with the Metadata Profiles Technical Reference for each applicable task for regulatory product deliverables, non-regulatory flood risk product deliverables, or relevant supporting data submittals

SID 186: A narrative must be submitted that summarizes the work performed (streams analyzed, type of Flood Risk Project, etc.), direction from FEMA, assumptions and issues, and any information that may be useful for the other mapping partners working on the project or subsequent users of the Flood Risk Project backup data for each task.

**Folder Structure and File Types**

Folder structures and file types shown below are examples from the Data Capture Technical Reference (2019) and should be used for all applicable Region 6 BLE MIP Delivery Data Capture task types. The Data Capture directory structure is provided in this submittal guidance as a reference for where and how to deliver products scoped for respective Region 6 BLE projects. If products are not scoped, and/or not applicable to MIP delivery, refer to the MIP Validation of BLE Deliverables section of this submittal guidance to note elements as not applicable for delivery.

## Terrain Folder Structure

- **Terrain Data Capture**/Task ID folder (Assigned by MIP)/
    - Task Documentation
        - Project Narrative – Word
        - Certification of Completeness (if applicable) – .PDF
        - Terrain Metadata – .XML
    - Correspondence
        - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes Word/.PDF
    - Final
        - Breaklines
            - 3D Breaklines (if applicable) – .SHP/.PGDB/.fGDB/.DXF

- 3D Breakline Tile Index (if applicable) – .SHP/.PGDB/.fGDB
- 2D Breaklines (if applicable) – .SHP/.PGDB/.fGDB/.DXF
- 2D Breakline Tile Index (if applicable) – .SHP/.PGDB/.fGDB
- Mass Points (if applicable) – .SHP/.PGDB/.fGDB/.DXF

Bare_Earth_DEM

- DEMs – Esri grid/GeoTIFF/ASCII grid
- DEM Tile Index (if applicable) – .SHP/.PGDB/.fGDB

Contours

- Contours (if applicable) – .SHP/.PGDB/.fGDB/.DXF
- Contour Tile Index (if applicable) – .SHP/.PGDB/.fGDB
- Bathymetric Data (if applicable) – .SHP/.PGDB/.fGDB/.DXF
- Bathymetry Tile Index (if applicable) – .SHP/.PGDB/.fGDB

TIN

- Uncorrected TIN Files (if applicable) – Esri ArcGIS
- Terrain (if applicable) – Esri ArcGIS
- TIN Tile Index (if applicable) – .SHP/.PGDB/.fGDB

HDEM

- Hydrologically Corrected DEMs (if applicable) – Esri grid/GeoTIFF/ASCII grid
- Terrain (if applicable) – Esri ArcGIS
- HDEM Tile Index (if applicable) – .SHP/.PGDB/.fGDB

Spatial_Files

- FIRM Database files as described in the FIRM Database Technical Reference Table 2 – .SHP/.PGDB/.fGDB/.GML - Source Index – .SHP/.PGDB/.fGDB/.GML

Supplemental_Data

- Any additional elevation data collected for use in the preparation of this Flood Risk Project – Format as received

**General Guidance for Terrain Deliverables**

The key component of a MIP submittal for a Terrain Data Capture task is the terrain surface that was used, or will be used, in the creation of the hydraulic model(s). This final surface along with its accompanying documentation and supporting data are the only mandatory elements of this deliverable. The final surface may be in any number of formats, including varieties of DEMs, TINs, or other. Study teams may elect to deliver the interim products that were created during the Terrain development process as well. For example, if contours were used as the basis for creating a TIN, which was then used to sample a DEM surface, it is recommended that both the interim TIN and the interim contours are provided, but the only item that is required to be provided is the final DEM surface (along with the accompanying documentation and supporting materials). The process by which the surface was developed should be outlined in detail in the Project Narrative. The Project Narrative must follow the structure outlined, and include the elements listed, in the Data Capture General Guidance (a Project Narrative template in word doc format is available to all study teams in Region 6).

If any aspect of the final Terrain surface is modified after the Terrain Data Capture task has been submitted and approved in the MIP, the study team must re-deliver the revised data, and any/all supporting materials to the MIP, and must also undergo a new MIP validation for the task.

Note: Any supporting data that are tiled must have an accompanying index spatial file. Tiles must be topologically correct and have only one part and cannot self-intersect (must be simple). Adjacent tiles must not overlap or have gaps between them. (SID 184)

## Hydrology Folder Structure

- **Hydrology Data Capture**/Task ID folder (Assigned by MIP)/ (1-D BLE only)
    - Task Documentation
        - Hydrology Report – Word and .PDF
        - Draft FIS Section 5.1 – Word and .PDF
        - Project Narrative – Word
        - Certification of Completeness (if applicable) - .PDF
        - Certification of Compliance - .PDF
        - Hydrology Metadata - .XML
    - Correspondence
        - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF
    - Watershed_Name
        - Simulations
            - Model Input and Output files – Native Format
            - ReadMe file explaining contents of each named file – .TXT
        - Supplemental_Data
            - Database file(s) and/or spatial files such as data and analyses for stream and rainfall gages and computations for regional regression equations such as output from USGS PeakFQ, NFF or NSS computer programs – Native format
            - Any additional Hydrology data collected for use in the preparation of this Flood Risk Project – Format as received
    - Spatial_Files
        - FIRM Database files as described in the FIRM Database Technical Reference Table 2** – .SHP/.PGDB/.fGDB/.GML - Source Index – .SHP/.PGDB/.fGDB/.GML

**Note that Hydrology data submitted for Large Scale Automated Engineering, Base Level Engineering, or Levee analyses may not include all FIRM Database files listed in the FIRM Database Technical Reference Table 2.

Hydrology Spatial Files – Mapping partners must always refer to the latest Database Technical Reference to determine whether items marked as Applicable need to be included on a study-by-study basis.

| Name | Description | Required/ Applicable | Name | Description | Required/ Applicable |
|---|---|---|---|---|---|
| S_Gage | Contains information about riverine gages for the Flood Risk Project area. **Required for all new studies containing riverine analysis** and should be populated with available data from existing studies when possible. | *A* | S_Submittal_Info | Contains **essential information** about the Flood Risk Project, such as the FEMA case number and utilized engineering models. | R |
| S_Hydro_Reach | **Required for all hydrologic analyses**. Represents the connectivity between the subbasins and the flow direction between nodes in the hydro model. | R | L_Source_Cit | Required for all Data Capture task types. Documents the **sources of data** used in the FIRM Database and FIS Report. | R |
| S_Nodes | **Required for non-coastal hydrologic analyses where nodes were defined as part of the analysis**. Nodes can represent sub basin outlets, junctions, reservoirs, structures or diversions. Note that nodes are required at all flow change locations. | R | L_Summary_Discharges | **Required when a Summary of Discharges table is to be included in the FIS Report**. Table stores the hydrologic information, including drainage area and peak discharges, associated with the node. | R |
| S_Subbasins | **Required for all studies with new or revised hydrologic data**. Table contains data specific to each subbasin in the hydrologic analysis, including the relationship of the subbasin to the hydrologic network. | R | L_Summary_Elevations | **Required when a Summary of Non-Coastal Stillwater Elevations table is included** in the FIS Report, when coastal stillwater elevations exist within the study or when nodes are used in the hydraulic analysis. | *A* |

## Hydraulics Folder Structure

- **Hydraulics Data Capture**/Task ID folder (Assigned by MIP)
    - Task Documentation
        - Hydraulics Report (Base Level Engineering Report) – Word and .PDF
        - Draft FIS Section 5.2 – Word and .PDF
        - Project Narrative – Word
        - Certificate of Completeness (if applicable) - .PDF
        - Certificate of Compliance - .PDF
        - Hydraulics Metadata - .XML
        - Work Maps (ZIP) - *optional*
    - Correspondence
        - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF
    - Hydrology **(included within Hydraulics folder structure for 2-D BLE only to capture minimum hydrology files and efforts associated with 2-D technical approach)**
        - Back up tables, model, gage analysis, etc. used to develop BLE flows – Native Format

- Hydraulic Models[1]
  - HUC10-1 Name (or Number)
    - Mainstem-1
      - Simulations
        - Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format
        - ReadMe file explaining contents of each named file – .TXT
      - Supplemental_Data
        - Database file(s) and/or spatial files such as high water mark data for model calibration – Native format
        - Zone A backup files – Native format
        - Any additional Hydraulics data collected for use in the preparation of this Flood Risk Project – Format as received
    - Reach 1
      - Simulations
        - Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format
        - ReadMe file explaining contents of each named file – .TXT
      - Supplemental_Data
        - Database file(s) and/or spatial files such as high water mark data for model calibration – Native format
        - Zone A backup files – Native format
        - Any additional Hydraulics data collected for use in the preparation of this Flood Risk Project – Format as received
    - Reach 2
      - Simulations
        - Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format
        - ReadMe file explaining contents of each named file – .TXT
      - Supplemental_Data
        - Database file(s) and/or spatial files such as high water mark data for model calibration – Native format
        - Zone A backup files – Native format
        - Any additional Hydraulics data collected for use in the preparation of this Flood Risk Project – Format as received
  - HUC10-2 Name (or Number)
    - Mainstem-2
      - Simulations
        - Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format
        - ReadMe file explaining contents of each named file – .TXT
      - Supplemental_Data

[1] Note that the sub-folder structure within the Hydraulic Models folder does not have to exactly match the example shown here. Each model must be in a separate folder, and that folder must contain; the model inputs, the model outputs, the model results, and a ReadMe file that explains the contents.

- Database file(s) and/or spatial files such as high water mark data for model calibration – Native format
- Zone A backup files – Native format
- Any additional Hydraulics data collected for use in the preparation of this Flood Risk Project – Format as received

Reach 3

Simulations

- Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format
- ReadMe file explaining contents of each named file – .TXT

Supplemental_Data

- Database file(s) and/or spatial files such as high water mark data for model calibration – Native format
- Zone A backup files – Native format
- Any additional Hydraulics data collected for use in the preparation of this Flood Risk Project – Format as received

Reach 4

Simulations

- Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format
- Readme file explaining contents of each named file – .TXT

Supplemental_Data

- Database file(s) and/or spatial files such as high water mark data for model calibration – Native format
- Zone A backup files – Native format
- Any additional Hydraulics data collected for use in the preparation of this Flood Risk Project – Format as received

Spatial_Files

- FIRM Database files as described in the FIRM Database Technical Reference Table 2* – .SHP/.PGDB/.fGDB/.GML

*Note that the submitted FIRM Database files must match the model output with respect to floodplain boundaries, cross sections, and water surface elevations and their precision. Unlike in the regulatory data submittals, floodplain boundaries and cross sections should not be cartographically modified.

Hydraulics Spatial Files – Mapping partners must always refer to the latest Database Technical Reference to determine whether items marked as Applicable need to be included on a study-by-study basis.

| Name | Description | Required/ Applicable |
|---|---|---|
| S_Alluvial_Fan | **Required when the modeling includes alluvial fans.** The spatial entities representing the alluvial fans are polygons. | A |
| S_BFE | **Required for any digital data where BFE lines will be shown on the FIRM**, with the exception of newly studied areas where a profile exists. Contains Base Flood Elevation (BFE) information. | A |
| S_Fld_Haz_Ar | **Required for all Flood Risk Projects.** Contains information about the flood hazards zones, used by FEMA to designate the regulatory Special Flood Hazard Area (SFHA). | R |
| S_Gen_Struct | **Required whenever hydraulic structures are shown in the flood profile.** Contains both riverine and coastal structure types. | A |
| S_HWM | Required when the community has provided high water mark data. Contains information about high water marks (HWMs). | A |
| S_Levee | **Required for all Flood Risk Projects that include levees.** Contains information about levees that are accredited, as well as levees that are provisionally accredited, de-accredited and never accredited. | A |
| S_Nodes | Required for non-coastal hydrologic analyses where nodes were defined as part of the analysis. Nodes can represent sub basin outlets, junctions, reservoirs, structures or diversions. Note that nodes are required at all flow change locations. | A |
| S_Profil_Basln | The S_Profil_Basln layer is **required for all types of riverine hydraulic analyses. Profile baselines are also required in new riverine Zone A areas with model backup.** | R |
| S_Riv_Mrk | This table is **required if the FIRM shows river distance marks.** | A |
| S_Stn_Start | **Required for any FIRM Database that has an S_Profil_Basln, S_Riv_Mrk or L_XS_Elev** table. contains information about station starting locations | A |
| S_Submittal_Info | Contains **essential information** about the Flood Risk Project, such as the FEMA case number and utilized engineering models. | R |
| S_XS | **All cross sections – modeled or interpolated – must be stored in the S_XS,** regardless of whether or not they are shown on the FIRM and regardless of the flood hazard zone. | A |
| L_Source_Cit | Required. Documents the **sources of data** used in the FIRM Database and FIS Report. | R |
| L_ManningsN | Contains information on Manning's "n" or "k" roughness coefficients used in the Flood Risk Project. This table is **required for all new studies** and should be populated if data is available in existing FIS Reports. | A |
| L_Profil_Bkwtr_El | Required when the stream profile in the FIS text includes backwater elevation and if RASPLOT v.3 or higher was used to generate the FIS profiles. This table stores the backwater elevations for each flood frequency by stream. | A |
| L_Profil_Label | Required when the stream profile in the FIS text includes user-defined landmark labels that are not associated with specific cross sections or structures and if RASPLOT v.3 or higher was used to generate the FIS profiles. This table stores the labels needed for FIS profiles by stream | A |
| L_Profil_Panel | Only required if RASPLOT v.3 or higher was used to generate the FIS profiles. This table stores the information used to define the panels for FIS profiles by stream. | A |
| L_Summary_Elevations | Required when a **Summary of Non-Coastal Stillwater Elevations** table is included in the FIS Report, when coastal stillwater elevations exist within the study or when nodes are used in the hydraulic analysis. | A |
| L_XS_Elev | **Required for hydraulic models that utilize cross sections.** This table includes cross-section information for all event types. | A |
| L_XS_Scruct | **Required when the cross section is associated with a structure.** This table is only required if RASPLOT v.3 or higher was used to generate the FIS profiles. | A |

All HEC-RAS modeling shall be delivered to the MIP under the Hydraulics task.

## Flood Risk Products Folder Structure

- **Flood Risk Products Data Capture**/Task ID folder (Assigned by MIP)
  - Task Documentation
    - Project Narrative – Word
    - Certification of Completeness (if applicable) - .PDF
    - Base Level Engineering Report – Word and .PDF
  - Correspondence
    - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF
  - Flood_Risk_Datasets
    - FDAG
      - Input and output data associated with the Flood Depth and Analysis Grids (FDAG) dataset (not the actual grids which are submitted with the FRD) – Native format
    - FRA
      - Input and output data associated with the Flood Risk Assessment (FRA) dataset, which include Hazus data (not the actual Risk Assessment dataset which is submitted with the FRD) – Native format (.hpr files for Hazus data)
  - Flood_Risk_Products
    - FRD
      - .ZIP file containing FRD and accompanying metadata file – SHP, DBF and .XML
      - .ZIP file containing FRD and accompanying metadata file – fGDB and .XML
      - .ZIP file containing Flood Depth and Analysis rasters and accompanying metadata file – GeoTIFF and .XML
    - FRR
      - Flood Risk Report (if applicable) – Word and .PDF or readme file with hyperlink to the location of the digital file if alternate format is prepared (i.e., Story Map)
    - FRM
      - Flood Risk Map (if applicable) - .PDF and .MXD or readme file with hyperlink to the location of the digital file if alternate format is prepared (i.e., Story Map)
    - Supplemental_Data
      - Input and output data associated with the FRD (not the actual FRD which is submitted with the final mapping data) – Native format
      - Any relevant input and output data associated with the Flood Risk Report (not the actual FRR which is submitted with the FRD), if applicable – Native format
      - Any relevant input and output data associated with the Flood Risk Map (not the actual FRM which is submitted with the FRD), if applicable – Native format
      - Any additional data used to assist in the preparation of this Flood Risk Project – Native format

### Large File Upload

Mapping partners are encouraged to coordinate with the RSC MIP Blackbelt for any questions on MIP delivery content, structure, metadata, etc. All data must be delivered to the MIP via digital file upload. Large files (up to 100GB in size) may be uploaded to the MIP via the Aspera plugin. Mapping Partners should not attempt to deliver BLE data to the MIP via external hard drive.

## MIP Validation of BLE Deliverables

Once a Data Capture task has been submitted by the Mapping Partner, a request should be made to the Region 6 Project Monitor to perform a MIP task validation. MIP task validation is not the same as the Regional Review of BLE products. Validation should be a reasonably quick review and verification that components previously submitted and approved by Regional Review have been uploaded and accounted for in the MIP delivery. Validation ensures deliverable elements required to be submitted to the MIP for the given data capture task type are complete and correct according to the data capture technical reference and any applicable guidance and standards. If there are any Independent QA/QC tasks within the Data Capture Purchase, the QC materials should be uploaded to that task and that task submitted before requesting a validation from the FEMA Project Monitor. The FEMA Project Monitor will complete the validation by comparing the submitted data against the data capture technical reference and reach out to the study team with any questions or comments. Validation is an important part of ensuring BLE data are accessible on the MIP and available for leverage as part of a future first time countywide or physical map revision.

Steps to request and complete MIP task validation are bulleted below:

- Mapping Partner retrieves a blank validation checklist, fills in the Required column (Yes/No) for each listed item. (validation checklists can be found in Appendix B of this submittal guidance and are available in the Region 6 section of RMD SharePoint)
- The Mapping Partner must provide a narrative justification in the comments section for all items noted as “No” in the Required column, these items will be excluded from the validation.
- All components associated with a respective MIP task are required for delivery unless explicitly documented and coordinated with the FEMA Project Monitor as not part of scope. Elements typically required as part of the data capture delivery but are not included shall be noted as such on the validation checklist provided to the Region.
- ReadMe.txt files should be included in MIP folder structure and noted on the validation checklist where files are not required or applicable or where data exists in another directory.
- Validation checklists should be included in the validation request email to the FEMA Project Monitor when the task is ready for validation.
- The FEMA Project Monitor will use the validation checklist from the Mapping Partner to assist in the review and validation of the data on the MIP.
- If the validation is approved in the first round, the FEMA Project Monitor will notify the Mapping Partner via email, upload the completed validation checklist to the MIP, approve the validation and submit the task.
- If the validation is rejected, the FEMA Project Monitor will notify the Mapping Partner and provide the validation checklist with the validation comments to be addressed. The FEMA Project Monitor will reject and submit the validation task in the MIP.
- The Mapping Partner will respond/correct/edit/update the materials on the MIP in accordance with the validation comments, resubmit the data capture task, and provide concurrence that the items have been addressed in the validation checklist.
- The Mapping Partner will then reinitiate the validation process with the updated checklist and the FEMA Project Monitor until approval is reached.

## Project Decision Form

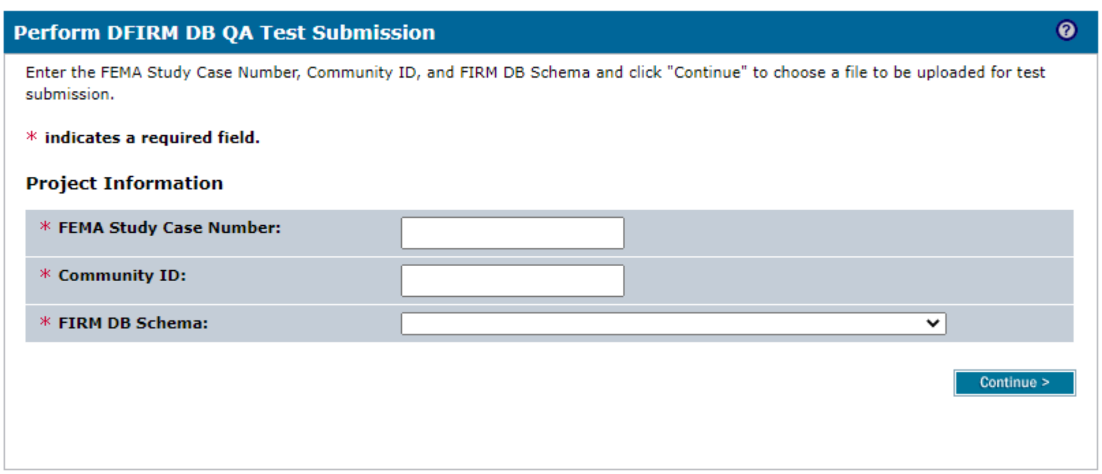
In instances where locations within a BLE project footprint may need additional consideration in order to achieve a Zone A product for Phase 3 advancement (e.g. tie-ins are not achievable within program and standards expectations, additional terrain/hydrology/hydraulic analyses and/or detail are required, effective AE require updates, etc.) and the required level of effort exceeds the scope and expectation of the current BLE, Mapping Partners shall coordinate with their Region 6 Project Monitor to document these instances on the Region’s Technical Memorandum/Project Decision Form template. The Region may use this documentation to better understand needs within a BLE footprint and make informed scoping decisions to advance studies to Phase 3.

[https://rmd.msc.fema.gov/Regions/VI/Regional%20Implementation%20Documents/1/R6_Delivery_Guidance/TEMPLATE_FEMAR6_TechMemo_ProjectDecision.doc](https://rmd.msc.fema.gov/Regions/VI/Regional%20Implementation%20Documents/1/R6_Delivery_Guidance/TEMPLATE_FEMAR6_TechMemo_ProjectDecision.doc)

## Database Verification Tool for Data Development

The Database Verification Tool (DVT) is a critical component of the regulatory products delivery process. It is a tool that provides embedded quality control checks on spatial files to promote standardization and consistency within FIRM database deliverables.  Because BLE data development is expected to produce a level of quality to achieve Zone A products, FEMA Region 6 may advance these data to Phase 3 regulatory updates.  To mitigate DVT conflicts at the Draft FIRM Database stage of Phase 3, Mapping Partners are advised to run their data MIP Delivery data through DVT and process the results by either amending the submitted data or providing written justification for a DVT bypass for future use.  Mapping Partners may refer to the FEMA Risk Map DVT Guidance document for additional information concerning the Database Verification Tool and the individual checks and warnings. The DVT report contains a list of checks and warnings, grouped by five categories: Attribute, Management, Schema, Spatial and Topology. Checks are the most important items to pass, warnings also important, but are mostly informational, and will not prevent DVT from retuning a pass overall. Not all the required layers and tables will be applicable for every data development task type. The study team shall ignore any checks or warning for empty layers or tables.

To enter the DVT test environment in the MIP; navigate to Tools and Links, click on DFIRM DB QA, click on Perform DFIRM DB QA and then fill in the required information in the graphic on the screen. Fill in the MIP case number, the CID (community ID) to validate against, and select the schema year from the drop-down options. Click the Continue button and DVT will begin to run, the submitter will be notified via email when DVT is finished. The notification email also contains a link to the DVT report.




The study team shall thoroughly review the DVT Report and perform any revisions to the data that are deemed necessary, ignoring all checks or warnings that pertain to unsubmitted layers or tables. The study team will then re-run the data through the DVT test environment in an iterative fashion until only the checks that would damage the integrity of the data, or misconstrue the intent of the model, remain. For these remaining checks, the team will provide written justification for the eventual DVT bypass when handing the study off to the regulatory products team. If all of the submitted layers and tables are passing, the study team will simply furnish a PDF of the DVT report and the spatial files deliverable will be complete.

## Hydraulic Model Data Delivery

To support the Map Service Center in the delivery of the modeling information, the models should be broken out into HUC10 sub-basin areas. For instance, the Upper Clear Fork Brazos HUC8 watershed has 9 HUC10 sub-basins, a folder will be prepared for each of these sub-basins in the Hydraulics Model folder. If there is a main flooding source that runs throughout the HUC8 and intersects multiple HUC10s, that model should be added to all the HUC10s that it runs through. The Mapping Partner may decide to name these HUC10 folders using the HUC10 number or name.

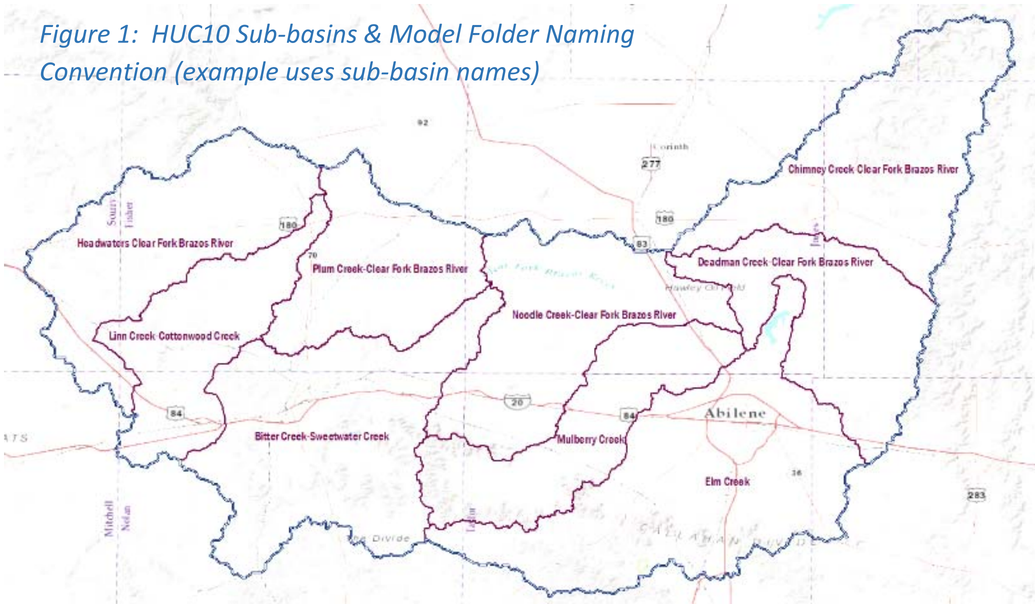



*Figure 1: HUC10 Sub-basins & Model Folder Naming Convention (example uses sub-basin names)*

Mapping Partner may also decide to use a numbering approach, in this case the HUC10 folders would be named with the appropriate HUC10 number, below this level, Mapping Partners may use their own internal numbering/naming convention. Mapping Partners shall assure that the folder names used below the HUC10 folder agree with the WTR_NM included in the S_WTR_LN layer delivered.

**Suggestion.** Within each HUC10 folder, it is suggested that an index map is created to support MSC and local use of the modeling information supplied by Base Level Engineering. The contents and feel of this map index are left to the Mapping Partner.

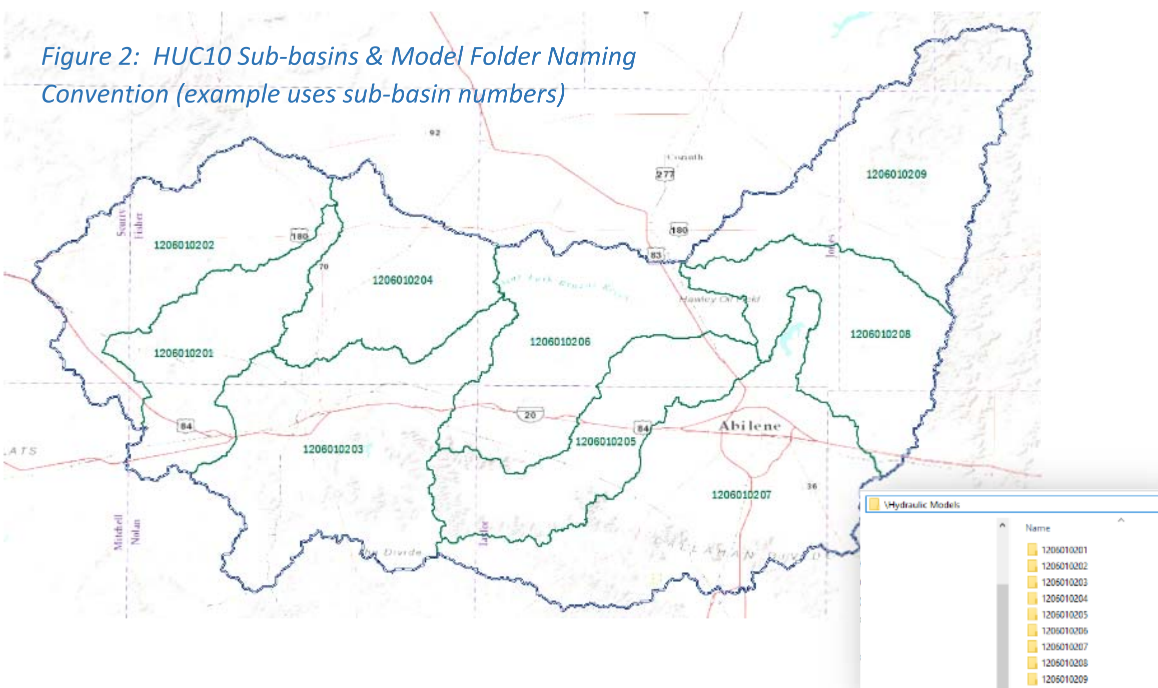



*Figure 2: HUC10 Sub-basins & Model Folder Naming Convention (example uses sub-basin numbers)*

Should the Mapping Partner decide to use a numbering system, it is suggested that a spatial line file: Model_Index is also included in the hydraulic submittal. The Model_Index file should relate the model reach numbering to a stream centerline and provide the file path, both HUC10 and Stream number to assist end users in locating the correct model files for the area of concern.

## 2-D Model Delivery Packaging

Two-Dimensional (2-D) modeling creates expansive datasets with large input and output files. Working with active Mapping Partners, the following guidance has been established for model submittal in watershed areas processed with the 2-D approach:

- Model inputs shall be delivered in several different zip files, outlined in the table following this section
- Models should be run with a time step identified and documented by the Mapping Partner, this time step shall be added to the BLE report and documented. The model output files shall be delivered on the hard drive sent to FEMA for archive and review.
- Each of the seven frequencies should then be run once more, these model outputs will be run with a time step of 6-hours or 12-hours, this longer time step will allow the output file to be significantly reduced.
- To aid the modeling submittal, Mapping Partners shall also provide a spreadsheet detailing various input/output files. This document will be packaged in the items made available to the public for download. The 2-D model inventory template can be downloaded at: https://rmd.msc.fema.gov/Regions/VI/Ph0_Investment/1/Base%20Level%20Engineering/Submittal%20Guidance/2D_Model_Inventory_TEMPLATE.xlsx

The table below identifies the file extensions that should be included in each zip file within the 2-D model delivery folder:

/Model/

| Subfolder (Zip File) | File Extension | Description | Comments |
|---|---|---|---|
| **Terrain**<br><br>Terrain is the ground surface used by HEC-RAS in analysis. | .hdf | Identifies all the GeoTiff files for the Terrain Layer, the priority in which to use GeoTiff values, and stores a computed surface for transitional area between GeoTiffs | Clip output raster file to area of interest<br><br>Use a 10' x 10' raster to reduce delivery file size |
| | .tif | The GeoTIFF includes terrain data (elevations) in the image, which is read into HECRAS and used to construct a surface model | Delete any duplicate files |
| | .vrt | Visualization file that allows for displaying multiple raster files at once using the same symbology with just the one VRT file in a GIS | |
| **Land Cover**<br><br>Land Cover is the file used for roughness in HEC-RAS 5.0.x analysis. This coverage is a | .hdf | One of two default datasets created as part of Land Cover dataset (LandCover.hdf is default name) | Clip output raster file to area of interest |
| | .tif | One of two default datasets created as part of Land Cover dataset (LandCover.tif is default name) | Delete any duplicate files |

| | | | |
|---|---|---|---|
| surrogate for roughness coefficients | .shp, .db, etc. | RAS Mapper supports the use of multiple grids or polygon shapefiles with a field describing the land classification | Remove excess and unnecessary files |
| **Input**<br><br>Files established for all HEC-RAS 5.0.x modeling analysis. Multiple input files are expected.<br><br>File types created are similar to those created with historic 1-D (steady-state) analysis. | .prj | RAS Project File | Include HUC8 Name in file name |
| | .prj | Projection file | Make unique name to avoid confusion with HEC-RAS project file. |
| | .P# | Plan files: Plan files have the extension. P01 to .P99. The "P" indicates a Plan file, while the number represents the plan number. | Be sure to provide information in excel attachment to assist follow on users that will be working with the files. |
| | .X# | Run file for unsteady flow plan (steady flow would use .R# files instead); Have extension .X01 to .X99 | |
| | .U# | File for unsteady Flow data (steady flow would use .F# files instead and quasi-unsteady flow would use .Q# files instead); have extension .U01 to .U99 | Document various unsteady flow files for users in excel spreadsheet |
| | .G# | Geometry files have the extension .G01 to .G99. The "G" indicates a Geometry file, while the number corresponds to the order in which they were saved for that particular project | Document various geometry files (as required) in excel spreadsheet |
| | .S# | File for sediment data | Not expected deliverable in BLE watersheds |
| | .H# | File for hydraulic design data | Not expected deliverable in BLE watersheds |
| | .W# | File for water quality data | Not expected deliverable in BLE watersheds |
| | .rasmap | RAS Mapper file | Include file if you are using spatial terrain data |
| | .dss entry (only include as appropriate) | Dependent on how flows are input to model | Include file if appropriate |
| **Output**<br><br>Output files contain all of the computed results from the requested computational engine. For example, if an unsteady flow analysis is requested, the output files will contain results from the unsteady flow computational engine | .hdf | The output size of this critical file is dependent on the selected time step interval. | To reduce the output .hdf file size below the 2GB limit, change the Hydrograph, Detailed, and Mapping time step intervals (i.e., choose 6 or 12 hour interval instead of 1 minute intervals). |
| | .O# | Output files have the extension .O01 to .O99. The "O" indicates an Output file while the number represents an association to a particular plan file | |

2-D models will be run with unsteady flow and will create several intermediate files to include those in the box to the right. These files should only be included in the model delivery folders if necessary.

After unsteady flow computations are performed, some additional files will get created during the computations that are only used by the software as intermediate files. These files are:

- One Boundary condition file for each plan executed (.b01 to .b99)
- One unsteady flow **Log** output file for project (.bco)
- One geometric pre-processor output file for each set of **Geometry** data (.c01 to .c99)
- One detailed computational level output file for each plan, if user turns this option on (.hyd01 to .hyd99)
- One initial conditions file for each unsteady flow plan executed (.IC.O01 to .IC.O99)
- One binary log file for each plan executed. Used only by the user interface (.p01.blf to .p99.blf)
- One restart file (Hot start) for each unsteady flow plan. This will only show up if the user turns on the option to write it (.p01.rst to .p99.rst)
- One HDF5 binary Output file for each plan that gets executed (.p01.hdf to .p99.hdf). This is the file that RAS Mapper uses for getting HEC-RAS computed results to then visualize as inundation maps and other spatial data displays.

## EBFE Viewer Delivery

Data provided for delivery to the Estimated BFE viewer are generally pared down from the MIP Data Capture delivery expectations. Mapping Partners shall organize and zip the eBFE viewer content into three zip files: Engineering Models, Geospatial Data, Reporting and Documentation. Similar to MIP delivery, eBFE viewer projects are generally delivered at the HUC8 extent.

- **eBFE Viewer**
  - Engineering Models
    - Hydrologic Models (as applicable)
    - HEC-RAS Models
  - Geospatial Data
    - Raster Data
    - Vector Data
    - Mapping Partner shall use the eBFE database schema (https://rmd.msc.fema.gov/Regions/VI/Ph0_Investment/1/Base%20Level%20Engineering/Submittal%20Guidance/201904_v5_R6_BLE_TEMPLATE.gdb.zip)
  - Reporting and Documentation
    - BLE Report (https://rmd.msc.fema.gov/Regions/VI/Ph0_Investment/1/Base%20Level%20Engineering/Submittal%20Guidance/BaseLevelEngineering_Report_Template_V2.docx)
    - Project Decision Form(s) as applicable

## EBFE Viewer GDB Specifications

Spatial Reference Systems

Delivered Base Level Engineering (BLE) spatial datasets shall have the following spatial reference standards.

**Coordinate System:** Geographic (GCS)

**Spheroid:**

- **Name:** GRS_1980
- **Semi major Axis:** 6378137
- **Semi minor Axis:** 6356752.3141403561

**Angular Unit:**

- **Name:** Degree
- **Radians per unit:** 0.017453292519943299

**Prime Meridian:**

- **Name:** Greenwich
- **Longitude:** 00° 00’ 00”

**Horizontal Datum:** NAD83

**Horizontal Units:** Decimal Degrees (dd)

**Vertical Datum:** NAVD88

**Vertical Units:** US Survey Feet

**Cluster Tolerance:** 0.000000784415 dd

**Spatial Resolution:** 0.0000000784415 dd

To provide national consistency, the above tolerances have been set based upon the approximate center of the contiguous 48 states (Meade's Ranch, Kansas).

All elevation data, including BLE water surface elevation rasters, shall reference the North American Vertical Datum of 1988 (NAVD88) with units of US Survey Feet. The use of other datums or vertical units will require approval of the FEMA Project Officer.

Non-geodatabase formats shall maintain these spatial reference standards where allowable by file type and format.

Null Values

Compiling a file Geodatabase (fGDB) allows support of "true" null values for data types, the shapefile (SHP) format does not. To provide consistency between the fGDB and SHP formats of the Flood Risk Database standards, the following conventions for inserting pseudo null values into the tables is followed for both fGDB and SHP formats.

The value to use for non-populated data for each field that is required by the Flood Risk Database (FRD) technical specification or the Statement of Work (SOW) is as follows:

**Text:** "NP"

**Numeric:** -8888

**Date:** 8/8/8888

The value to use for fields that are optional or required when applicable either by the FRD technical specification or the SOW is as follows:

**Text:** Null (or "", the empty string)

**Numeric:** -9999

**Date:** 9/9/9999

For raster data, the value 'NODATA' should be used to represent the absence of data or null values. Generally, all areas outside the project area (i.e., the polygon in S_FRD_Proj_Ar) will be set to 'NODATA' in the depth and analysis rasters.

Topology Rules

Vector data files must meet the following data structure requirements:

- Digitized linework must be collected at a reasonably fine line weight.
- Only simple point, polyline, and polygon elements may be used. Multi-part features are not allowed.
- Line features must be continuous (no dashes, dots, patterns or hatching).
- Spatial files must not contain any linear or area patterns.
- Area spatial features for a given theme must cover the entire BLE Project area without overlaps or sliver polygons between adjacent polygons. Gaps or overshoots between features that should close must be eliminated.

| Spatial Layer | Topology Rule | Minimum Cluster Tolerance (dd) |
|---|---|---|
| Line_Feature | Must Be Larger Than Cluster Tolerance | 0.000000784415 |
| Line_Feature | Must Not Overlap | 0.000000784415 |
| Line_Feature | Must Be Single Part | 0.000000784415 |
| Line_Feature | Must Not Self-Intersect | 0.000000784415 |
| Line_Feature | Must Not Self-Overlap | 0.000000784415 |
| Polygon_Feature | Must Be Larger Than Cluster Tolerance | 0.000000784415 |
| **Spatial Layer** | **Topology Rule** | **Minimum Cluster Tolerance (dd)** |
| Polygon_Feature | Must Not Overlap | 0.000000784415 |
| Polygon_Feature | Must Not Have Gaps | 0.000000784415 |

## EBFE Viewer GDB Layers and Tables

### HUC8_StatusInfo

This polygon feature class is used to visualize the status for planned, in progress and completed Base Level Engineering assessments completed within the Region. **This feature class is maintained and updated by Region 6 and/or the RSC.**

**Required:** Yes, information is visualized on the Estimated BFE Viewer. Data is submitted via email to the Regional Support Center.

**Exceptions:** None

**Viewer Requirements:** Mapping Partners shall coordinate with the RSC to assure the proper status is depicted on the Estimated BFE Viewer.

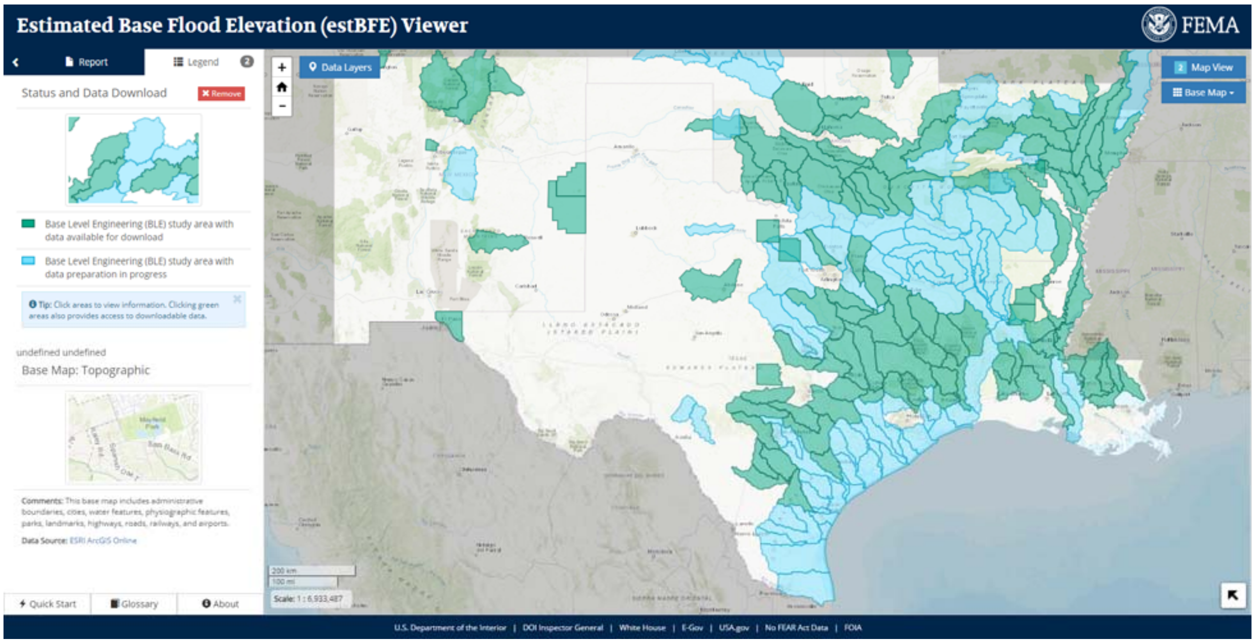



*Figure 3: Base Level Engineering Project Status*

To maintain the HUC8 Status on the viewer, Mapping Partners shall follow coordination instructions below:

**Update 1 – Project Start - Add BLE Watershed to Viewer**

When a Base Level Engineering project is initiated, Mapping Partners shall provide the following data via email to the RSC for inclusion in the dataset. Mapping Partners should email the RSC Lead and cc their FEMA Project Monitor.

- HUC8 — Provide the 8-digit HUC8 number (i.e. 12060102)
- Name — Provide the HUC8 watershed name as indicated in the NHD Watershed Boundary Dataset (i.e. Upper Clear Fork Brazos)
- Status — Choose from the following: Planned, In Progress, Complete
- BLE Delivery — Provide Target BLE Data Delivery Date (MM/DD/YYYY format)
  ***Note:*** Date on viewer will be Target + 30 days to allow for review/upload

**Update(s) 2 – Update Delivery Date**

Once the project is underway, the CTP Lead or Mapping Partner should provide regular updates to the FEMA Project Monitor on status and any changes in anticipated delivery dates.

**Update 3 – Alert FEMA Region 6 of pending Data Submittal for Review**

When the BLE deliverables are nearly ready for submittal, the Mapping Partner shall alert Diane Howe (diane.howe@fema.dhs.gov) with FEMA Region 6 that that a watershed, or other project area is nearing completion.

Data should be delivered to FEMA via hard drive or FFX for review. FEMA will perform a completeness check of the dataset. At the same time, FEMA R6 will review the information to assure that submitted files and datasets meet all requirements for loading the models, reports, and spatial information to the viewer.

Mapping Partners should consult the tips and tricks within this document prior to submitting a BLE dataset to assure the spatial reviews identified within are performed. This will reduce the number of comments and speed up the data load of the BLE data (models, report and spatial) onto the Estimated BFE Viewer site.

## HUC10_ModelInfo

This polygon feature class catalogs the data availability and location of HEC-RAS model information once Base Level Engineering models have been delivered through the Mapping Information Platform. This file leverages the HUC10 sub-basins developed and included in the NHD Watershed Boundary Dataset and provides URL information for inclusion in the automated Detailed Report prepared by the Estimated BFE Viewer.

**Required:** Yes, information is queried and included in the Detailed Report prepared by the Estimated BFE Viewer. Data is submitted via email, using table below, to RSC.

**Exceptions:** None

**Viewer Requirements:** Mapping Partners shall coordinate with the RSC once Base Level Engineering data is delivered to the MIP. Mapping Partners will need to provide a shortened path for each set of HEC-RAS models delivered by HUC10.

To provide the user the location of the modeling files on the MIP for inclusion in the HUC10 coverage maintained by the RSC, Mapping Partners shall prepare the table below and include in Update 3 email (project status) sent to the RSC.

| **HUC8** | **12060102** | **Upper Clear Fork Brazos** |
|---|---|---|
| **BLE Data** | **Complete** | **04/30/2017** |
| **Hydraulic Model Data Location on the MIP** | | |
| **HUC10** | **Name** | **Model_Loc** |
| 1206010201 | Linn | K:/FY2016/16-06-3600S/Hydraulics - Fisher County, TX - 1/Hydraulic Data Capture - Hydraulic Data Capture 48151C - 1/Hydraulic_Models/Linn |
| 1206010202 | Headwaters | K:/FY2016/16-06-3600S/Hydraulics - Fisher County, TX - 1/Hydraulic Data Capture - Hydraulic Data Capture 48151C - 1/Hydraulic_Models/Headwaters |
| | | |
| | | |

Mapping Partners will need to support the RSC in providing the location of the hydraulic models by HUC10 by providing a shortened URL for inclusion in the data service maintained by the RSC. The URL should be shortened as shown below. If the URL is **not** shortened, it **will not fit within** the report area and may run off the page. An example of how to shorten the URL is described below.

**MIP Project Path:** K:/FY2016/16-06-3600S/Hydraulics - Fisher County, TX - 1/Hydraulic Data Capture - Hydraulic Data Capture 48151C - 1/Hydraulic_Models/Linn

State Abbreviation    County Name

**Remove/Adjust:** K:/R06/TEXAS_48/FISHER_48151/FISHER_151C/16-06-3600S/ SubmissionRepository/Hydraulics/2186733/Hydraulic_Models/Linn

Hydraulics/Models

**Shorten to:** **(Name)** K:/R06/TX/Fisher/16-06-3600S/Hydraulics/Models/Linn

**(HUC10 Number)** K:/R06/TX/Fisher/16-06-3600S/Hydraulics/Models/1206010201

## S_Pol_AR

This polygon feature class combines any information available in modernized DFIRM Database S_POL_AR feature class for the project area. The Mapping Partner shall compile the polygon feature class to include one record (polygon) per community. This will require the use of multi-part polygons for non-contiguous community boundaries/areas.

This dataset is described in detail within the [Guidance for Flood Risk Analysis and Management (fema.gov)](fema.gov) feature Class: S_Pol_AR). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset.

**Note (April 2019):** The S_Pol_AR dataset replaces the historic submittal of the FRC_Pol_AR dataset and L_RA_Results table within the Spatial deliverables for each BLE submittal.

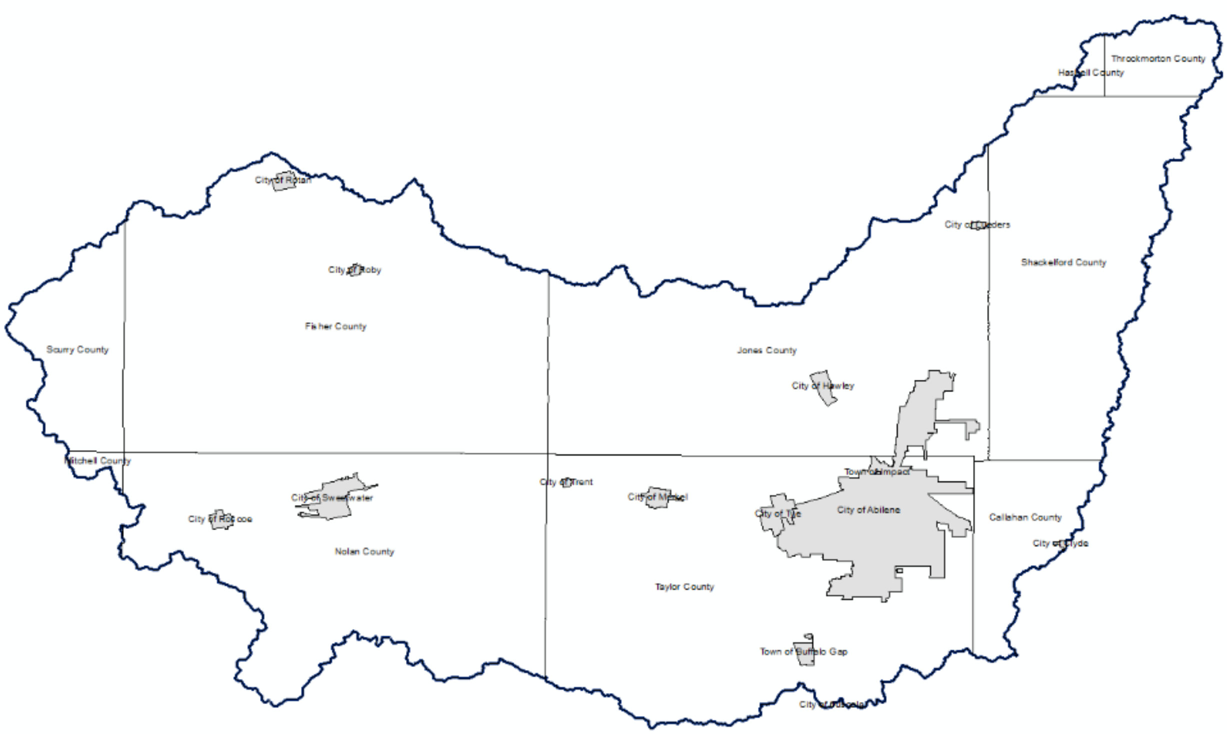
**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas. The S_Pol_AR feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** Mapping Partners may decide to leave community polygons complete instead of clipping them to the project boundary. Leaving the community boundaries complete and intact will support the preparation of Community Dashboards when the Flood Risk Report is being compiled.

**Inclusions:** No additional data elements (columns) have been added to this dataset.

**Viewer Requirements:** None. Layer not used in Estimated BFE Viewer.

*Figure 4: Example S_Pol_AR*



## S_HUC_AR

This polygon feature class defines the watershed project area (HUC8 expected). The Mapping Partner shall compile the polygon feature class to include one record (polygon) per HUC8 area.

This dataset is described in detail within the [Flood Risk Database Technical Reference (fema.gov)]() (2018). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas. The S_HUC_AR feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

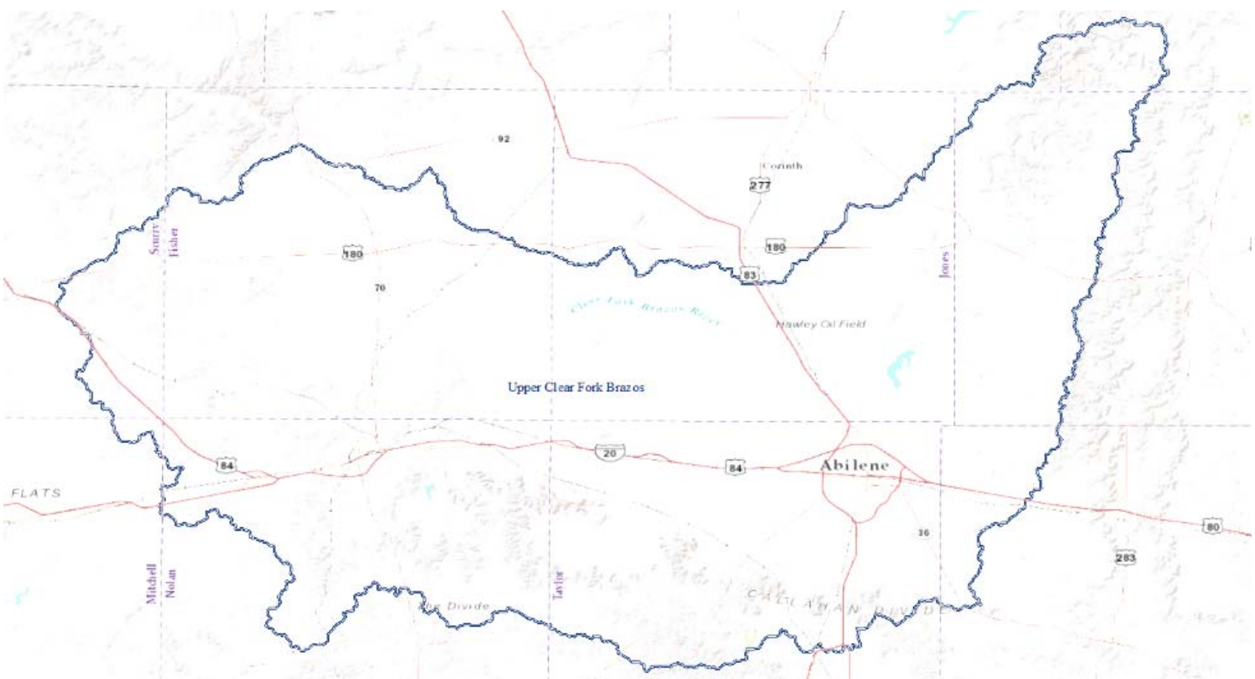
**Exceptions:** Mapping Partners may include a HUC4, HUC6, HUC10, or HUC12 watershed boundary if the Base Level Engineering assessment was completed at a different watershed level.

Mapping Partners may describe a subset (county boundary) or other project area (part county/part watershed) using this file if the complete HUC8 or other watershed unit was not used as a study limit. Note, use of this file in this manner shall be limited to describe Paper Inventory Reduction Projects.

**Inclusions:** No additional data elements (columns) have been added to this dataset.

**Viewer Requirements:** None. Layer not used in Estimated BFE Viewer.

*Figure 5: Example S_HUC_AR*



## SUB-BASINS

This polygon feature class collects data and calculations used in the preparation of Base Level Engineering hydrology, which uses the Regional Regression Equations to calculate the flow volumes expected throughout study reaches.

This dataset leverages the DFIRM database S_SUB-BASINS feature class described in [Guidance for Flood Risk Analysis and Management (fema.gov)] (Feature Class: S_SUB-BASINS). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within.

**Required:** **Yes**, minimum deliverable for 1-D analysis. The S_SUB-BASINS feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** Not required for delivery in 2-D BLE analysis watersheds.

**Inclusions:** Additional feature information related to basin area, basin slope, upstream basins, downstream basins are expected for BLE assessment areas, additional data requirements outlined in the table below.

**Viewer Requirements:** Layer not used in Estimated BFE Viewer.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| EST_ID | DFIRM_ID | Study Identifier: Suggest HUC8 (or other be used) to define the study area – I.E. 12060102_BLE |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version and relates the feature to standards according to how it was created (Suggest BLE_MMYYYY) |
| E_SUBAS_ID | SUBBAS_ID | Primary key for table lookup. Assigned by table creator |
| HUC8_CODE | HUC8 | USGS HUC8 code number of sub-basin |
| E_SUBAS_NM | SUBBAS_NM | Name of sub-basin |
| EST_AREA | SUB_AREA | Area of sub-basin |
| AREA_UNIT | AREA_UNIT | Area Units - Indicates the measurement system used for the basins. **Use values in D_Area_Units.** |
| US_1 | NEW Field | Upstream basin 1 |
| US_2 | NEW Field | Upstream basin 2 |

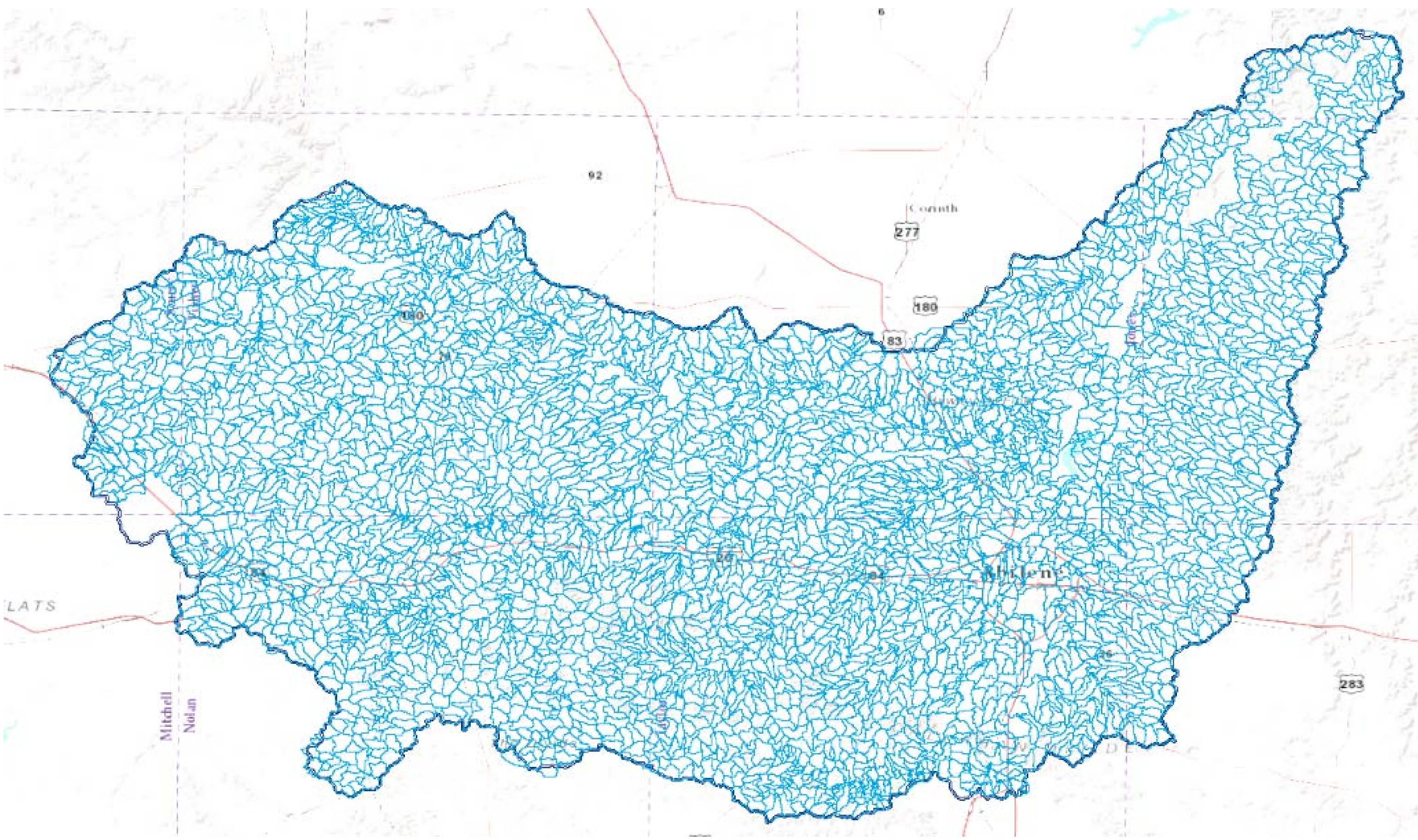
| | | |
|---|---|---|
| US_3 | NEW Field | Upstream basin 3 |
| US_4 | NEW Field | Upstream basin 4 |
| DS_1 | NEW Field | Downstream basin |
| PRECIP_IN | NEW Field | Precipitation in inches |
| MAINCHSLP | NEW Field | Main channel slope of basin |
| E_Q_10PCT | NEW Field | Flow calculated for the 10% Flood |
| **EBFE Database Data Element** | **DFIRM Database Data Element** | **Description** |
| E_Q_04PCT | NEW Field | Flow calculated for the 4% Flood |
| E_Q_02PCT | NEW Field | Flow calculated for the 2% Flood |
| E_Q_01PCT | NEW Field | Flow calculated for the 1% Flood |
| E_Q_01PLUS | NEW Field | Flow calculated for the 1%+ Flood |
| E_Q_01MIN | NEW Field | Flow calculated for the 1%- Flood |
| E_Q_0_2PCT | NEW Field | Flow calculated for the 0.2% Flood |
| SOURCE_CIT | SOURCE_CIT | Abbreviation used in the metadata file when describing the source information for the feature |
| **These fields will remain in geodatabase but will be hidden.** | | |
| HIDE | WTR_NM | Surface water feature name |
| HIDE | BASIN_DESC | Sub-basin description |
| HIDE | NODE_ID | Node Identification |
| HIDE | BASIN_TYP | Type of Sub-basin |

EBFE_SUBBASINS

| OBJECTID * | SHAPE * | EST_ID | VERSION_ID | EST_SUBBAS_ID | HUC8 | EST_SUBBAS_NM | EST_AREA | AREA_UNIT | US_1 | US_2 | US_3 | US_4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | Polygon | 1206010 | BLE_032017 | Main_BASIN231 | 1206010 | Clear Fork Brazos Rv | 272.21901 | Square_Miles | Main_BASIN2 | | | |
| 35 | Polygon | 1206010 | BLE_032017 | Main_BASIN24 | 1206010 | Clear Fork Brazos Rv | 412.35813 | Square_Miles | Main_BASIN2 | | | |
| 36 | Polygon | 1206010 | BLE_032017 | Main_BASIN251 | 1206010 | Clear Fork Brazos Rv | 134.60666 | Square_Miles | Main_BASIN2 | | | |
| 37 | Polygon | 1206010 | BLE_032017 | Main_BASIN29 | 1206010 | Clear Fork Brazos Rv | 298.93479 | Square_Miles | Main_BASIN2 | | | |
| 38 | Polygon | 1206010 | BLE_032017 | Main_BASIN40 | 1206010 | Clear Fork Brazos Rv | 536.57502 | Square_Miles | Main_BASIN2 | | | |
| 39 | Polygon | 1206010 | BLE_032017 | Main_BASIN41 | 1206010 | Clear Fork Brazos Rv | 1.123092 | Square_Miles | | | | |
| 40 | Polygon | 1206010 | BLE_032017 | Main_BASIN42 | 1206010 | Clear Fork Brazos Rv | 1.418213 | Square_Miles | Main_BASIN4 | | | |

| OBJECTID * | DS_1 | PPT_IN | MAINCHSLOP | EST_Q_10PCT | EST_Q_4PCT | EST_Q_2PCT | EST_Q_1PCT | EST_Q_1PCTPLU | EST_Q_1PCTMINU | EST_Q_0PT2PCT | SOURCE_CIT | SHAPE_Length | SH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | Main_BASIN23 | 22 | 0.001706 | 6200 | 10500 | 14500 | 19500 | 26800 | 12200 | 35000 | STUDY1 | 2.371684 | |
| 35 | Main_BASIN25 | 23 | 0.00109 | 7560 | 12400 | 16600 | 21700 | 29800 | 13500 | 36100 | STUDY1 | 3.348388 | |
| 36 | Main_BASIN29 | 25 | 0.000914 | 8030 | 13000 | 17300 | 22400 | 30800 | 14000 | 36600 | STUDY1 | 1.488868 | |
| 37 | Main_BASIN40 | 25 | 0.000851 | 8450 | 13500 | 17900 | 23000 | 31700 | 14400 | 36800 | STUDY1 | 3.081177 | |
| 38 | Main_BASIN1A | 25 | 0.00084 | 9090 | 14400 | 18800 | 23900 | 32900 | 14900 | 37200 | STUDY1 | 3.632308 | |
| 39 | Main_BASIN42 | 22 | 0.002828 | 162 | 216 | 260 | 309 | 425 | 193 | 442 | STUDY1 | 0.11101 | |
| 40 | Main_BASIN43 | 22 | 0.005572 | 403 | 577 | 723 | 898 | 1240 | 560 | 1400 | STUDY1 | 0.204938 | |

*Figure 6: Example S_SUB-BASINS*



## XS_1D

This polyline feature class depicts the location and orientation of the analysis cross-sections used to determine the Base Level Engineering hydraulic modeling.

This dataset leverages the DFIRM database S_XS feature class described in [Guidance for Flood Risk Analysis and Management (fema.gov)] (Feature Class: S_XS). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within.

**Required:** Yes, minimum deliverable for 1-D analysis. The XS feature class shall be compiled for the study area but should be no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** Not required for delivery in 2-D BLE analysis watersheds.

**Inclusions:** Additional feature information to describe the calculated flow values and estimated Base Flood Elevation at each of the seven frequencies have been added to the S_XS fields for reference.

**Viewer Requirements:** The field labeled E_WSE_1PCT will be used to label cross-sections on the viewer. The water surface elevations loaded to the seven WSEL fields should be included to the nearest tenth of a foot (0.0 ft) when loaded into the database.

Mapping Partners shall review the stream WSEL profile of the 1% annual chance water surface elevations to determine which cross-sections should be visualized on the Estimated BFE Viewer tool. Providers shall update the XS_LN_TYP field to indicate the cross-sections as “MAPPED” to indicate which of the cross-sections will be visible on the Estimated BFE Viewer tool.

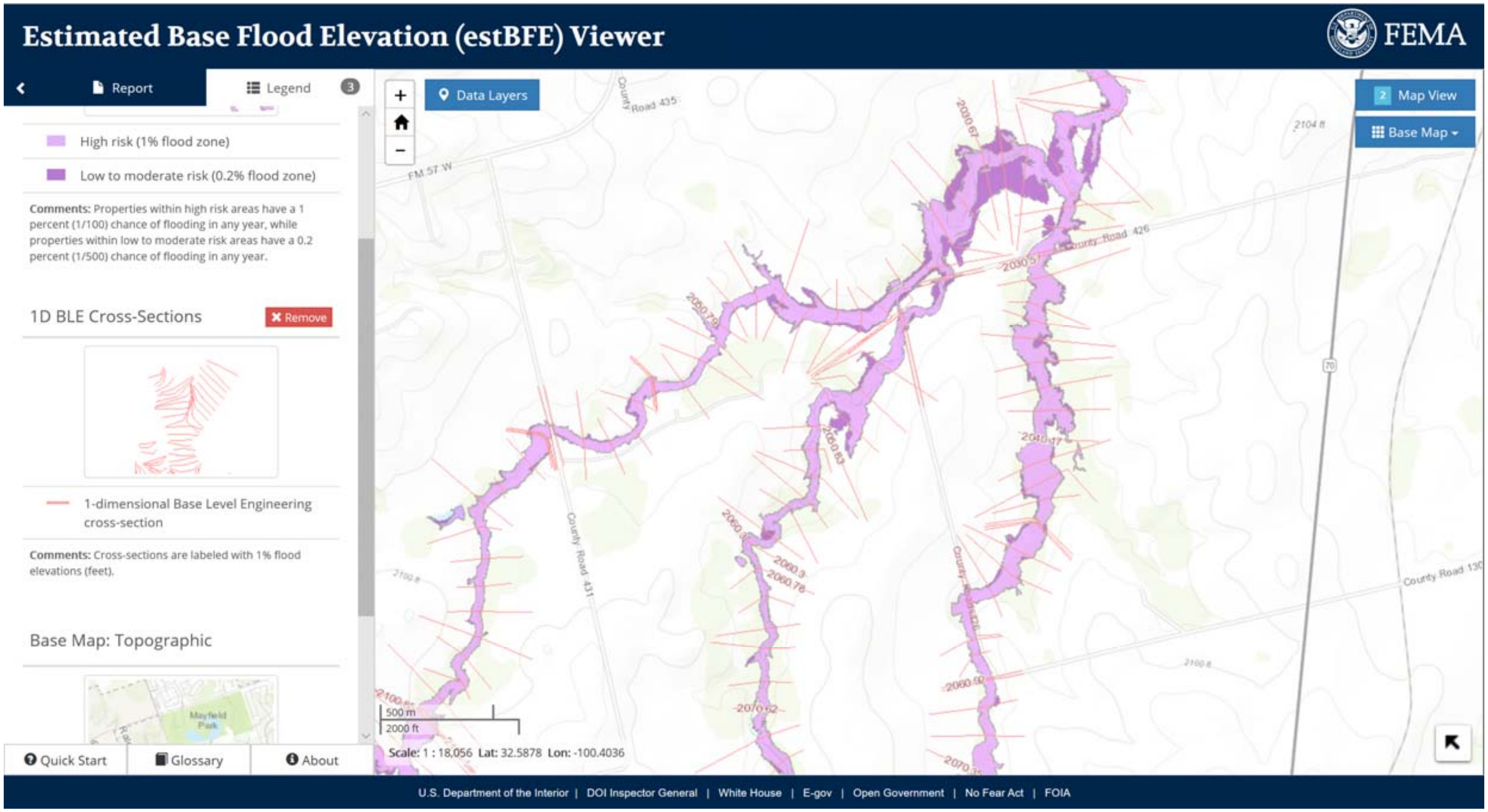
- Each cross-section in backwater shall be indicated as “NOT MAPPED” in the XS_LN_TYP field.
- Cross-sections at inflection points along the water surface elevation profile should be indicated as “MAPPED”
- A “MAPPED” cross-section should be included at least every 2,500 ft along the stream centerline to support community use of the tool and datasets.
- NOTE – All prepared BLE WSEL grids MUST include backwater effects even though E_WSE_1PCT attribute in the XS file is not required to include backwater.

Mapping Partners shall complete all NEW FIELDS identified in the table below.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| EST_ID | DFIRM_ID | Study Identifier: Suggest HUC8 (or other be used) to define the study area – I.E. 12060102_BLE |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version (**Suggest BLE_MMYYYY)** |
| XS_LN_ID | XS_LN_ID | Primary Key for table lookup |
| WTR_NM | WTR_NM | Stream ID value from WTR_LN layer |
| STREAM_STN | STREAM_STN | Stream Station - This is the measurement along the profile baseline to the cross-section location |
| START_ID | START_ID | Station Start Identification - This is the foreign key to the S_Stn_Start layer. The station start describes the origin for the measurements in the STREAM_STN field. |
| XS_LN_TYP | XS_LN_TYP | Similar to XS shown in DFIRM DB. All modeling XS should be included and then select XS that will be shown on EBFE Viewer. Use "MAPPED" as value for XS's that should be shown on viewer. "NOT MAPPED" should be used for all others. **Use values in D_XS_Ln_Typ.** |
| E_WSE_1PCT | WSEL_REG | Modeled Water Surface Elevation for the 1% Flood - This is the calculated water surface elevation produced by the engineering model for the 1% flood in the stream channel at this cross section. Elevations should include data in the following format 000.0 ft (rounded to the tenths place). |
| V_DATUM | V_DATUM | The vertical datum indicates the reference surface from which the flood and streambed elevations are measured. **Use values in D_V_Datum.** |
| MODEL_ID | MODEL_ID | This field stores the feature's identifier that was used during H&H modeling. |
| SOURCE_CIT | SOURCE_CIT | Abbreviation used in the metadata file when describing the source information for the feature |
| E_WSE_10PC | NEW Field | Modeled Water Surface Elevation for the 10% Flood |
| E_WSE_4PCT | NEW Field | Modeled Water Surface Elevation for the 4% Flood |
| E_WSE_2PCT | NEW Field | Modeled Water Surface Elevation for the 2% Flood |
| E_WSE_1PLU | NEW Field | Modeled Water Surface Elevation for the 1%+ Flood |
| E_WSE_1MIN | NEW Field | Modeled Water Surface Elevation for the 1%- Flood |

| | | |
|---|---|---|
| E_WSE_0_2P | NEW Field | Modeled Water Surface Elevation for the 0.2% Flood |
| E_Q_10PCT | NEW Field | Flow used for the 10% Flood |
| E_Q_04PCT | NEW Field | Flow used for the 4% Flood |
| E_Q_02PCT | NEW Field | Flow used for the 2% Flood |
| E_Q_01PCT | NEW Field | Flow used for the 1% Flood |
| E_Q_01PLUS | NEW Field | Flow used for the 1%+ Flood |
| E_Q_01MIN | NEW Field | Flow used for the 1%- Flood |
| E_Q_0_2PCT | NEW Field | Flow used for the 0.2% Flood |
| **EBFE Database Data Element** | **DFIRM Database Data Element** | **Description** |
| **These fields will remain in geodatabase but will be hidden.** | | |
| HIDE | XS_LTR | Cross Section Letter - This is the letter or number that is assigned to the cross section on the hardcopy FIRM and FIS report. |
| HIDE | STRMBED_EL | Streambed Elevation - This is the water-surface elevation for the thalweg or the lowest point in the main channel |
| HIDE | LEN_UNIT | Water Surface and Streambed Elevation Units - This unit indicates the measurement system used for the water-surface and streambed elevations |

*Figure 7: Data Visualization – XS with labeling using value from E_WSE_1PCT field*



## BFE_2D

This polyline feature class depicts whole foot elevations of the 1%-annual-chance-flood resulting from a 2-D Base Level Engineering analysis.

This dataset leverages the DFIRM database S_BFE feature class described in [Guidance for Flood Risk Analysis and Management (fema.gov)](fema.gov) (Feature Class: S_BFE). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within and review the additional guidance to assure the datasets will be correctly compiled for use and upload to the Estimated BFE Viewer.

**Required:** Yes, minimum deliverable for 2-D analysis. The BFE feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** Not required for delivery in 1-D BLE analysis watersheds.

**Inclusions:** None.

**Viewer Requirements:** BFE lines shall be loaded into the BFE feature class. Viewer requires the Mapping Partner to complete the field BLELEV1PCT with the whole foot elevation of the 1-percent-annual-chance event.

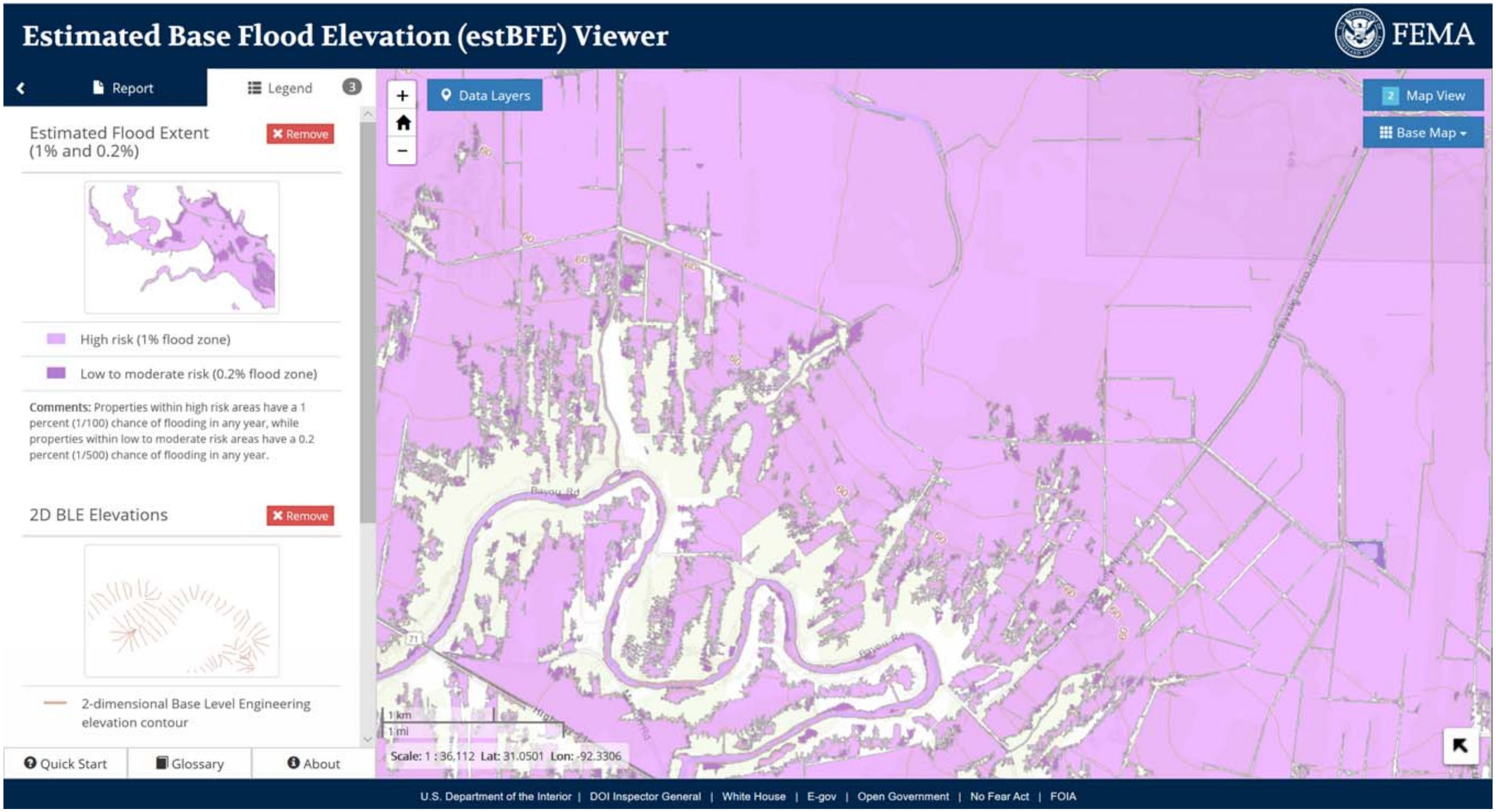
- The field labeled BLELEV1PCT will be used to label the BFE lines on the viewer. The water surface elevation contours should be generated at a one-foot contour interval.
- Mapping Partners shall prepare a BFE line file leveraging the 1-percent annual chance water surface elevation grid prepared during the Base Level Engineering watershed assessment.

Mapping Partners shall complete all NEW FIELDS identified in the table below.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| EST_ID | DFIRM_ID | Study Identifier - Consists of State FIPS Code, County FIPS Code, and the Letter "C". E.G. 48107C **(Suggest HUC8# be included)** |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version and relates the feature to standards according to how it was created **(Suggest BLE_MMYYYY)** |
| EBFE_LN_ID | BFE_LN_ID | Primary Key for table lookup. |
| BLELEV1PCT | ELEV | The rounded, whole-foot elevation of the 1-percent-annual-chance flood. This is the value of the BFE that is shown next to the BFE line in the viewer. |

| | | |
|---|---|---|
| BFE_LN_TYP | BFE_LN_TYP | Similar to XS shown in DFIRM DB. All modeling XS should be included and then select XS that will be shown on EBFE Viewer. Use "MAPPED" as value for XS's that should be shown on viewer. "NOT MAPPED" should be used for all others. **Use values in D_XS_Ln_Typ.** |
| LEN_UNIT | LEN_UNIT | Length Units - Indicates the measurement system used for the BFEs and/or depths. **Use values in D_Length_Units.** |
| **EBFE Database Data Element** | **DFIRM Database Data Element** | **Description** |
| V_DATUM | V_DATUM | Vertical Datum - Indicates the reference surface from which the flood elevations are measured. **Use values in D_V_Datum.** |
| SOURCE_CIT | SOURCE_CIT | Abbreviation used in the metadata file when describing the source information for the feature |

*Figure 8: Data Visualization – BFE_2-D with labeling using value from E_WSE_1PCT field (site labels each 10-foot increment at this time) 60' elevation is labeled, but each contour (brown) represents 1-foot elevation change*



## WTR_LN

This polyline feature class depicts the location of stream centerlines used in hydrologic and hydraulic analysis.

This dataset leverages the DFIRM database S_WTR_LN feature class described in [Guidance for Flood Risk Analysis and Management (fema.gov)](Guidance for Flood Risk Analysis and Management (fema.gov)) (Feature Class: S_WTR_LN). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas. The WTR_LN feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** The field WTR_NM will be used to label the stream centerline in the image in the detailed report. This field should be completed for all Base Level Engineering streams studied. Mapping Partners may determine their own labeling system (numbering 1.1.1, or naming Tributary 1 to Stream), but should be consistent and should assure that model delivery through the MIP uses the same naming convention to support MSC staff in providing the appropriate and correct model when requested.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| EST_ID | DFIRM_ID | Study Identifier: Suggest HUC8 (or other be used) to define the study area – I.E. 12060102_BLE |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version **(Suggest BLE_MMYYYY)** |
| WTR_LN_ID | WTR_LN_ID | Primary key for table lookup. Assigned by table creator |
| WTR_NM | WTR_NM | Surface Water Feature Name<br>Formal name of the water feature as it will appear in the Estimated BFE Viewer Detailed Report. |
| SOURCE_CIT | SOURCE_CIT | Abbreviation used in the metadata file when describing the source information for the feature |
| **These fields will remain in geodatabase but will be hidden.** | | |
| HIDE | SHOWN_FIRM | Shown on FIRM. If the water feature is shown on the FIRM this field is "True" |
| HIDE | SHOWN_INDX | Shown on Index Map - If the water feature is shown on the Index Map this field would be "True" |

## WTR_AR

This polyline feature class depicts the location of water bodies throughout the study area.

This dataset leverages the DFIRM database S_WTR_AR feature class described in [Guidance for Flood Risk Analysis and Management (fema.gov)] Feature Class: S_WTR_AR). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within.

**Required:** Yes, minimum deliverable, no matter which analysis approach (1-D or 2-D) is used. The WTR_AR feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** None.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| EST_ID | DFIRM_ID | Study Identifier: Suggest HUC8 (or other be used) to define the study area – I.E. 12060102_BLE |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version **(Suggest BLE_MMYYYY)** |
| WTR_AR_ID | WTR_AR_ID | Primary key for table lookup. Assigned by table creator |
| WTR_NM | WTR_NM | Surface Water Feature Name - Formal name of the water feature as it will appear on the hardcopy FIRM. |
| SOURCE_CIT | SOURCE_CIT | Abbreviation used in the metadata file when describing the source information for the feature |
| **These fields will remain in geodatabase but will be hidden.** | | |
| HIDE | SHOWN_FIRM | Shown on FIRM. If the water feature is shown on the FIRM this field is "True" |
| HIDE | SHOWN_INDX | Shown on Index Map - If the water feature is shown on the Index Map this field would be "True" |

## DTL_STUD_LN

This polyline feature class identifies streams that have detailed study depicted on the current effective Flood Insurance Rate Map (FIRM) that are available in portions of a study area. This dataset was created for the purposes of the Estimated BFE Viewer. The polyline file leverages the feature class S_LOMR described in Guidance for Flood Risk Analysis and Management (fema.gov)

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis. DTL_STUD_LN shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** Added fields to include FIRM panel numbers, FIRM panel type, and community contact information to allow Estimated BFE Viewer to return the FIRM panels through the tool. The polyline should be clipped to each FIRM panel to allow the tool to return the correct FIRM number. It is understood that Community Contact Information fields will be left blank until community meetings are held.

**Viewer Requirements:** Mapping Partners shall review existing FIRM panels and include a stream centerline in DTL_STUD_LN where an effective FIRM shows more detailed information.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| DTL_LN_ID | DFIRM_ID | Study Identifier: Suggest HUC8 (or other be used) to define the study area – I.E. 12060102_BLE |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version (**Suggest BLE_MMYYYY)** |
| EFF_DATE | EFF_DATE | Effective Date of FIRM Panel |
| FIRM_PAN | NEW Field | Include FIRM panel number (E.G. 48107C0125F) |
| TYPE | NEW Field | **Use values in D_Type**. Effective, Preliminary, Community Data |
| CD_YN | NEW Field | Community or other has additional best available data for use and consideration (PRELIM, YES or NO) |
| CD_POC | NEW Field | Point of Contact for Community Data (First and Last Name) |
| CD_ADD1 | NEW Field | Address Line 1 for Community Data POC |
| CD_ADD2 | NEW Field | Address Line 2 for Community Data POC |
| CD_CTY | NEW Field | City for Community Data POC |
| CD_STATE | NEW Field | State for Community Data POC |
| CD_ZIP | NEW Field | Zip for Community Data POC |
| CD_PHONE | NEW Field | Phone Number for Community Data POC |
| CD_EMAIL | NEW Field | Email Address for Community Data POC |
| SOURCE_CIT | SOURCE_CIT | |
| HIDE | LOMR_ID | This field will remain in geodatabase but shall be hidden. |
| HIDE | CASE_NO | This field will remain in geodatabase but shall be hidden. |

| | | |
|---|---|---|
| HIDE | SCALE | This field will remain in geodatabase but shall be hidden. |
| HIDE | STATUS | This field will remain in geodatabase but shall be hidden. |

## DTL_STUD_AR

This polygon feature class identifies areas that have detailed study depicted on the current effective Flood Insurance Rate Map (FIRMs) that are available in portions of a study area. The polygon file leverages the feature class S_LOMR described in Guidance for Flood Risk Analysis and Management (fema.gov). This dataset was created for the purposes of the Estimated BFE Viewer.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis. DTL_STUD_AR shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** Added fields to include FIRM panel numbers, FIRM panel type, and community contact information to allow Estimated BFE Viewer to return the FIRM panels through the tool. The polygon should be clipped to each FIRM panel to allow the tool to return the correct FIRM number. It is understood that Community Contact Information fields will be left blank until community meetings are held.

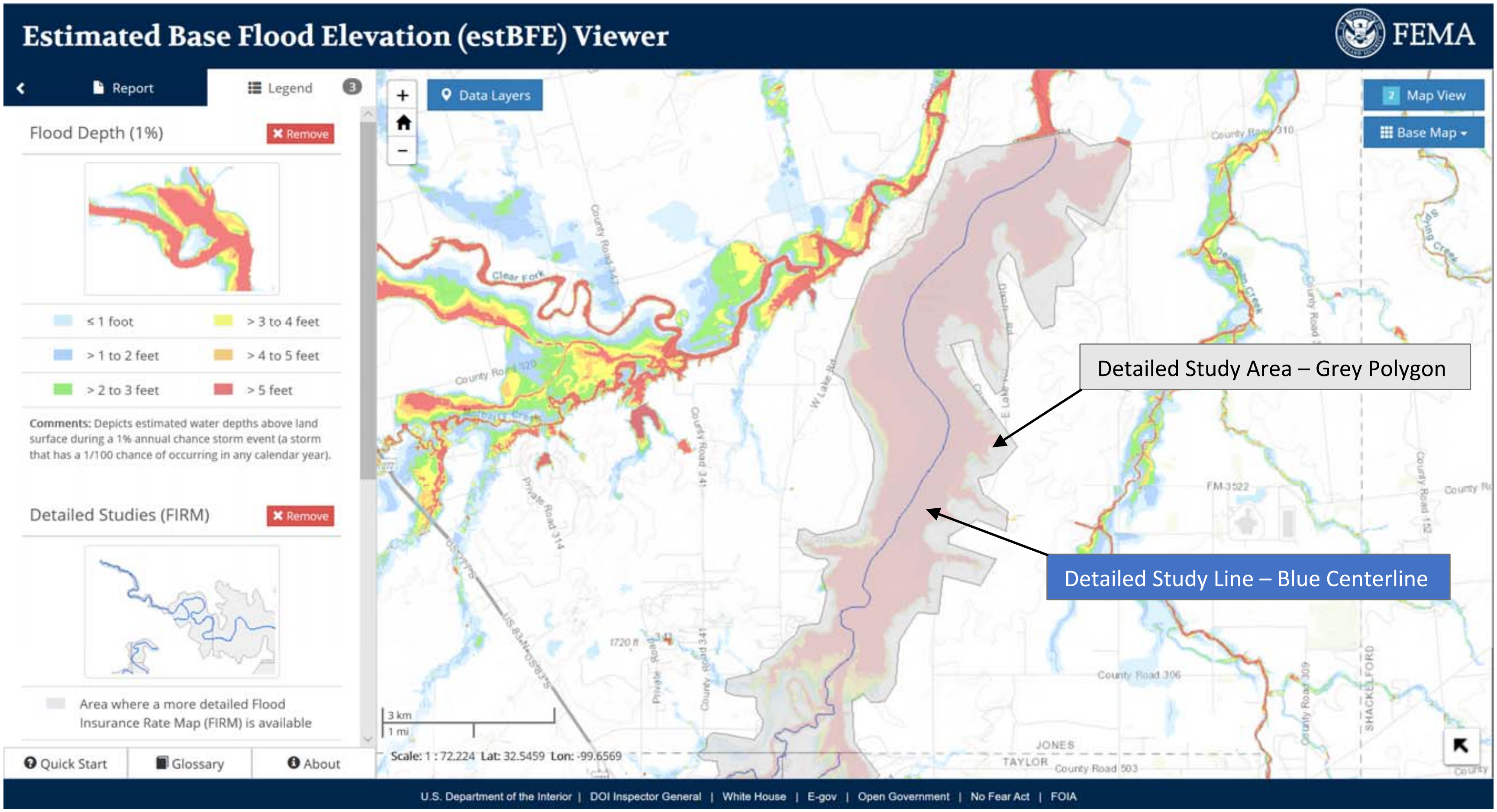
**Viewer Requirements:** Mapping Partners shall review existing FIRM panels and include an area in DTL_STUD_AR where an effective FIRM shows more detailed information.

Mapping Partners should prepare a polygon to bound the existing detailed floodplains depicted on the FIRMs.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| DTL_AR_ID | DFIRM_ID | Study Identifier – Suggest HUC8 (or other be used) to define the study area – I.E. 12060102_BLE |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version (Suggest BLE_MMYYYY) |
| EFF_DATE | EFF_DATE | Effective Date of FIRM Panel |
| FIRM_PAN | NEW Field | Include FIRM panel number (E.G. 48107C0125F) |
| TYPE | NEW Field | **Use values in D_Type.** (Effective, Preliminary, or Community Data) |
| CD_YN | NEW Field | Community or other has additional best available data for use and consideration (PRELIM, YES or NO) |
| CD_POC | NEW Field | Point of Contact for Community Data (First and Last Name) |
| CD_ADD1 | NEW Field | Address Line 1 for Community Data POC |
| CD_ADD2 | NEW Field | Address Line 2 for Community Data POC |

| | | |
|---|---|---|
| CD_CTY | NEW Field | City for Community Data POC |
| CD_STATE | NEW Field | State for Community Data POC |
| CD_ZIP | NEW Field | Zip for Community Data POC |
| CD_PHONE | NEW Field | Phone Number for Community Data POC |
| CD_EMAIL | NEW Field | Email Address for Community Data POC |
| SOURCE_CIT | SOURCE_CIT | |
| **EBFE Database Data Element** | **DFIRM Database Data Element** | **Description** |
| HIDE | LOMR_ID | This field will remain in geodatabase but shall be hidden. |
| HIDE | CASE_NO | This field will remain in geodatabase but shall be hidden. |
| HIDE | SCALE | This field will remain in geodatabase but shall be hidden. |
| HIDE | STATUS | This field will remain in geodatabase but shall be hidden. |

*Figure 9: Data Visualization – Detailed Study Streams and Detailed Study Areas*



## FLD_HAZ_AR

This polygon feature class contains information about the flood hazards within the Flood Risk Project area. The spatial elements representing the flood zones are polygons. The entire area of the jurisdiction(s) mapped by the FIRM should have a corresponding flood zone polygon. There is one polygon for each contiguous flood zone designated.

This dataset leverages the DFIRM database S_FLD_HAZ_AR feature class described in [Guidance for Flood Risk Analysis and Management (fema.gov)] (Feature Class: S_FLD_HAZ_AR). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within and review the additional guidance to assure the datasets will be correctly compiled for use and upload to the Estimated BFE Viewer.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis. The FLD_HAZ_AR feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** Added a field FLD_RISK to allow inclusion of Moderate, or High flood risk evaluation. This value is returned in the report and in the interactive use of the Estimated BFE Viewer.

**Viewer Requirements:** 1% floodplains and 0.2% floodplains shall be loaded into the FLD_HAZ_AR feature class.

Viewer requires the Mapping Partner to complete the field EST_RISK. A “moderate” value should be used for areas that are within the 0.2% annual chance floodplain area, and “high” is associated with the areas within the 1% annual chance floodplain. Domain table D_Fld_Risk should be used for these values.

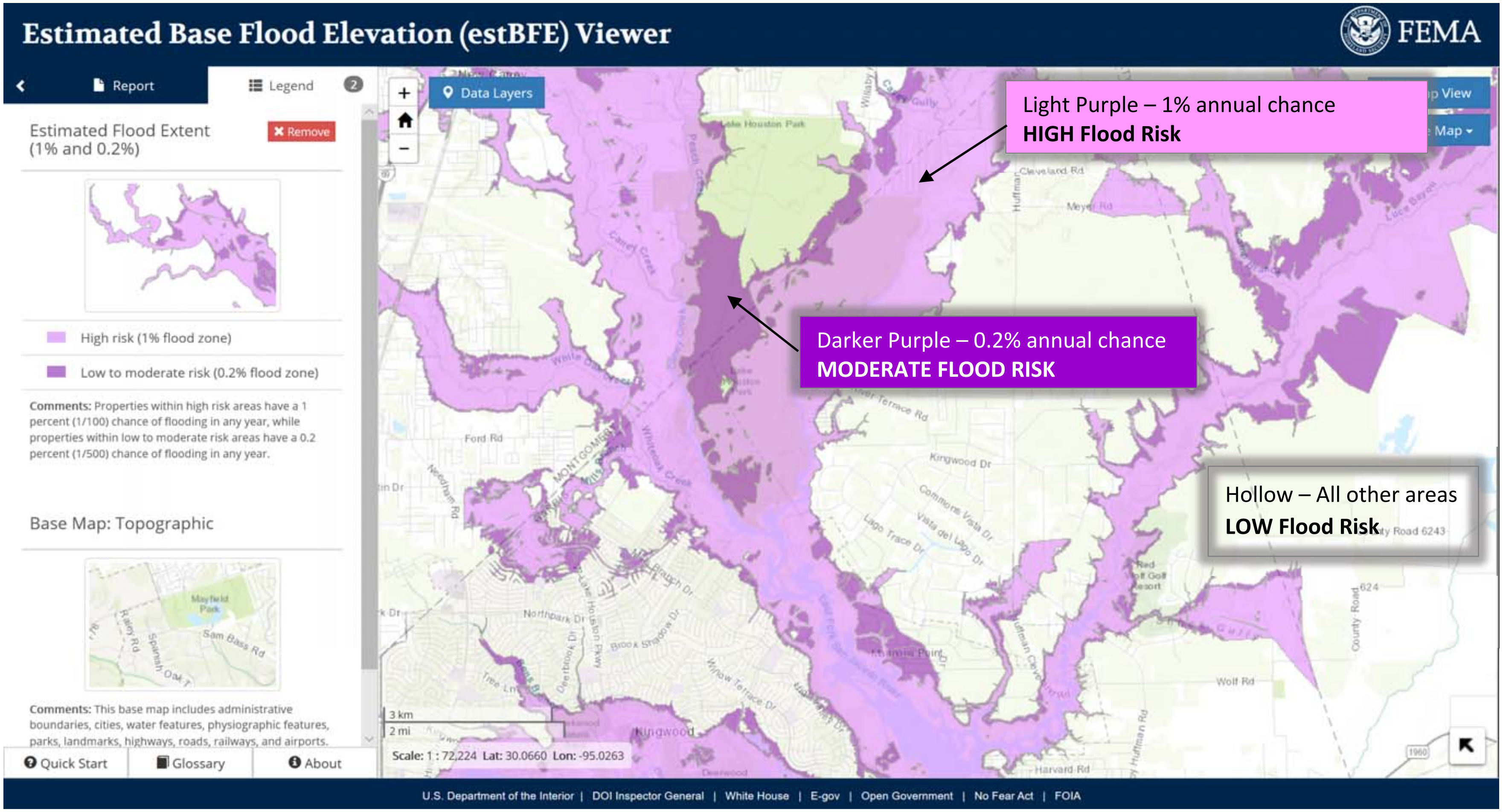
Mapping Partner is NOT required to complete the FLD_ZONE field since the Base Level Engineering information is NOT updating a FIRM when completed and compiled. If the Mapping Partner decides to complete this field the 1% annual chance polygon should be labeled “A”, and the 0.2% annual chance polygon should be labeled “X”.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| EST_ID | DFIRM_ID | Study Identifier - Consists of State FIPS Code, County FIPS Code, and the Letter "C". E.G. 48107C (Suggest HUC8# be included) |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version and relates the feature to standards according to how it was created (Suggest BLE_MMYYYY) |

| | | |
|---|---|---|
| EST_AR_ID | FLD_AR_ID | Primary key for table lookup. Assigned by table creator |
| ZONE_SUBTY | ZONE_SUBTY | Flood Zone Subtype - Captures additional information about the flood zones not related to insurance rating purposes |
| **EBFE Database Data Element** | **DFIRM Database Data Element** | **Description** |
| V_DATUM | V_DATUM | Vertical Datum - Indicates the reference surface from which the flood elevations are measured. **Use values in D_V_Datum.** |
| LEN_UNIT | LEN_UNIT | Length Units - Indicates the measurement system used for the BFEs and/or depths. **Use values in D_Length_Units.** |
| SOURCE_CIT | SOURCE_CIT | Abbreviation used in the metadata file when describing the source information for the feature |
| EST_Risk | NEW Field | "Moderate" - 0.2% floodplain; "High" - within 1% floodplain. **Use values in D_Fld_Risk.** |
| **These fields will remain in geodatabase but will be hidden.** | | |
| HIDE | STUDY_TYP | Study Type - Describes the type of Flood Risk Project performed for flood hazard identification. |
| HIDE | SFHA_TF | Special Flood Hazard Area - If the area is within an SFHA, this field is "True". If not, field is "False" |
| HIDE | STATIC_BFE | Static Base Flood Elevation - Populated for areas that have been determined to have a constant BFE over a flood zone |
| HIDE | DEPTH | Depth for Zone AO areas |
| HIDE | VELOCITY | Velocity measurement of the flood flow in an area |
| HIDE | VEL_UNIT | Unit of measurement for the velocity |
| HIDE | AR_REVERT | If this area is Zone AR in FLD_Zone, this field would hold the zone that area would revert to if the AR zone were removed |
| HIDE | AR_SUBTRV | If this area is Zone AR in FLD_Zone, this field would hold the zone subtype that area would revert to if the AR zone were removed |
| HIDE | BFE_REVERT | Depth Revert - If zone is a Zone AR in FLD_ZONE this field would hold the static base flood elevation for the reverted zone. |

| | | |
|---|---|---|
| HIDE | DEP_REVERT | Depth Revert - If zone is a Zone AR in FLD_ZONE this field would hold the flood depth for the reverted zone. |
| HIDE | DUAL_ZONE | Flood Control Restoration Zone - Populated if the flood hazard areas shown on the effective FIRM will be designated as "duel" flood insurance rate zones |
| HIDE | FLD_ZONE | Not required - Flood Zone designation |

*Figure 10: Data Visualization – Estimated Flood Extents (depicts the 1% and 0.2% annual chance events determined in Base Level Engineering assessment)*



## TENPCT_FP

This polygon feature class contains information about the flood hazard extent expected during the 10% annual chance event, also referred to as the 10-year floodplain. The spatial elements representing this flood extent are described by polygons. One polygon for the 10% annual chance event is expected.

This dataset leverages the DFIRM database S_FLD_HAZ_AR feature class described in Guidance for Flood Risk Analysis and Management (fema.gov) (Feature Class: S_FLD_HAZ_AR). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within and review the additional guidance to assure the datasets will be correctly compiled for use and upload to the Estimated BFE Viewer.

**Required:** Yes, minimum deliverable. The TENPCT_FP feature class shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** Added the EST_Risk field similar to the FLD_HAZ_AR layer to allow inclusion of an extreme flood risk evaluation to describe the 10-year event. This value is not currently returned by the viewer but may be leveraged in the near future. Mapping Partner is NOT required to complete the FLD_ZONE field since the Base Level Engineering information is NOT updating a FIRM when completed and compiled.

**Viewer Requirements:** ONLY the 10% annual chance floodplain polygon shall be loaded into the TENPCT_FP feature class.

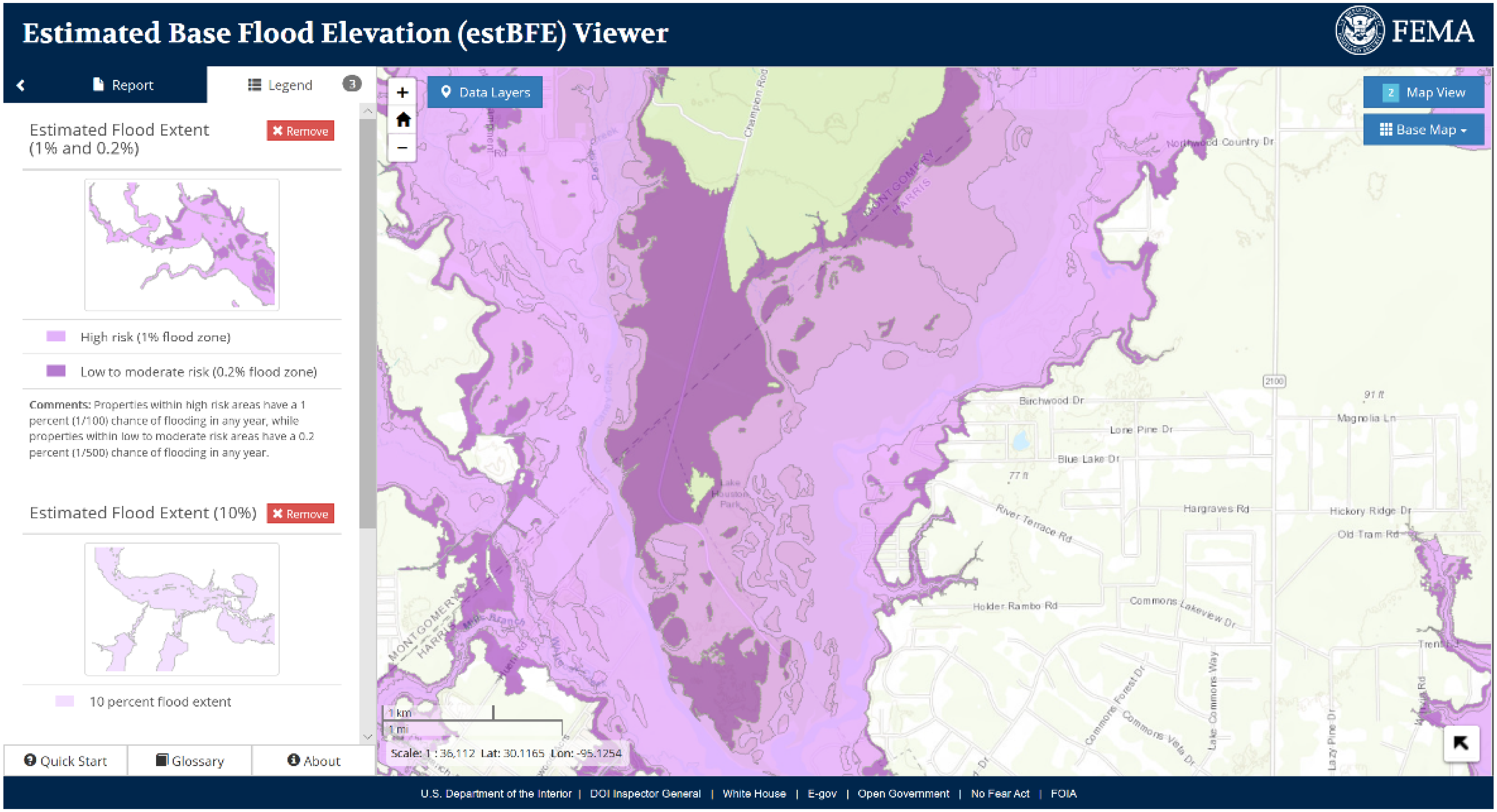
Mapping Partners shall include a value of “EXTREME” in the EST_Risk field to describe the 10% annual chance event. This value is currently not used in the Estimated BFE Viewer but will likely be added in the near future.

| EBFE Database Data Element | DFIRM Database Data Element | Description |
|---|---|---|
| EST_ID | DFIRM_ID | Study Identifier - Consists of State FIPS Code, County FIPS Code, and the Letter "C". E.G. 48107C **(Suggest HUC8# be included)** |
| VERSION_ID | VERSION_ID | Version Identifier - Identifies the product version and relates the feature to standards according to how it was created **(Suggest BLE_MMYYYY)** |
| EST_AR_ID | FLD_AR_ID | Primary key for table lookup. Assigned by table creator |
| V_DATUM | V_DATUM | Vertical Datum - Indicates the reference surface from which the flood elevations are measured. **Use values in D_V_Datum.** |

| | | |
|---|---|---|
| LEN_UNIT | LEN_UNIT | Length Units - Indicates the measurement system used for the BFEs and/or depths. **Use values in D_Length_Units.** |
| SOURCE_CIT | SOURCE_CIT | Abbreviation used in the metadata file when describing the source information for the feature |
| EST_Risk | NEW Field | "Extreme" should be used to label the 10% event |
| **EBFE Database Data Element** | **DFIRM Database Data Element** | **Description** |
| **These fields will remain in geodatabase but will be hidden.** | | |
| HIDE | STUDY_TYP | Study Type - Describes the type of Flood Risk Project performed for flood hazard identification. |
| HIDE | SFHA_TF | Special Flood Hazard Area - If the area is within an SFHA, this field is "True". If not, field is "False" |
| HIDE | ZONE_SUBTY | Flood Zone Subtype - Captures additional information about the flood zones not related to insurance rating purposes |
| HIDE | STATIC_BFE | Static Base Flood Elevation - Populated for areas that have been determined to have a constant BFE over a flood zone |
| HIDE | DEPTH | Depth for Zone AO areas |
| HIDE | VELOCITY | Velocity measurement of the flood flow in an area |
| HIDE | VEL_UNIT | Unit of measurement for the velocity |
| HIDE | AR_REVERT | If this area is Zone AR in FLD_Zone, this field would hold the zone that area would revert to if the AR zone were removed |
| HIDE | AR_SUBTRV | If this area is Zone AR in FLD_Zone, this field would hold the zone subtype that area would revert to if the AR zone were removed |
| HIDE | BFE_REVERT | Depth Revert - If zone is a Zone AR in FLD_ZONE this field would hold the static base flood elevation for the reverted zone. |
| HIDE | DEP_REVERT | Depth Revert - If zone is a Zone AR in FLD_ZONE this field would hold the flood depth for the reverted zone. |

| | | |
|---|---|---|
| HIDE | DUAL_ZONE | Flood Control Restoration Zone - Populated if the flood hazard areas shown on the effective FIRM will be designated as "duel" flood insurance rate zones |
| HIDE | FLD_ZONE | Not Required - Flood Zone - 10-year event boundary (Label 10% event) |

*Figure 11: Data Visualization –10% Estimated Flood Extents (depicts the 10% annual chance event flood extent as lightest shade of purple)*



## BLE_WSE01PCT

This raster dataset class contains the water surface elevation (WSEL) for the 1% annual chance event determined during the Base Level Engineering assessment. This dataset leverages the Raster Dataset guidance described in Flood Risk Database Technical Reference (fema.gov) (2018).

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas. The BLE_WSE01PCT grid shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** ONLY the calculated 1% annual chance water surface elevation shall be included in this dataset as the grid value.

Mapping Partners will need to assure that grids have been adjusted to include any backwater effects from larger streams near each confluence area.

Mapping Partners shall calculate the grid value to the tenths place (0.0 feet).

Mapping Partners shall not use a grid cell size any larger than 10 foot by 10 foot.

Mapping Partners shall clip the gridded information to match the extent of the 1% annual chance floodplain.

The 1% annual chance water surface elevation is leveraged by the Estimated BFE Viewer to return a value to the user for the estimated base flood elevation at any location selected within the 1% annual chance event floodplain.

## BLE_WSE0_2PCT

This raster dataset class contains the water surface elevation (WSEL) for the 0.2% annual chance event determined during the Base Level Engineering assessment. This dataset leverages the Raster Dataset guidance described in Flood Risk Database Technical Reference (fema.gov) (2018).

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas. The BLE_WSE0_2PCT grid shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** ONLY the calculated 0.2% annual chance water surface elevation shall be included in this dataset as the grid value.

Mapping Partners will need to assure that grids have been adjusted to include any backwater effects from larger streams near each confluence area.

Mapping Partners shall calculate the grid value to the tenths place (0.0 feet).

Mapping Partners shall not use a grid cell size any larger than 10 foot by 10 foot.

Mapping Partners shall clip the gridded information to match the extent of the 0.2% annual chance floodplain.

## BLE_DEP01PCT

This raster dataset class contains the estimated flood depth throughout the 1% annual chance floodplain determined during the Base Level Engineering assessment. This dataset is created by performing a calculation to subtract the ground elevation from the water surface elevation dataset, thereby calculating the estimated depth of flooding within the 1% annual chance floodplain extents. This dataset leverages the Raster Dataset guidance described in Flood Risk Database Technical Reference (fema.gov) (2018).

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas. The BLE_DEP01PCT grid shall be created for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** ONLY the calculated flood depth for the 1% annual chance event shall be included in this dataset as the grid value.

Mapping Partners shall use the BLE_WSE01PCT grid and the Terrain developed for the Base Level Engineering assessment to calculate an estimated flood depth throughout the 1% annual chance floodplain. See warnings for backwater and confluence areas in BLE_WSE01PCT description.

Mapping Partners shall calculate the grid value to the tenths place (0.0 feet).

Mapping Partners shall not use a grid cell size any larger than 10 foot by 10 foot.

Mapping Partners shall clip the gridded information to match the extent of the 1% annual chance floodplain.

The estimated flood depth calculated for the 1% annual chance event is leveraged by the Estimated BFE Viewer to return a value to the user for the estimated depth of flooding for any location within the 1% annual chance event.

## BLE_DEP0_2PCT

This raster dataset class contains the estimated flood depth throughout the 0.2% annual chance floodplain determined during the Base Level Engineering assessment. This dataset is created by performing a calculation to subtract the ground elevation from the water surface elevation dataset, thereby calculating the estimated depth of flooding within the 0.2% annual chance floodplain extents. This dataset leverages the Raster Dataset guidance described in Flood Risk Database Technical Reference (fema.gov) (2018).

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas. The BLE_DEP0_2PCT grid shall be compiled for the study area, but no larger than one (1) HUC8 watershed per delivery area.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** ONLY the calculated flood depth for the 0.2% annual chance event shall be included in this dataset as the grid value.

Mapping Partners shall use the BLE_WSE0_2PCT grid and the Terrain developed for the Base Level Engineering assessment to calculate an estimated flood depth throughout the 0.2% annual chance floodplain. See warnings for backwater and confluence areas in BLE_WSE0_2PCT description.

Mapping Partners shall calculate the grid value to the tenths place (0.0 feet).

Mapping Partners shall not use a grid cell size any larger than 10 foot by 10 foot.

Mapping Partners shall clip the gridded information to match the extent of the 0.2% annual chance floodplain.

## S_AOMI_AR

This polygon feature class is intended to be used as a communication tool to direct users to areas that warrant further investigation or research for possible mitigation (significant land use change, non-levee embankments, coastal features, mitigation successes, key emergency routes, etc.). The intent of this coverage area is to allow a visualization and depiction of areas that may be refined in future local, state, regional or federal modeling efforts.

This dataset leverages the Flood Risk Database S_AOMI_Ar feature class described in [Flood Risk Database Technical Reference (fema.gov)](https://www.fema.gov) (2018). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within.

**Required:** No. Optional layer that can be used to identify mitigation areas including significant land use changes, future mitigation actions, mitigation successes, etc.

**Exceptions:** None.

**Inclusions:** Possible inclusions include:

Significant land use change – Proposed/recent development and areas with current or project population growth. Potential sources for this data include: Discovery meeting materials and discussions; community comprehensive plans; state growth management plans and real estate trends. If review of an aerial image identifies centralized development in a location that soils, or land use information define as natural/non-impervious, the Mapping Partner shall include a polygon to describe a future prioritization area for local refinement and identify that the hydrology may require additional review. If intense and centralized development significantly alters the percent of impervious land in a watershed or sub-basin within the engineering analysis, the flow volume may be altered.

Altered stream/drainage channel location - If local development has modified a stream channel location/alignment Mapping Partners shall include a polygon to describe the general area of disagreement between the LiDAR/engineering modeling and a recent aerial.

Coastal structures – Structures along the coast that “harden” the shoreline, interrupt the natural dynamic shoreline process, or accelerate erosion along the shore. Potential sources for this data include: Discovery meeting materials and discussions; community input; NOAA National Shoreline Survey; State Coastal Zone Management programs and Beach Management Plans.

Mitigation successes – Structural/grading projects that mitigate flooding. These can include but are not limited to increase in size of storm drain pipe, drainage rerouted via grading, floodwall construction, etc.

Key emergency routes overtopped – Key emergency and evacuation routes that are overtopped during the 4-percent or more annual chance event. Potential sources for this data include: Discovery meeting materials and discussions; community stakeholders and flood profiles.

Non-levee embankments – Embankments/structures that are not designed for flood control but have an impact on flooding. These may include but are not limited to railroad embankments and roadways.

Non-accredited levees – Levees that do not meet the 44 CFR Part 65.10 or those that have recently had their provisionally accredited status expire. Potential sources for this data include: Discovery meeting materials and discussions; community input; and National Levee Database.

Storage Areas Modeled – Numerous stock tanks, local dams/reservoirs, and other detention structures exist throughout the Region, these structures may alter the nature of flow and timing within a riverine environment. The Mapping Partner shall include polygons to describe modeled Storage Areas utilized in the Base Level Engineering HEC-HMS and HEC-RAS efforts. Inclusion of these items allows the Mapping Partner to communicate that there is opportunity for refinement of the hydrology and expansion of the hydraulic modeling prepared in the Base Level Engineering effort.

Optional items include:

Past claims hot spots – Indicators of repeated flood-related insurance claims. Care must be taken to no identify claim or property specific losses and must abide privacy requirements.

**Viewer Requirements:** None.

| EBFE Database Data Element | Required (R) Applicable (A) | Description |
|---|---|---|
| OBJECTID | R | Object Identifier.<br>Internal Primary Key used by ArcGIS software to provide unique access to each record. |
| SHAPE | R | Shape Geometry Field.<br>Internal field used by ArcGIS software to store the feature geometry. |
| AOMI_ID | R | Area of Mitigation Interest Identifier. User-defined Primary Key / Unique Identifier.<br>This field should be sequentially numbered for all records in the table. |
| CID | A | Community Identification Number.<br>This is the six-digit CID assigned by FEMA in which this AOMI lies. See the definition in S_Pol_Ar for more detail. If the AOMI does not lie in an area covered by a FEMA community identifier, this field shall be populated with a null value. |
| POL_NAME1 | A | Political Area Name 1.<br>This is the primary name of the community in which the AOMI lies. This field is included in this table instead of retrieval by joining to S_Pol_Ar table. See the definition in S_Pol_Ar for more detail. If the AOMI does not lie in an area covered by a FEMA community identifier, this field shall be populated with a null value. |
| AOMI_CLASS | R | Area of Mitigation Interest Class. This is the general class to which the AOMI belongs (e.g., Riverine, Coastal, other, uses D_AOMI_Class).<br>**For BLE – enter "Riverine or Coastal", whichever is applicable** |

| EBFE Database Data Element | Required (R) Applicable (A) | Description |
|---|---|---|
| AOMI_TYP | R | Type of Mitigation Interest. This is the general type to which the AOMI belongs (e.g., Dam, Levee, Erosion, etc., uses D_AOMI_Typ).<br>**For BLE – enter value necessary (Significant land use change, mitigation success, etc.)** |
| AOMI_INFO | A | AOMI Information. This field provides the specific reasons this location is considered an AOMI. Comments explaining the relevance of this AOMI point. |
| HUC8_CODE | R | WBD 8-digit Hydrologic Unit Code for the sub-basin in which the AoMI lies. |
| CASE_NO | R | FEMA Case Number. See the CASE_NO field in the S_FRD_Proj_Ar feature class for a more detailed description. |
| VERSION_ID | R | Version Identifier. Identifies the product version and relates the feature to standards according to which it was created. |
| SOURCE_CIT | R | Source Citation from L_SOURCE_CIT. See field definition in L_Source_Cit for more detail. |

**Mapping Partners may add information collected at Discovery, to include, but not limited to:** areas of mitigation success, significant land use changes, areas of local community interest for future mitigation action, indication of major flood sources for communities, coastal features, non- accredited levees, etc.

## S_FRAC_AR

This polygon feature class is the spatial foundation for all census block-based flood risk assessment data. All the inventory and damage estimates for flood risk assessments performed at the Census Block level are stored in this dataset. This feature class contains the spatial location of the Census Blocks for the project. The census block geometries shall be based on the version of Hazus used to perform the analysis, which should be documented in the metadata.

This should include information on whether the census block type was homogenous or dasymetric (https://www.fema.gov/sites/default/files/documents/fema_flood-risk-assessment-guidance.pdf). This feature class also stores the Asset Replacement Value, as well as the estimated flood risk assessment results for each block. This feature class is required to be populated when the Flood Risk Assessment dataset is produced.

This dataset leverages the Flood Risk Database S_FRAC_Ar feature class described in Flood Risk Database Technical Reference (fema.gov) (2018). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within.

**Note (April 2019):** The S_FRAC_AR dataset replaces the historic submittal of the S_CenBlk_AR dataset and L_RA_Results table within the Spatial deliverables for each BLE submittal.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas.

**Exceptions:** None.

**Inclusions:** Hazus results based on WSEL and Depth of flooding grids produced in Base Level Engineering effort.

**Viewer Requirements:** None.

| EBFE Database Data Element | Required (R) Applicable (A) | Description |
|---|---|---|
| OBJECTID | R | Object Identifier.<br>Internal Primary Key used by ArcGIS software to provide unique access to each record. |
| SHAPE | R | Shape Geometry Field. Internal field used by ArcGIS software to store the feature geometry. |
| CEN_BLK_ID | R | This field should be populated with the Census Block identifier. This identifier is based on the following format with an optional single alphabetic character suffix to accommodate the 2010 decennial Census:<br>06 071 003602 1003<br>State County Census Tract Block Group Block Group |
| ARV_BG_TOT | REQUIRED for BLE | Asset Replacement Value of Buildings of All Structure Types. Obtained from General Building Stock data, in whole dollars. |

| | | |
|---|---|---|
| ARV_CN_TOT | REQUIRED for BLE | Asset Replacement Value of Contents for All Structure Types. Obtained from General Building Stock data, in whole dollars. |
| **EBFE Database Data Element** | **Required (R) Applicable (A)** | **Description** |
| TOT_LOSS01 | REQUIRED for BLE | 1 Percent Chance Total Losses. For each Census Block, the estimate of the total value of all losses for the return period. |
| BL_TOT01 | REQUIRED for BLE | 1 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of building losses for the return period. |
| CL_TOT01 | REQUIRED for BLE | 1 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of content losses for the return period. |
| HIDE | HAZARD_TYP | Hazard Type. Indicates the Hazard Type for which the loss fields apply. This field uses D_Hazard_Type. |
| HIDE | SCENAR_ID | Levee or Dam Scenario Identification. |
| HIDE | TOT_LOSS10 | 10 Percent Chance Total Losses. For each Census Block, the estimate of the total value of all losses for the return period. |
| HIDE | BL_TOT10 | 10 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of building losses for the return period. |
| HIDE | CL_TOT10 | 10 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of content losses for the return period. |
| HIDE | TOT_LOSS04 | 4 Percent Chance Total Losses. For each Census Block, the estimate of the total value of all losses for the return period. |
| HIDE | BL_TOT04 | 4 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of building losses for the return period. |
| HIDE | CL_TOT04 | 4 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of content losses for the return period. |
| HIDE | TOT_LOSS02 | 2 Percent Chance Total Losses. For each Census Block, the estimate of the total value of all losses for the return period. |
| HIDE | BL_TOT02 | 2 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of building losses for the return period. |
| HIDE | CL_TOT02 | 2 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of content losses for the return period. |
| HIDE | TOT_LSS0_2 | 0.2 Percent Chance Total Losses. For each Census Block, the estimate of the total value of all losses for the return period. |
| HIDE | BL_TOT0_2 | 0.2 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of building losses for the return period. |
| HIDE | CL_TOT0_2 | 0.2 Percent Chance Total Building Losses. For each Census Block, the estimate of the total value of content losses for the return period. |

| | | |
|---|---|---|
| HIDE | TOT_LSSAAL | Average Annualized Total Losses. For each Census Block, the estimate of the total value of all losses for the return period. |
| **EBFE Database Data Element** | **Required (R) Applicable (A)** | **Description** |
| HIDE | BL_TOTAAL | Average Annualized Total Building Losses. For each Census Block, the estimate of the total value of building losses for the return period. |
| HIDE | CL_TOTAAL | Average Annualized Total Building Losses. For each Census Block, the estimate of the total value of content losses for the return period. |
| HUC8_CODE | R | WBD 8-digit Hydrologic Unit Code for the sub-basin in which the Census Block lies. If a Census Block crosses a HUC-8 boundary, the field shall be populated with the HUC-8 value in which the majority of the Census Block lies. |
| CASE_NO | R | FEMA Case Number. See the CASE_NO field in S_FRD_Proj_Ar for more detail. |
| VERSION_ID | R | Version Identifier. Identifies the product version and relates the feature to standards according to which it was created. |
| SOURCE_CIT | R | Source Citation from L_SOURCE_CIT. See field definition in L_Source_Cit for more detail. |
| SHAPE_LENGTH | R | Internal field used by ArcGIS software to store the length of the feature's geometry. |
| SHAPE_AREA | R | Internal field used by ArcGIS |

## S_FRAS_PT

This point feature class locates structures or buildings for which site- or location-specific risk assessments are performed. There is one record for each structure or building assessed. This feature class also stores the Asset Replacement Value, as well as the estimated flood risk assessment results for each structure/building. This feature class is required to be populated when flood risk assessments for a Flood Risk Project performed at the site-specific level. This feature class provides the location, inventory and loss data where site-specific risk assessments were performed. Risk assessments results for the five standard flood events (10-, 4-, 2-, 1-, and 0.2-percent-annual-chance) are stored in this table when available. Risk assessment results for other flood events or scenarios can be added to S_FRAS_Pt or saved in a supplemented FRD table which includes the FRAS_ID field to allow database linking to the standard S_FRAS_Pt table.

**Required:** No, optional deliverable for 1-D and 2-D BLE analysis areas.

**Exceptions:** N/A

**Inclusions:** Hazus results based on WSEL and Depth of flooding grids produced in Base Level Engineering effort.

**Viewer Requirements:** None.

| EBFE Database Data Element | Required (R) Applicable (A) | Description |
|---|---|---|
| OBJECTID | R | Object Identifier.<br>Internal Primary Key used by ArcGIS software to provide unique access to each record. |
| SHAPE | R | Shape Geometry Field. Internal field used by ArcGIS software to store the feature geometry. |
| FRAS_ID | R | Structure/Building Identifier. User-defined Primary Key / Unique Identifier. This field should be sequentially numbered for all records in the table. |
| CEN_BLK_ID | R | This field should be populated with the Census Block identifier. This identifier is based on the following format with an optional single alphabetic character suffix to accommodate the 2010 decennial Census:<br>06 071 003602 1003<br>State County Census Tract Block Group Block Group |
| OCCUP_TYP | R | Specific Occupancy Type from risk assessment analysis. Uses D_Occupancy_Typ for valid values. |
| ARV_BG | R | Asset Replacement Value of Buildings of All Structure Types. Obtained from General Building Stock data, in whole dollars. |
| ARV_CN | RE | Asset Replacement Value of Contents for All Structure Types. Obtained from General Building Stock data, in whole dollars. |

| | | |
|---|---|---|
| HAZARD_TYP | R | Hazard Type. Indicates the Hazard Type for which the remaining fields apply. The valid values for this field are in the domain D_Hazard_Typ and include Riverine, Coastal, Levee, Dam, and Total. |
| SCENAR_ID | A | Scenario Identification. Used for either dam scenario (L_Dam_Scenario) or levee scenario (L_Levee_Scenario). |
| BLD_LOSS10 | A | 10 Percent Chance Building Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| CNT_LOSS10 | A | 10 Percent Chance Contents Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| INV_LOSS10 | A | 10 Percent Chance Inventory Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| BLD_LOSS04 | A | 4 Percent Chance Building Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| CNT_LOSS04 | A | 4 Percent Chance Contents Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| INV_LOSS04 | A | 4 Percent Chance Inventory Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| BLD_LOSS02 | A | 2 Percent Chance Building Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| CNT_LOSS02 | A | 2 Percent Chance Contents Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| INV_LOSS02 | A | 2 Percent Chance Inventory Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| BLD_LOSS01 | A | 1 Percent Chance Building Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| CNT_LOSS01 | A | 1 Percent Chance Contents Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| INV_LOSS01 | A | 1 Percent Chance Inventory Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| BLD_LOSS0_2 | A | 0.2 Percent Chance Building Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| CNT_LOSS0_2 | A | 0.2 Percent Chance Contents Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| INV_LOSS0_2 | A | 0.2 Percent Chance Inventory Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| BLD_LSSAAL | A | Average Annualized Building Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |

| | | |
|---|---|---|
| CNT_LSSAAL | A | Average Annualized Contents Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| INV_LSSAAL | A | Average Annualized Inventory Loss. Asset Value Loss to the nearest dollar for the Building for the combination of Hazard Type and Return Period. |
| HUC8_CODE | R | WBD 8-digit Hydrologic Unit Code for the sub-basin in which the Census Block lies. If a Census Block crosses a HUC-8 boundary, the field shall be populated with the HUC-8 value in which the majority of the Census Block lies. |
| CASE_NO | R | FEMA Case Number. See the CASE_NO field in S_FRD_Proj_Ar for more detail. |
| VERSION_ID | R | Version Identifier. Identifies the product version and relates the feature to standards according to which it was created. |
| SOURCE_CIT | R | Source Citation from L_SOURCE_CIT. See field definition in L_Source_Cit for more detail. |
| SHAPE_LENGTH | R | Internal field used by ArcGIS software to store the length of the feature’s geometry. |
| SHAPE_AREA | R | Internal field used by ArcGIS |

## L_Source_Cit

The Source Citations table should contain a record for each data source used (both vector and raster) used to compile the Base Level Engineering data submittal. This table is required to be populated. Source Citation Type Abbreviations (BASE, LOMC, FIRM, STUDY, etc) followed by sequential numbers, should be used in creating the references. These citations provide a link to the metadata where the data sources are more fully described.

This dataset leverages the L_Source_Cit tables from the DFIRM Database and Flood Risk Database national templates. The lookup table is described in Flood Risk Database Technical Reference (fema.gov) (2018). Mapping Partners shall follow the instructions within the Technical Reference for the compilation of this dataset elements described within.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas.

**Exceptions:** None.

**Inclusions:** STUDY and FIRM references should be added to Table and associated BLE Datasets at a minimum.

**Viewer Requirements:** None.

| EBFE Database Data Element | Required (R) Applicable (A) | Description |
|---|---|---|
| OBJECTID | R | Object Identifier. Internal Primary Key used by ArcGIS software to provide unique access to each record. |
| SOURCE_CIT | R | Source Citation identifier used in the FIRM Database and in the FIRM metadata file. Source citations start with the type of source followed by sequential numbers, for example “BASE1”, “BASE2”, etc. |
| DFIRM_ID | R | Regulatory Product Identifier. For a single-jurisdiction Flood Risk Project, the value is composed of the 2-digit State FIPS code and the 4-digit FEMA CID code (e.g., 480001). For a countywide Flood Risk Project, the value is composed of the 2-digit State FIPS code, the 3-digit county FIPS code and the letter “C” (e.g., 48107C). Within each FIRM database, the DFIRM_ID value is identical. |
| PUBLISHER | A | Publisher Name Used in FIS Report Bibliography and References Table. This is the name of the publishing entity, for example FEMA, USGS, etc. |
| TITLE | A | Title of referenced publication or data Used in FIS Report Bibliography and References Table. Should include the volume number if applicable, for example National Flood Hazard Layer, Preliminary Flood Insurance Study – project name. |
| Author/Editor | A | Used in FIS Report Bibliography and References Table. This is the author or editor of the reference. Multiple authors may be listed in this field. |

| | | |
|---|---|---|
| PUB_PLACE | A | Publication Place Used in FIS Report Bibliography and References Table. This is the place of publication (e.g., “Washington DC”). |
| PUB_DATE | A | Publication Date Used in FIS Report Bibliography and References Table. This is the date of publication or date of issuance. |
| WEBLINK | A | A Reference Web Address Used in FIS Report Bibliography and References Table. This is the web address for the reference, if applicable. |
| MEDIA | A | Media through which the source data were received. |
| CASE_NO | R | FEMA Case Number. See the CASE_NO field in S_FRD_Proj_Ar for more detail. |
| VERSION_ID | R | Version Identifier. Identifies the product version and relates the feature to standards according to which it was created. |

## CNMS Process and Delivery

For BLE projects, there are two touchpoints when CNMS must be updated; once at scoping (within 30 days of the project start) and again once engineering on the BLE study is completed (Production Phase Update). FEMA's [Coordinated Needs Management Strategy (CNMS) Technical Reference (fema.gov)](#) should be referenced during completion of these tasks. Mapping Partners shall request the latest version of the CNMS Database from the RSC for the project area prior to completing each of these touchpoints.

**BLE Scoping Phase Update**

FEMA requires that only BLE studies that are used to update the regulatory FIRM and counted in the Risk MAP Project Planning and Purchasing Portal (P4) as initiated miles will be treated as initiated miles in CNMS and receive the BEING STUDIED classification. Fully automated LSAE or BLE studies not being used to update the regulatory FIRM can be leveraged for assessment work only and may have tracking fields in CNMS populated but will not receive a BEING STUDIED classification and will not count toward NVUE initiated. The Mapping Partner will consult with the RSC or FEMA Region to confirm whether the BLE study is being used to update the regulatory FIRM and counted in P4 as initiated miles. Some Regional Guidance has been previously prepared to detail the Roles and Responsibilities of provider teams and Mapping Partners that may be of assistance (available at RMD SharePoint > R6 > Resources > Regional Delivery Guidance:

- CNMS Roles & Responsibilities – Flood Risk Studies
- CNMS Roles & Responsibilities – Quarterly Regional Database Maintenance
- CNMS Guidance – Unmapped Unstudied Streams

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** None.

1. Add Unmapped Miles into S_Studies_Ln:

   BLE studies often extend past the reaches representing effective SFHA in the CNMS inventory, since unmapped stream reaches are gathered for drainage areas > 0.5 sq. mile in urban areas and > 1.0 sq. mile in rural areas. Where BLE analysis does not overlap with existing CNMS inventory (i.e. in non-SFHA areas), these unmapped stream reaches should be loaded into S_Studies_Ln and edited to tie into existing features. The most common source for unmapped stream features will be the S_Unmapped_Ln feature class in CNMS; staff should first contact the Compass RSC CNMS lead to confirm the appropriate source to use. If unmapped miles are not available at the time of scoping, they can be added later to the BLE study area during the Production Phase Update.

Once new stream centerline features representing unmapped miles have been added to S_Studies_Ln, the following basic fields will need to be populated:

- REACH_ID: see Table F-1 in *CNMS Technical Reference, February 2018*
- STUDY_ID: see Table F-1 in *CNMS Technical Reference, February 2018*
- COFIPS: see Table F-1 in *CNMS Technical Reference, February 2018*
- CID: see Table F-1 in *CNMS Technical Reference, February 2018*
- WTR_NM: see Table F-1 in *CNMS Technical Reference, February 2018*; BLE study is typically the best source of these water names
- FLD_ZONE: effective flood zone ("X" for unmapped miles)
- VALIDATION_STATUS: for all unmapped miles, "ASSESSED"
- MILES: see Table F-1 in *CNMS Technical Reference, February 2018*
- SOURCE: see Table F-1 in *CNMS Technical Reference, February 2018 (*"COUNTY DFIRM DATABASE ACQUIRED DURING STUDY PERIOD" is an acceptable default entry for BLE unmapped miles)
- REASON: note the BLE project name and BS_MIP_CASE_NUMBER, if available (see Step 3 "BEING STUDIED Fields" below)
- HUC8_KEY: see Table F-1 in *CNMS Technical Reference, February 2018*
- STUDY_TYPE: description of effective study type (for Zone X, "UNMAPPED d")
- TIER: "TIER 0" (classification for Zone X (non-SFHA))
- LINE_TYPE: e.g. "RIVERINE"; see Table F-1 in *CNMS Technical Reference, February 2018*
- FBS_CMPLNT: "Unknown" (default entry for Zone X)
- FBS_CHKDT: current date (default entry for Zone X)
- FBS_CTYP: "COUNTY - BULK ATTRIBUTION" (default entry for Zone X)
- DUPLICATE: see Table F-1 in *CNMS Technical Reference, February 2018* (Zone X is "CATEGORY 3" by default)

In addition, all of the fields detailed in Step 2 "BLE Tracking Fields" and Step 3 "BEING STUDIED Fields" below will need to be populated, with the following exception:

- BS_STDYTP: description of new study type ("NEW OR UPDATED APPROXIMATE" for effective Zone X)

2. BLE Tracking Fields:

The following fields in S_Studies_Ln should be populated for all reaches within the BLE project footprint (Zone A, Detailed, and Unmapped reaches), as this information can facilitate the query of BLE extent in CNMS:

- BLE: BLE study classification (select either Tier A, B, C, D, E; 2D; or LSAE; see Table 1 of the BLE Analysis and Mapping Guidance, February 2018 for domain code descriptions. Most Compass BLE studies are either Tier A or B. If unsure, default is Tier A.)

- BLE_POC: Preferred FEMA Regional contact or project manager to be added to the Point_of_Contact Table. Instructions for creating this 12-digit number can be found in Table F-6 of the CNMS Technical Reference, February 2018 (e.g. “482450500001”; the first five digits are the county, “05” is the identifier for the POC table, and the last five digits are a counter for each unique POC entry for that county) This attribute will be replaced with BLE_CASE_NUMBER in the future.
- BLE_DATE: date that engineering was completed on the BLE study

3. BEING STUDIED Fields:

All the approximate reaches included in the BLE study are classified with a Status Type of “Being Studied.” This update in Status Type requires additional fields specific to the BLE study to be populated at this point as well. The definition query created for S_Studies_Ln should be updated to isolate only the Zone A reaches located within the BLE study area (i.e. CO_FIPS = '48141' AND FLD_ZONE = 'A' or HUC8_KEY = '12030102' AND FLD_ZONE = 'A'). The following fields in S_Studies_Ln should then be populated as follows:

- STATUS_TYPE: “BEING STUDIED”
- STATUS_DATE: current date
- BS_MIP_CASE_NUMBER: FEMA-assigned case number used for storage on the Mapping Information Platform (MIP) (REQUIRED)
- BS_ZONE: flood zone of the new study (“A” for BLE studies”)
- BS_STDYTYP: description of new study type (“NEW OR UPDATED APPROXIMATE” for existing Zone A)
- BS_HYDRO_M: hydrologic method/model used in BLE study (e.g. “REGRESSION EQUATIONS”)
- BS_HYDRO_CMT: comment field regarding hydrologic method/model
- BS_HYDRA_M: hydraulic method/model used in BLE study (e.g. “HEC-RAS 4.1”)
- BS_HYDRA_CMT: comment field regarding hydraulic method/model
- BS_FY_FUND: fiscal year from which BLE study is funded (e.g. “FY21”)
- PRELIM_DATE: date the BLE study will go preliminary (This date is not known at this time, so it should be populated with a date far in the future, such as 1/1/2030. This field will get updated again when a preliminary date is known.)
- LFD_DATE: date the letter of final determination for the BLE study is issued (This date is not known at this time, so it should be populated with a date one year ahead of the PRELIM_DATE entered, such as 1/1/2031. This field will get updated again when the LFD is issued.)

Much of the information needed to complete these fields can be collected from the BLE Project Manager or Technical Lead. Prior to completing the attribution of these fields, best practice is to perform a QC check on the HUC8 attribution of all reaches located in the study area to be sure it is correct and that reaches are split at the HUC boundary. This QC should occur before the definition query is created for the BLE project footprint.

4. Run the CNMS QC tool:

   As with all CNMS submittals, the Mapping Partner will run the CNMS QC Tool on their updated CNMS database extract and address all Critical and Secondary errors prior to delivery of the CNMS database. The CNMS QC Tool is typically updated once a year when an updated CNMS Schema is distributed. If necessary, the Mapping Partner can obtain the latest copy of the QC Tool from the RSC.

**BLE Production Phase Update**

The BLE Production Phase Update to the CNMS DB is focused on the population of the A1-A4 and A5 Validation Assessment Checks and the resulting update to the Validation Status classification. Fields populated during the Scoping Phase Update should first be reviewed for accuracy and updated with newly provided information as necessary (for example, a BLE analysis completion date). Unmapped miles can be added at this point if not previously, see Step 1 “Add Unmapped Miles into S_Studies_Ln” above.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas.

**Exceptions:** None.

**Inclusions:** CNMS database with the revised S_Studies_Ln feature and the validation points (as a separate shapefile) should be submitted along with the associated BLE report documenting the results.

**Viewer Requirements:** None.

For the following steps, a definition query should be created for S_Studies_Ln isolating the approximate reaches located within the BLE study area (i.e. CO_FIPS = '48141' AND FLD_ZONE = 'A' or HUC8_KEY = '12030102' AND FLD_ZONE = 'A').

1. A1 – A4 Assessment
   Existing Zone A studies within the BLE study area must go through the entire Zone A validation assessment process. Several sources of data are needed to complete this step:

   - Effective FIS report
   - Effective DFIRM DB
   - LOMR data (if applicable)

- Topography inventory/data
- National Urban Change Indicator (NUCI) data

Background Data

The following fields in the S_Studies_Ln file should be determined and verified or updated based on the *effective* study data (not the BLE study) using the above sources:

- MIP_CASE_NUMBER - FEMA-assigned case number used for storage on the Mapping Information Platform (MIP) (if known)
- STUDY_TYPE – verify description of study type
- TIER – verify Tier classification is correct
- DATE_EFFECT - date that engineering was completed for the effective approximate study
- HYDRO_MDL - hydrologic method/model used for the effective approximate study
- HYDRO_MDL_CMT - comment field regarding hydrologic method/model
- HYDRA_MDL - hydraulic method/model used for the effective approximate study
- HYDRA_MDL_CMT - comment field regarding hydraulic method/model
- IS_URBAN – classifies reach as rural or urban according hydrologic standards

Elements A1 – A4

Refer to Appendix C of the CNMS Technical Reference for detailed explanation of completing the following fields:

- A1_TOPO – determines if there has been a significant update of topography since the effective study was completed
- A2_HYDRO - determines if new regression equations have become available since the effective study was completed that would significantly affect flows
- A3_IMPAR – determines if there has been significant development in the HUC-12 watershed the reach is in since the effective study was completed
- A4_TECH – determines if the effective study is supported by modeling or sound engineering judgment

Each of the above element fields have a corresponding comment, source, and URL field (i.e. A1_CMT, A1_SRC, and A1_URL) that should be completed as well. These fields document the reasoning of the validation assessment and the source/s of data used to make that determination.

2. A5 Assessment

The A5 check involves a comparison of the refined Zone engineering analysis (BLE study) and the effective Zone A study. The process results in pass/fail classified points across the full study area. Even though all checks A1-A5 will be completed, only the result of the A5 check will be used to classify the effective Zone A as either Valid or Unverified. The A5 assessment procedures in appendix C of the CNMS Technical reference are primarily geared toward 1-D BLE studies. When a BLE study is performed using 2-D methods, the steps for conducting the A5 validation requires some modification. See the accompanying (Appendix A) for specific instructions on how the A5 check should be performed when using 2-D BLE outputs.

Before reclassifying the validation status of the effective Zone As within the BLE project footprint, the Mapping Partner will consult with the RSC to determine if any effective Zone A studies classified as VALID in the project area should be subject to the A5 assessment results. For example, any recently incorporated LOMRs or other valid Zone A studies with a recent STATUS_DATE should be reviewed prior to changing to UNVERIFIED.

Note that any effective detailed studies (e.g., Zone AE, AO, AH, AR) within the BLE project footprint will not be subject to assessment checks A1-A5 and will not have their validation status changed. Validation assessment of any effective detailed studies, which have a unique set of checks described in the CNMS Tech Ref, will not be part of the BLE submittal unless explicitly directed by the Region.

Mapping partners need to pay special attention to attribute updates if there are any ongoing studies (PMR for example) within the BLE project footprint. For records with this situation (STATUS_TYPE field in CNMS is currently set to BEING STUDIED), steps 1-3 below can still proceed, but for step 4 only the STATUS_DATE and DATE_RQST fields should be updated. No other fields will be updated (BS fields).

3. Production Update Wrap up

After assessment work has been completed on the Zone A reaches, further work will need to be completed to prepare the CNMS database for submittal.

**There will be no updates to Zone X (Unmapped) OR detailed (AE, AO, AH, AR) for Production Phase. Updates are for effective Zone A ONLY.**

The following fields in S_Studies_Ln must be updated once A1-A5 assessment has occurred:

- **A5_COMPARE:** Will be entered as PASS, FAIL, or NULL (insufficient points, less than 20). No UNKNOWN allowed.
- **VALIDATION STATUS:**
  - If A5 is PASS = VALID;
  - If A5 is FAIL = UNVERIFIED.
  - If A5 is NULL, update based on A1-A4; any single failed check = UNVERIFIED

- **STATUS_TYPE:** Remains BEING STUDIED
- **STATUS_DATE:** Update to current date
- **REASON:**
  - If A5 is PASS ="Study passes BLE comparison check";
  - If A5 is FAIL = "Study fails BLE comparison check;
  - If A5 is NULL = "Insufficient sample points for A5 comparison, Validation based on A1-A4 checks", (in addition to a note explaining validation result of A1-A4 checks.)
- **A5 CMT:** Based on A5 result for the reach -**"**passes BLE analysis", "fails BLE analysis", "No BLE analysis-insufficient points"
- **A5 SRC:** Compass 1D BLE Analysis or Compass 2D BLE Analysis
- **A5 URL:** Path to BLE comparison raw results on server

4. Post Production Updates

Once the Final production updates have been made to the attributes the post production updates to the database will need to occur prior to BLE submittal.

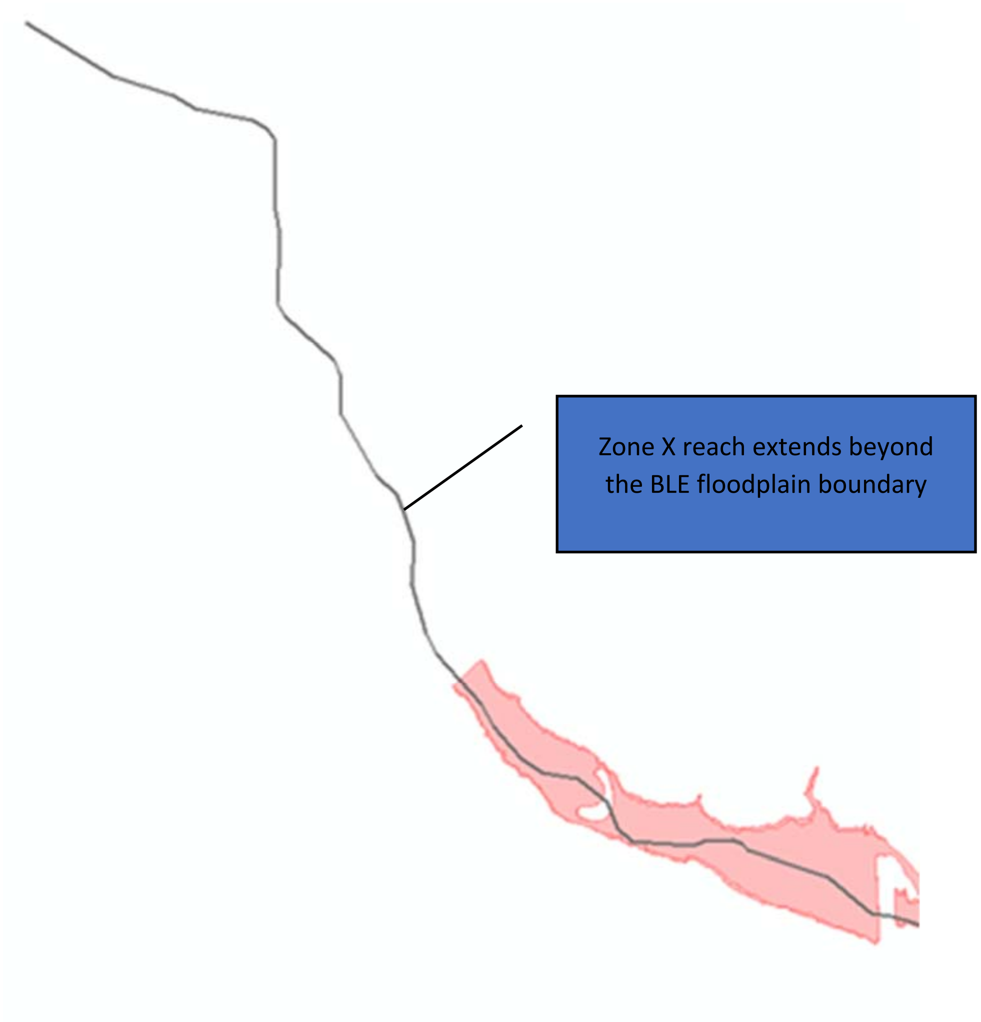
The Post Production update ensures that S_Studies_Ln accurately reflects the footprint of the final BLE. This update requires review of S_Studies_Ln and S_Unmapped_Ln with the BLE 1% boundaries and WTR_LN file from the BLE.

1.) Where new reaches were modeled but there is no effective reach in S_Studies_Ln but there is new BLE floodplain, linework must be added into S_Studies_Ln as Zone X / ASSESSED / BEING STUDIED (Most of these will be covered by incorporated reaches from S_Unmapped_Ln at the Scoping phase, however there will still be reaches which were previously unknown which the BLE studied and need to be added. The attributes for these new reaches can be copied from other Zone X reaches added as unmapped at Scoping.

**2.)** Where there is no underlying BLE floodplain, S_Studies_Ln needs to be clipped at the boundary of the BLE floodplain. The clipped portion of S_Studies_Ln which has no underlying BLE floodplain needs to be copied and pasted into the S_Unmapped_Ln feature class. This will for the vast majority of instances; if not all of them, be for reaches which are currently Zone X in the HUC. Reaches which are existing as Zone A but have a smaller BLE floodplain are suspect so please note these if they are found.

**Example:**

Here you will see the BLE floodplain and the Zone X BEING STUDIED reach (There is no effective FP in this area so it's all Zone X but has a new FP from the BLE). You will notice that the Zone X reach extends beyond the extent of the modeled FP. This reach needs to be clipped at the modeled FP extent.

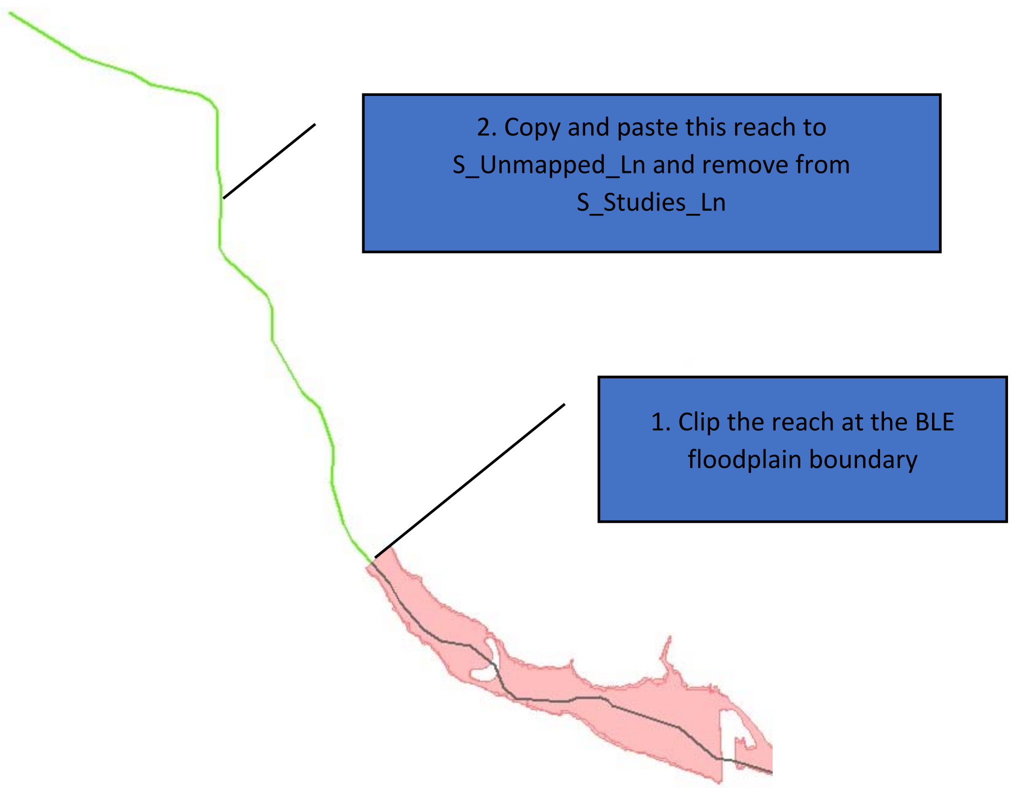


***Example after clip:***

After clipping, below is how the reach should look. The gray reach remains in S_Studies_Ln as Zone X, the Green reach now should reside in the S_Unmapped_Ln feature class.

To do this have both S_Studies_Ln and S_Unmapped_Ln in an MXD, clip S_Studies_Ln at the FP extent, highlight the portion of the reach which was clipped that is outside of the FP, copy, and paste it into S_Unmapped_Ln.

Once it has been transferred over it can be removed from S_Studies_Ln. This should leave you with an S_Studies_Ln file that only covers the extent of the BLE FP. (IMPORTANT- Do not adjust existing reaches that are effective Zone A or AE to BLE FPs. The effective reaches need to maintain effective geometry and attributes until LFD. Only reaches which are Zone X Unmapped should be adjusted).



3.) In the rare instance that the BLE WTR_LN file has no underlying BLE floodplain and is not represented in CNMS, it should be added in as a reach in S_Unmapped_Ln

These changes should leave you with a CNMS S_Studies_Ln and S_Unmapped_Ln feature classes which combined has the same extent as the BLE WTR_LN. S_Studies_Ln will contain all reaches underlain by BLE floodplain. The S_Unmapped_Ln feature class will contain all those reaches which do not have an underlying BLE floodplain.

After Post Production Updates have occurred inform the Region 6 CNMS Lead. Send the BLE 1% floodplain boundary, WTR_LN, and updated S_Studies_Ln and S_Unmapped_Ln for review.

5. Run the CNMS QC tool

As with all CNMS submittals, the Mapping Partner will run the CNMS QC Tool on their updated CNMS database extract and address all Critical and Secondary errors prior to delivery of the CNMS database. The CNMS QC Tool is typically updated once a year when an updated CNMS Schema is distributed. If necessary, the Mapping Partner can obtain the latest copy of the QC Tool from the RSC.

6. CNMS Submittal and Reporting

The updated CNMS database with the revised S_Studies_Ln feature and the validation points (as a separate shapefile) should be submitted along with the associated BLE report documenting the results.

7. CNMS Results Graphic and Table (REQUIRED) – BLE Submittal Report

Mapping Partners should include a graphic representation of the CNMS validation results in their Base Level Engineering report (https://rmd.msc.fema.gov/Regions/VI/Ph0_Investment/1/Base%20Level%20Engineering/Submittal%20Guidance/BaseLevelEngineering_Report_Template_V2.docx). Mainly, this allows the FEMA Project Monitor and any community end user to understand the location of streams determined to be valid through the CNMS validation process, it also indicates areas where the Base Level Engineering assessment identified issues with the current flood hazard inventory. One example of CNMS results visualization is included in Figure 11 for reference.

Mapping Partners may review the results and determine different visualization schemas and components.

The Region's investment in Base Level Engineering data also allows assessment of the current inventory of streams and stream validation status throughout each of the Base Level Engineering basins. Mapping Partners shall include a table of pre- and post-Base Level Engineering stream validation status. The BLE Report template (V2) has been updated (April 2019) to include a table for Mapping Partners to communicate the number of stream miles in each HUC8 (County or River Basin) that are determined to be valid by data created in the Base Level Engineering assessment.

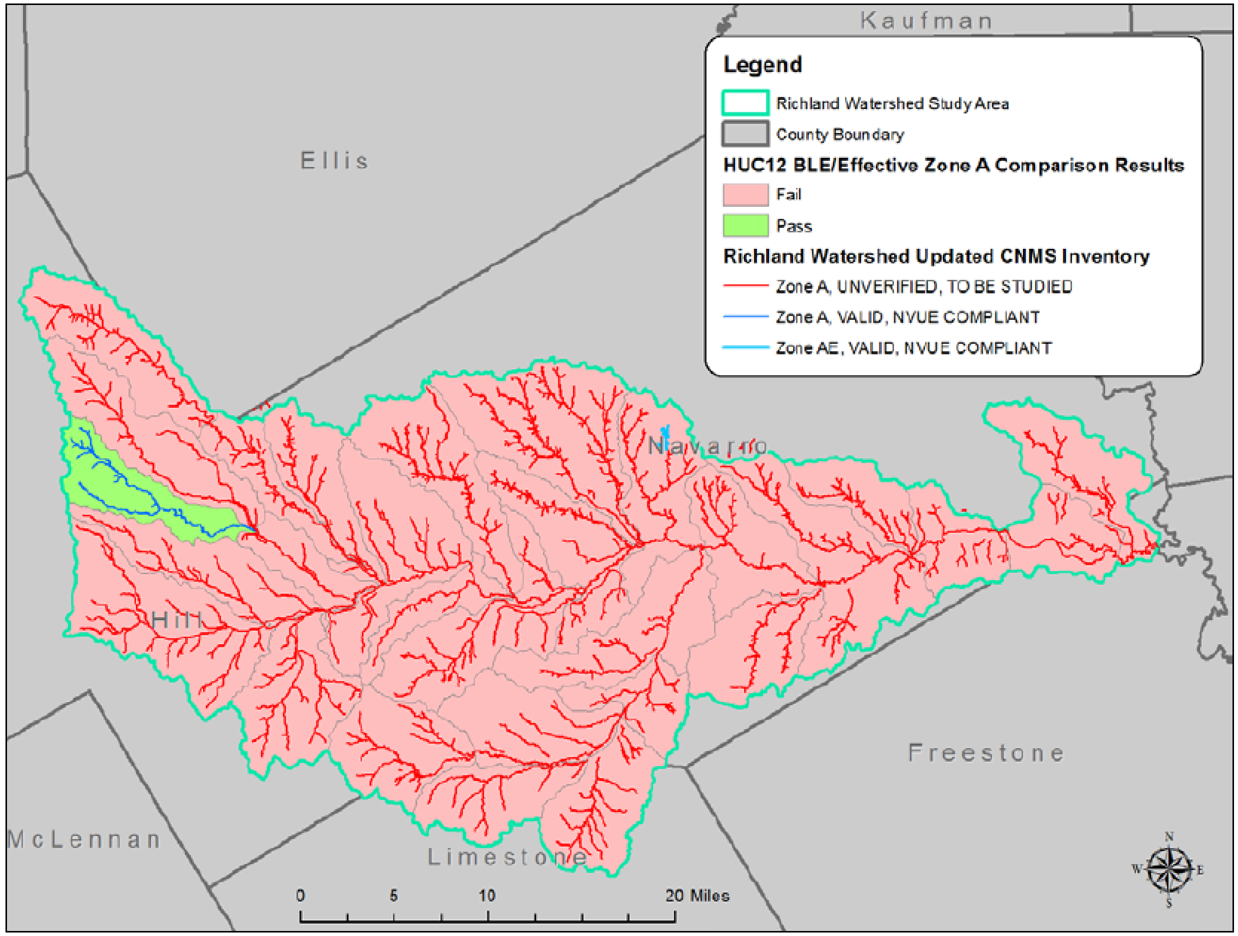



*Figure 11: CNMS Validation Graphic (HUC8 Study Area)*

## HAZUS DATASETS

To populate the **S_FRAC_Ar dataset**, an Advanced Hazus analysis will need to be performed for each BLE project area. For the advanced analysis, the flooding extent is represented in the various flood depth grids prepared during the Base Level Engineering assessment (these grids may also be referred to as 'refined' grids) that the user will need to import into Hazus. Once the Base Level Engineering Flood Depth Grids are imported, Hazus will calculate the losses. Once the losses are produced, those values will be used to populate the attributes required within S_FRAC_Ar. When loading the data into the dataset, the user will need to multiply the loss fields by 1,000 to reflect actual dollars.

**Required:** Yes, minimum deliverable for 1-D and 2-D BLE analysis areas.

**Exceptions:** None.

**Inclusions:** None.

**Viewer Requirements:** None.

- To populate the S_FRAC_Ar dataset, the user will need to complete the advanced Hazus analysis, and export the following features will be exported from the Hazus loss menu:
    - Residential_Total
    - Commercial_Total
    - Total
- For specific information regarding how to process a basic and/or advanced Hazus analysis please refer to the current available Hazus User Manuals and Technical Reference Materials available in the FEMA Library.

Once the losses have been populated in the S_FRAC_Ar dataset located within the BLE Database, the user will need to export out the Hazus project. The exported Hazus project is referred to as an .hpr. For instructions to export a Hazus project, please refer to the current Hazus User Manual.

- As a reminder, the losses are reported via census blocks. It is important to note that Hazus version 3.2 and current use 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

Base Level Engineering producers shall export the .hpr files from the Hazus software and submit the .hpr files with the Base Level Engineering submittal.

# PRODUCER TIPS & TRICKS

The following section will be added to and maintained to highlight some issues that may arise in preparing Base Level Engineering. This section also provides solutions to assist producers of Base Level Engineering minimize rework between model preparation and flood risk dataset development. This section will assist in on-boarding new Mapping Partners and broadening the number of practitioners.

## Hydraulic Model Development

There are a limited number of inputs used to prepare automated modeling routines, HEC-GeoRAS is readily available and free for download. The approaches outlined below should be reviewed for their application in any other modeling preparation or automated processes generated to prepare and produce Base Level Engineering models. Tips are provided for the preparation of each input shapefile or geodatabase feature class, to include: elevational data, stream centerlines and cross-sections.

**Elevational Data**

- When more than one source dataset describing the ground elevation is used, teams may benefit their follow-on model and dataset development processes by spending some time reviewing the merged ground elevation dataset, known as the Digital Terrain Model (DTM).
- Producers will benefit from review of the resultant Digital Terrain Model (DTM), specifically, along any edges where two or more elevation datasets are joined.
- Producers will benefit from reviewing the Digital Terrain Model (DTM) along the study streams to determine or identify any areas where vegetation may remain in the dataset.
- **If issues are identified, the Producer may include a polygon in the S_AOMI_AR data set.** Producers should note these findings as areas where future studies will require and benefit from some field reconnaissance or field survey to determine and refine the Digital Terrain Model (DTM) and resultant hydraulic cross-sections.

**Stream Centerlines (1-D hydraulic analysis)**

- Producers will benefit from investing some review time to evaluate any source streamline feature class against the Digital Terrain Model (DTM) produced.
- A stream centerline feature class is necessary for most 1-D hydraulic modeling software.
- Streamlines produced for use in the Base Level Engineering effort should describe the stream centerline, producers may review aerial imagery and consult the Digital Terrain Model (DTM), in cases where the aerial and DTM disagree, the producer should prioritize the DTM over the aerial.
- Adjustments to the streamline at a later date may adjust stream stationing of your cross-sections.

**Stream Centerlines (2-D hydraulic analysis)**

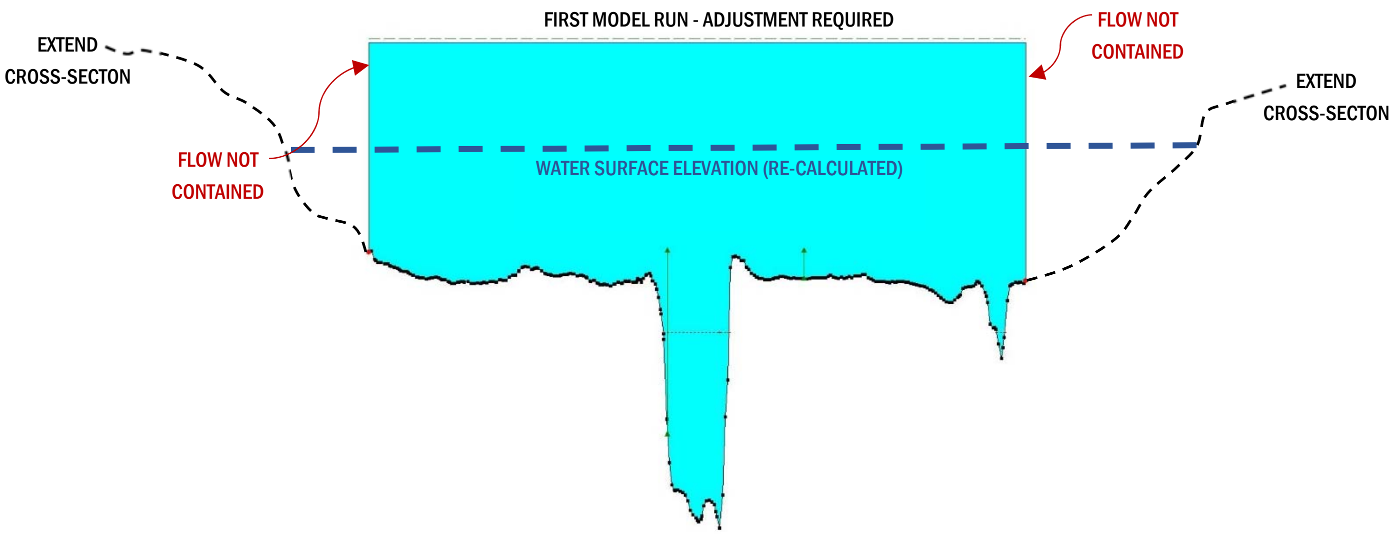
- Use streamlines available in CNMS database – both S_Studies_LN and S_Unmapped_LN to submit CNMS streamlines at project initiation
- Once your hydraulic analysis has been completed, create streamlines through GIS processing using the terrain dataset used for 2-D modeling. At completion of BLE study, resubmit streamlines to CNMS team to identify all 2-D streams studied

**Cross-Sections (1-D hydraulic analysis)**

- When producers are placing cross-sections, they should evaluate any automated cross-sections developed, some of the high-level checks that should be performed include:
  - **Determine an adequate spacing for any automated cross-section placement routines.** Cross-sections may be placed at variable distances.
  - **Review cross-section orientation**. All cross-section lines should be drawn from LEFT to RIGHT. To determine correct cross-section orientation, picture yourself standing on the stream centerline and looking downstream into the stream you are analyzing. Cross-sections that face in different directions may introduce additional difficultly in the iterative calculations being solved by hydraulic modeling software resulting in erroneous water-surface elevations. Use a line type with arrow heads (→→) to easily review cross-sections that have been autogenerated.
  - **Cross sections must be perpendicular to the flow lines at all locations.** Remember Base Level Engineering assessments include analysis of the 10% annual chance event and may require the producer to include cross sections that snap at different angles outside the main channel (also known as dog-legged cross-sections).
  - **Determine an adequate cross-section width.** The width of your cross-sections may vary by stream reach, review the largest storm event to assure flood volume is contained, but cross-sections shouldn't be excessive in length.
  - **Review cross-sections for any overlap.** Cross-section lines from the same flooding source SHOULD NOT overlap one another. Review the conveyance area, determine how many cross-sections are necessary to describe that location and its vicinity. More is not always better. Cross-sections should be added where floodplains rapidly expand or contract.
  - **Review cross-sections to assure they do not cross multiple flooding sources.** Review your cross-section placement/alignment to assure cross-sections are oriented and drawn to provide the software an understanding of the stream being analyzed. Cross-sections should be drawn perpendicular and should not include extra drainage area unless it is appropriate.
  - **Describe general location of hydraulic structures (bridges, culverts, and dams).** Upstream and downstream cross-sections should be added near bridges, culverts, and dams. For in-line dams, a cross-section should also be placed on top of the structure.
  - **Review bank station locations. Adjust where required.** Bank stations should be close to the stream centerline for the stream channel being modeled. Bank stations locations support the application of n-values across the 1-D cross-sections.
  - **Review tie-in elevations with receiving stream.** Cross-sections should be placed far enough downstream to ensure a tie-in with the receiving stream's backwater elevation.
  - **Ineffective flow areas may be added to the model cross-sections but should be used sparingly.** In some cases, reorienting and clean-up of cross-sections may reduce the need for these to be added to the modeling. Ineffective flow areas may be added when appropriate in the following cases:
    - Ineffective areas may be appropriate for use in the bounding cross sections of all roadway crossings. Expansion and contraction ratios of 2:1 and 1:1 (reach length to width) should be used from the estimated edge of the culvert opening. If placed for this reason, the process should be carried through to the next upstream or downstream cross section until the flow is completely expanded.

- Where a roadway overtop is assessed, it may be necessary to include an ineffective flow area in the downstream cross-section at the estimated edge of the road overtop.
- Ineffective flow areas may be assessed for addition in stream reaches experiencing drastic changes in floodplain width. The locations of these areas should be set using the expansion/contraction ratios based on engineering judgment.
- Floodplain areas located within cross sections that were not hydraulically connected to the upstream or downstream cross sections may also require the addition of an ineffective flow area.

o **Cross sections should be wide and deep enough to contain the calculated flow volume where possible.** Set up and run your hydraulic model, then review the cross-sections and model results. Any cross-section that does not contain flow will produce and estimate a water surface elevation greater than what should be expected.




## Flood Risk Dataset Preparation & Data Checks

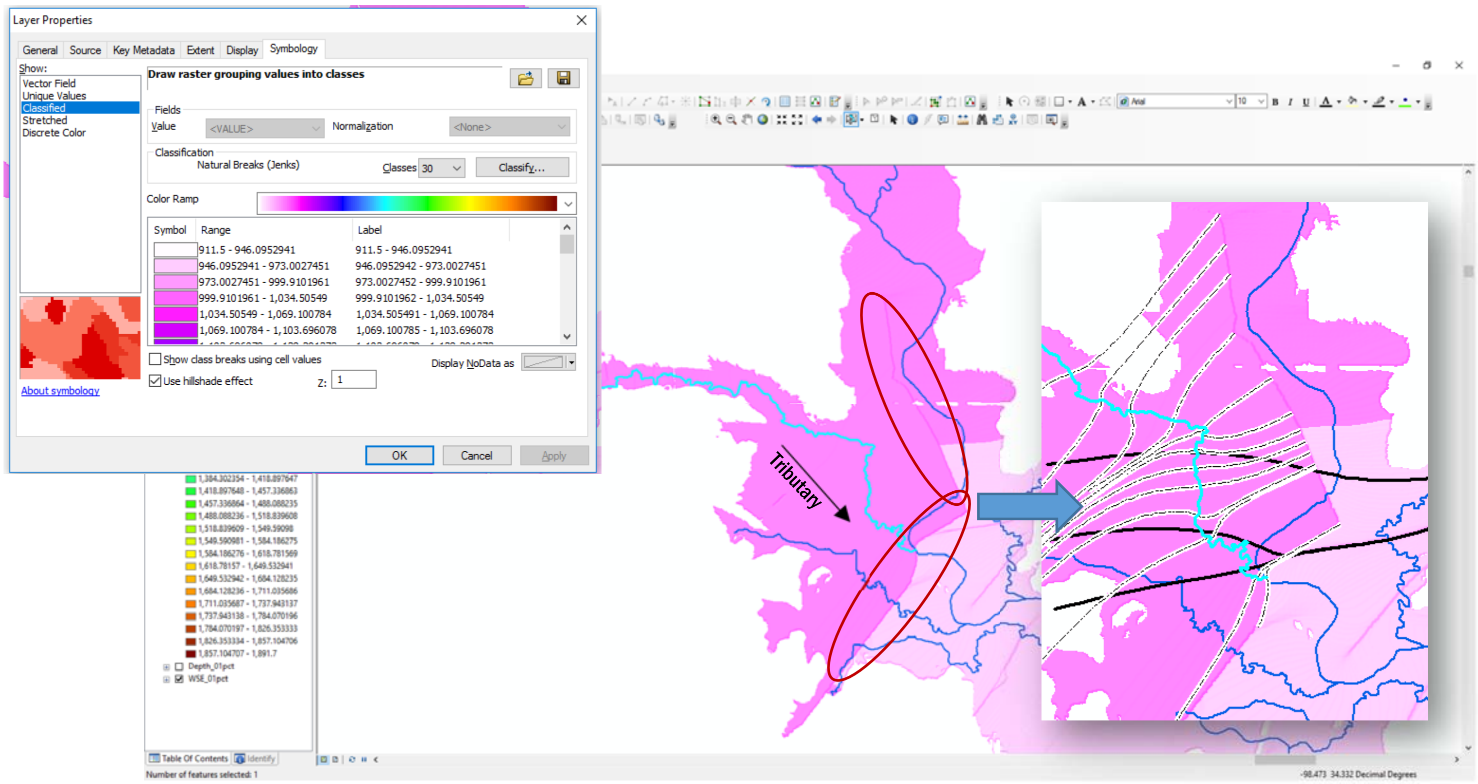
Once modeling is prepared and rough floodplains are created, producers will begin preparation of the flood risk datasets. Some items to review with your production teams are included below. The intent is to reduce incident and rework for all project teams producing Base Level Engineering.

**XS Feature Class (1-D Hydraulic Results)**

- Once models are completed, load water surface elevation information to the feature class as appropriate.
- Review the spacing and location of your cross-sections to define MAPPED and NOT MAPPED cross-sections. Review the suggestions in the XS section of this document.
- Review entire XS dataset to reduce overlap occurrences from adjacent streams. Based upon procedure used to create flood risk rasters, consider using a buffer applied to the 0.2% annual chance event floodplain to clip your cross-sections prior to preparation of other surfaces. Some procedures may result in erroneous results if cross sections are not clipped.
- If mapped and unmapped is not available, Estimated BFE Viewer has a setting to show every fifth cross-section.

**Water Surface Elevation and Flood Depth Grids (built from 1-D Hydraulic Results)**

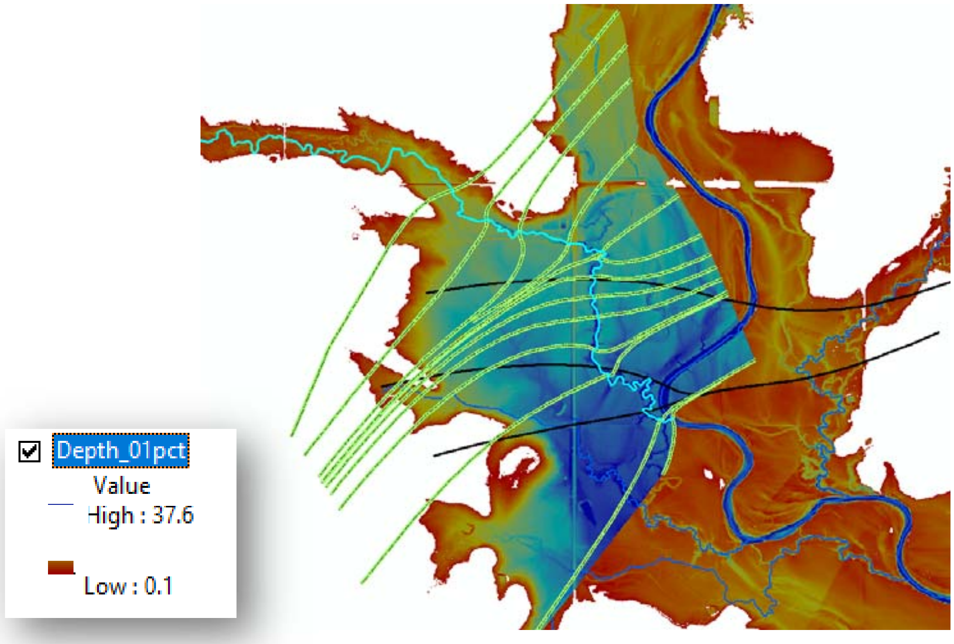
- Ensure that backwater is included in the water surface elevation and flood depth rasters.
- Review entire XS dataset to reduce overlap occurrences from adjacent streams. Consider using a buffer applied to the 0.2% annual chance event floodplain to clip your cross-sections prior to preparation of other surfaces.
- Once you have produced a grid surface, take time to review the results. One way to determine if you have any “waterfalls” in the grid is to use GIS. Modify the properties of the grid, use CLASSIFIED, add 30 or more CLASSES, and select a multi-colored color ramp. Finally, select USE HILLSHADE EFFECT in the Layer Properties window.



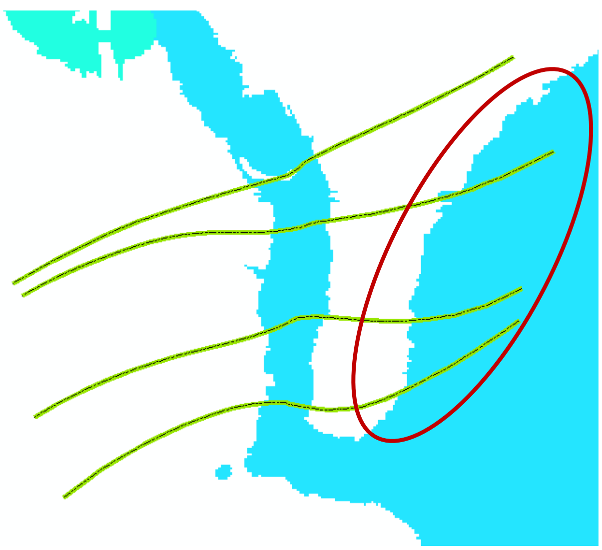

**Root Cause Review – Grid Waterfall**

Upon closer inspection, the following issues were determined:

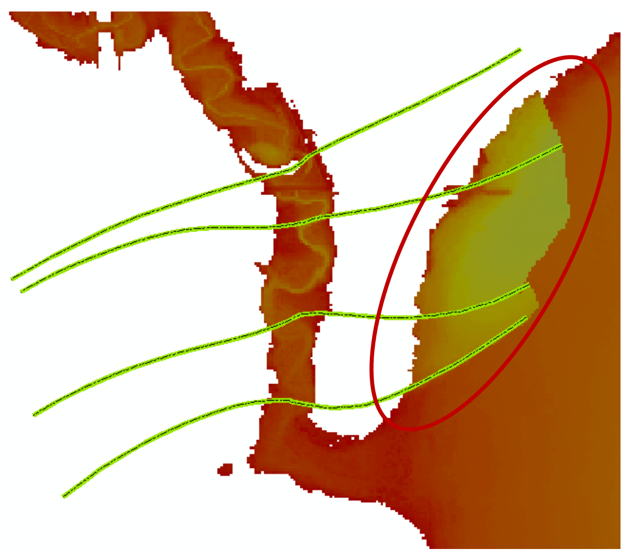
- The tributary model was found to have issues
  - Calculated flow was not contained within cross-section and produced WSELs significantly greater than mainstem stream
  - Cross-sections reached into adjacent floodplains versus being doglegged towards the ridgeline between streams
- Furthermore, the difference in the water surface elevations and corresponding cross-section alignment resulted in a waterfall into the mainstem stream floodplain.
- If these issues are not corrected and the producer follows through with the creation of the depth grid, the issue presents itself a bit more boldly, see below.




- As mentioned previously, review cross-section orientation and length to reduce issues in grid preparation. If cross-sections are left extremely long, they may reach into adjacent floodplains and cause issues in your grid preparation. Data and outputs should be reviewed at each production step. In the case below, the issue did not present itself in the WSEL grid review (left) but identifies itself in the flood depth grid (right).



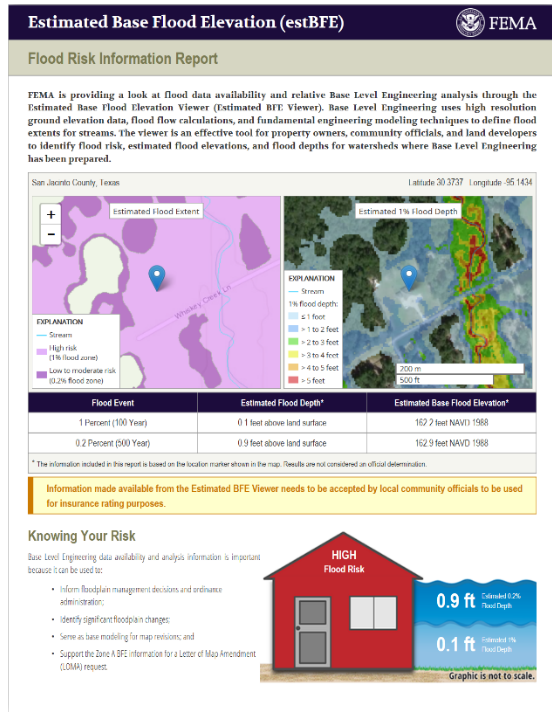
Water Surface Elevation Grid Review
(classify)



Flood Depth Grid Review

**Water Surface (and Flood Depth) Grid review versus FLD_HAZ_AR (Floodplains)**

The Estimated Base Flood Elevation Viewer features an upgraded report with side by side images using the floodplain (FLD_HAZ_AR) and Depth Grid information.



Estimated Base Flood Elevation (estBFE) FEMA

Flood Risk Information Report

FEMA is providing a look at flood data availability and relative Base Level Engineering analysis through the Estimated Base Flood Elevation Viewer (Estimated BFE Viewer). Base Level Engineering uses high resolution ground elevation data, flood flow calculations, and fundamental engineering modeling techniques to define flood extents for streams. The viewer is an effective tool for property owners, community officials, and land developers to identify flood risk, estimated flood elevations, and flood depths for watersheds where Base Level Engineering has been prepared.

San Jacinto County, Texas Latitude 30.3737 Longitude -95.1434

Estimated Flood Extent

EXPLANATION
Stream
High risk (1% flood zone)
Low to moderate risk (0.2% flood zone)

Estimated 1% Flood Depth

EXPLANATION
Stream
1% flood depth:
≤ 1 foot
> 1 to 2 feet
> 2 to 3 feet
> 3 to 4 feet
> 4 to 5 feet
> 5 feet

200 m
500 ft

| Flood Event | Estimated Flood Depth* | Estimated Base Flood Elevation* |
| --- | --- | --- |
| 1 Percent (100 Year) | 0.1 feet above land surface | 162.2 feet NAVD 1988 |
| 0.2 Percent (500 Year) | 0.9 feet above land surface | 162.9 feet NAVD 1988 |

* The information included in this report is based on the location marker shown in the map. Results are not considered an official determination.

Information made available from the Estimated BFE Viewer needs to be accepted by local community officials to be used for insurance rating purposes.

Knowing Your Risk

Base Level Engineering data availability and analysis information is important because it can be used to:

- Inform floodplain management decisions and ordinance administration;
- Identify significant floodplain changes;
- Serve as base modeling for map revisions; and
- Support the Zone A BFE information for a Letter of Map Amendment (LOMA) request.

HIGH Flood Risk
0.9 ft Estimated 0.2% Flood Depth
0.1 ft Estimated 1% Flood Depth
Graphic is not to scale.

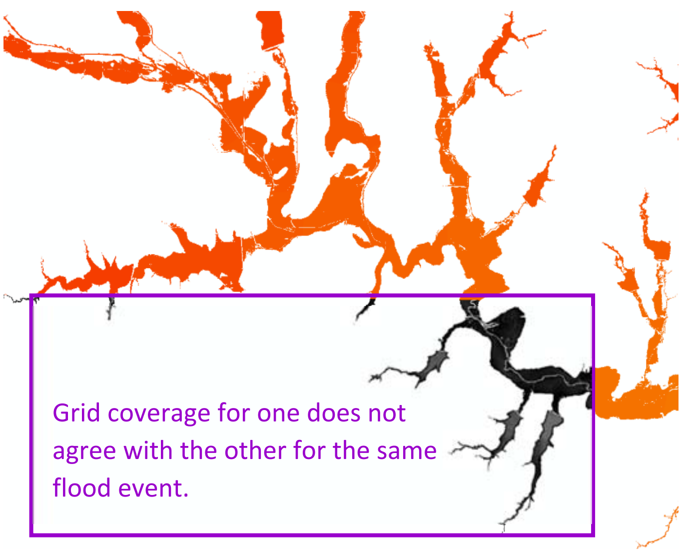
Additionally, the report returns flood depth values and water surface elevations within report tables and graphics. It is important that deliveries have agreement between grid coverage and floodplain delineations.

Submittals should be reviewed with a few easy reviews that should identify any disagreement between datasets.

- Review 1% WSEL and Depth Grids against "HIGH" floodplain to assure agreement
- Review 0.2% WSEL and Flood Depth Grids against "HIGH" and "MODERATE" floodplains to assure agreement
- Review WSEL and Flood Depth Grids for 1% against each other, review 0.2% grids against each other to assure complete coverage for the same gridded area.

Quick checks for agreement are shown below to provide users a series of review options.

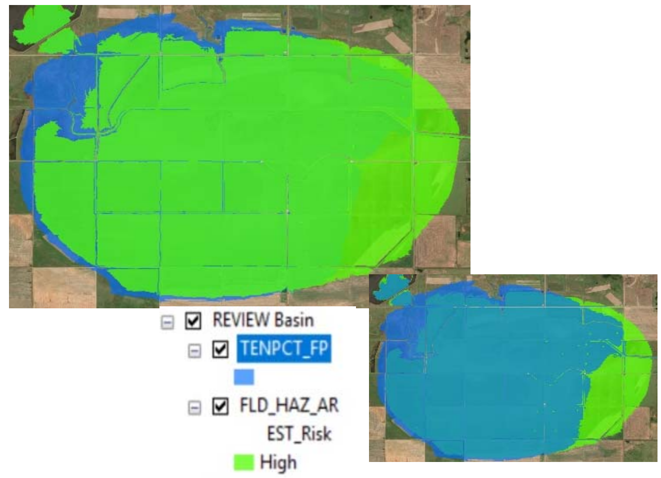
Assure that coverage for the WSEL and Flood depths are coincident, when the grid coverage is not the same between the event (1%) water surface and flood depth grids, the user report will not have a source of information to report from.




In the graphic to the left, the black area shows where a WSEL grid (red/orange, top layer) is missing grid information when overlaid and reviewed against the Flood Depth grid (black). Grids should have the same coverage of data availability for the 1% and 0.2% events.

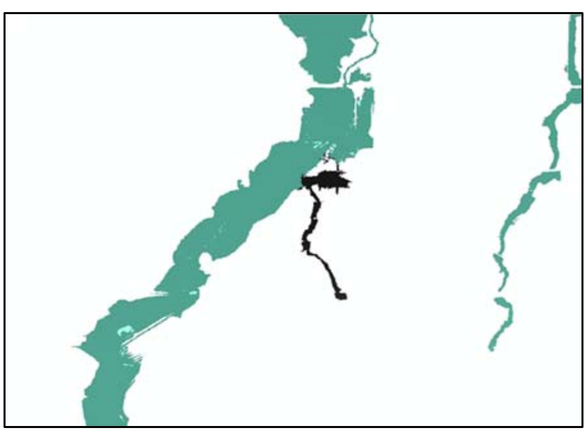
**10% annual chance floodplain review –**

- Review 10% floodplains against 1% floodplain locations, the 10% annual chance flood extents should be narrower than the 1% floodplain location, in most instances. It is not expected that the 10% is larger than the 1% event, it is possible that they are very similar in deeply eroded channels.
- Add FLD_HAZ_AR (flood extent) and categorize using column EST_FLD_RISK, add “HIGH” to the categories and add transparency to the color chosen. Vibrant colors work better than muted ones.
- Load TENPCT_FP and review 10% and 1% floodplains, review flood extents for potential issues.
- The graphic to the right includes a floodplain submittal requiring update to resolve the 10% annual chance floodplain. The 1% is shown as green, but the 10% floodplain (blue) indicates additional areas as flood prone in the 10% event but are not included in the 1% floodplain areas. Graphics show the blue 10% floodplain above and below the 1% floodplain for clarity to readers of this document.




**1% annual chance review – Quick Steps**

- Add FLD_HAZ_AR (flood extent) and categorize using column EST_FLD_RISK, add “HIGH” to the categories and add transparency to the color chosen. Vibrant colors work better than muted ones.
- Add BLE_WSE01PCT (water surface elevation grid) and classify as one value – set color to black
- Review each coverage for disagreements
- Once WSEL review is complete, repeat review of floodplains against the BLE_DEP01_PCT (flood depth) coverage – classify as one value and set to black

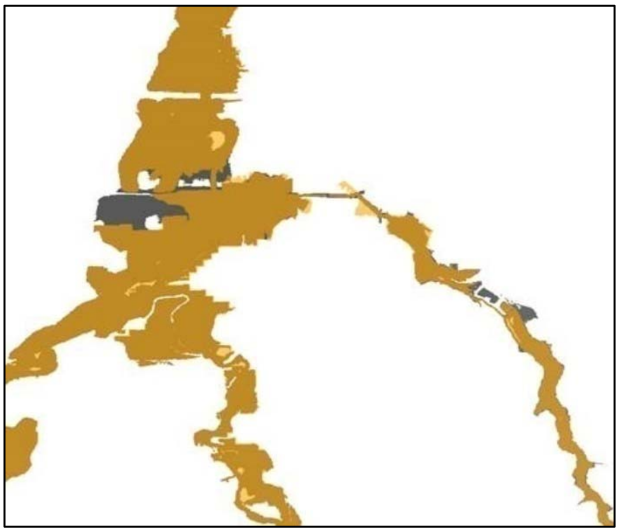


Teal (looks green) = 1% Estimated Flood Extent and Black = WSEL Grid
Grid includes areas that are not shown in the floodplain coverage

Teal = 1% Estimated Flood Extent and Black = WSEL Grid
Floodplain shows flood prone areas where grid is showing no flood risk

**0.2% annual chance review – Quick Steps**

- Add FLD_HAZ_AR (flood extent) and categorize using column EST_FLD_RISK, add "HIGH" and "MODERATE" to the categories and choose one color for both values chosen. Vibrant colors work better than muted ones. Set transparency (50-60%) to allow review against depth grid.
- Add BLE_WSE0_2PCT (water surface elevation grid) and classify as one value – set color to black
- Review each coverage for disagreements
- Repeat review of floodplains against the BLE_DEP0_2PCT (flood depth) coverage – classify as one value and set to black



Orange = 1% AND 0.2% Estimated Flood Extent and Grey = WSEL Grid

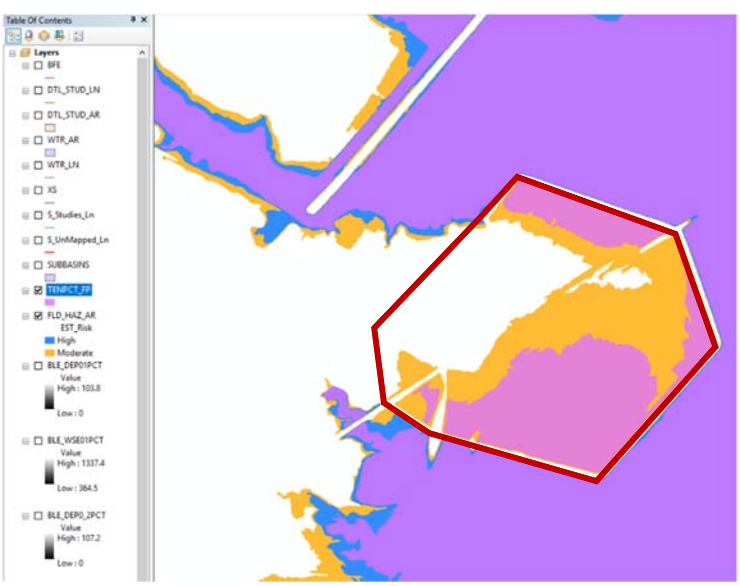
Grid includes areas that are not shown in the floodplain coverage

Orange = 1% AND 0.2% Estimated Flood Extent and Grey = WSEL Grid

Floodplain shows flood prone areas where grid is showing no flood risk

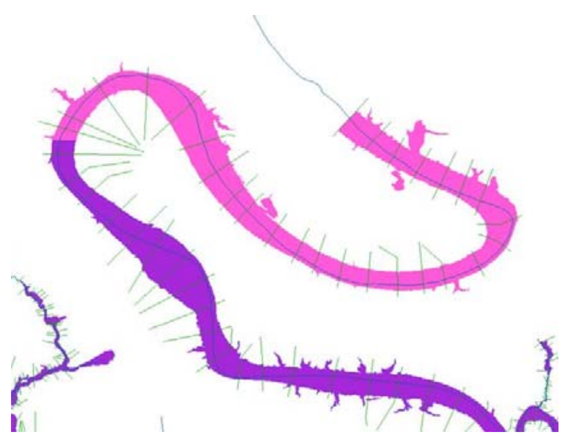
**Floodplain Completeness Check**

To review 1% flood extent completeness, Mapping Partners can perform a quick visual check using the 10%, 1% and 0.2% floodplains. If 10% and 0.2% are showing floodplain areas, it is likely the 1% coverage should also include floodplain in that area.



Blue = 1% floodplain grid reviewed against 10% and 0.2% floodplains

ISSUE → 1% floodplain is missing in the marked area



ISSUE → 1% Floodplain is NOT included (purple) for all analysis cross-sections, but results are included in WSEL grid.

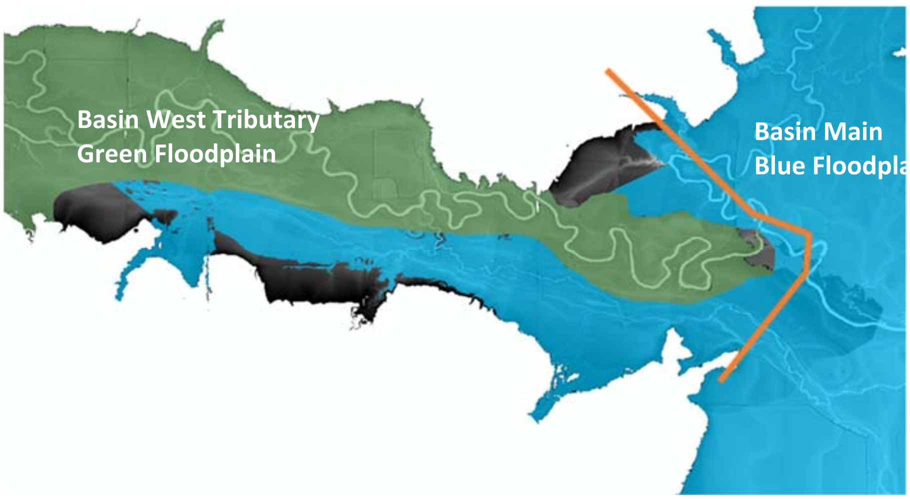
Resolution – Update S_FLD_HAZ_AR areas and include floodplains for all analysis cross-sections (green) to assure complete data packaging and coverage is in submission.

**Preparation of Base Level Engineering for more than one HUC8**

FEMA fully supports the preparation of multiple HUC8 watersheds at the same time. There are significant benefits to preparing information for more than one HUC8. It is suggested that HUC6 and HUC4 basins are reviewed and used should a Mapping Partner be interested in preparing multiple HUC8 watersheds in a coordinated manner. The use of the HUC6 and HUC4 basins allow Mapping Partners to perform hydrology at once time across the HUC8 watersheds that drain a similar geographical area.

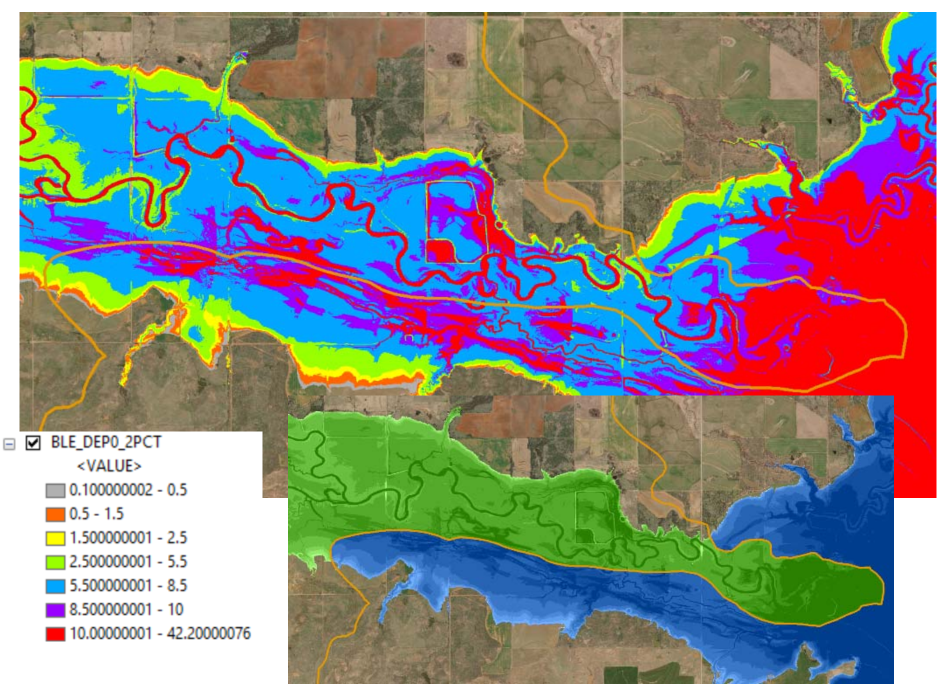
When Mapping Partners prepare Base Level Engineering data for more than one HUC8 at a time, there are a few additional checks that should be performed when grids and floodplains are created. It is critical that the data in each watershed is complete for the defined watershed boundary and that where mainline and large tributaries converge the flood information being prepared and provided is reviewed for edge matching.

In the case shown below, the WSEL grids and floodplains are not in agreement, furthermore, the adjacent HUC8 basin results (green vs blue floodplain) when reviewed against the WSEL grid suggest that the area needs further resolution prior to finalizing the submittal. The orange line indicates the location of the HUC8 basin divide.




The floodplains and grid creation should review and use the back-water elevations to create an interconnected basin result for the floodplain, WSEL and flood depth grids.

**Interconnected Basin Preparation Guidance.** To minimize issues with adjacent and interconnected flooding source and interconnected HUC8 watersheds, Mapping Partners shall utilize the analysis cross-sections and calculated water surface elevations from the HEC-RAS hydraulic model to create the water surface elevation grids and floodplains. Back-water elevations may need to be transposed from the Mainline stream analysis cross-sections near the convergence of flood sources to identify the appropriate back-water value.




Care should be taken to assure the backwater from the larger stream is included to prepare the grids and floodplains. When the basins are reviewed, and the datasets/grids are prepared together. The graphic to the left shows the revised flood depth grid, there is good agreement between the watersheds (HUC8 boundary shown in orange). Floodplains and grids are also resolved by this approach.

# Appendix A – 2-D BLE Considerations

## A-1 Introduction

In recent years there have been notable improvements in the capabilities of hydraulic modeling software. The advancements in two-dimensional (2-D) modeling have improved model accuracy particularly in areas of complex floodplain flow. Until recently, FEMA and the engineering community did not widely adopt 2-D modeling due to the proprietary nature of the software and the complex nature of model setup. With the release of HEC-RAS 5.0 (RAS5) which included 2-D modeling capabilities and development of tools for streamlining the model building process, 2-D modeling has become increasingly popular.

This document focuses on the capabilities of RAS 5.0.x 2-D to produce Base Level Engineering (BLE) products in FEMA Region 6 as it is not a proprietary software package and accessible to all at no cost. It should be noted that other packages such as XPSWMM, TUFLOW, MIKE-21 and InfoWorks ICM offer similar 2-D modeling capabilities but will require the purchase of a license.

The *HEC-RAS River Analysis System, 2D Modeling Users' Manual 5.0* (Bruner, 2016) was referenced extensively in developing the methodologies outlined in this document. Testing of the software in a variety of scenarios informed the recommendations for 2-D BLE analysis. Additionally, FEMA technical references and guidance documents should be used when developing models. A list of relevant resources and references are listed in sections A-5 and A-6 of this appendix.

### A1.1 2-D Modeling Advantages and Considerations

As previously discussed, BLE products can be developed using one-dimensional (1-D) or 2-D hydraulic modeling packages. Shallow floodplains with flat, undulating, braided, and interconnected drainage areas benefit from an initial assessment using 2-D modeling approach.

One of the primary benefits of a rain-on-grid 2-D simulation is that flood flows are governed by the terrain model used, as opposed to being constrained by the placement of 1-D cross-sections and associated assumptions. It should be noted that when modeling large catchments, care should be taken to maximize the area modeled to ensure all possible flood flow routes are captured and to minimize the need to transfer flows between separate 2-D models. Chapter 6 of the *HEC-RAS River Analysis System, 2D Modeling Users' Manual 5.0* provides a useful overview of how 2-D modeling can best be leveraged on a project.

As with any flood modeling and mapping exercise, the use of high-resolution terrain data is of paramount importance; in 2-D modeling, LiDAR or similar terrain data availability will affect the precision and accuracy of the model output. One of the unique features of RAS5 is sub-cell detail of a 2-D computational mesh. That is, the 2-D mesh computational cell size can be much larger than the terrain grid cell size, while still capturing hydraulic detail. As shown in Figure 1, flows and water surface elevations (WSELs) calculated across each computational cell face utilize the underlying geometry of the higher resolution terrain data, as opposed to an averaged value governed by the mesh cell size. Mapped output is also based on the terrain grid cell size, rendered from the computational mesh cell size. For this and other reasons, it is recommended that the best available terrain data always be leveraged.

Transforming rainfall into runoff for a watershed is a challenging problem in flood hazard identification, due to drastic ranges of soil moisture and other conditions across seasons, months, and days. Care must be taken in the development of the model. Despite the limitations and engineering assumptions required for any rain on grid modeling, and RAS5 specifically, the 2-D Base Level Engineering Approach remains more sophisticated than traditional 1-D hydrologic and hydraulic modeling methods. This is particularly true for flat terrain where water can propagate across the floodplain in several different directions.

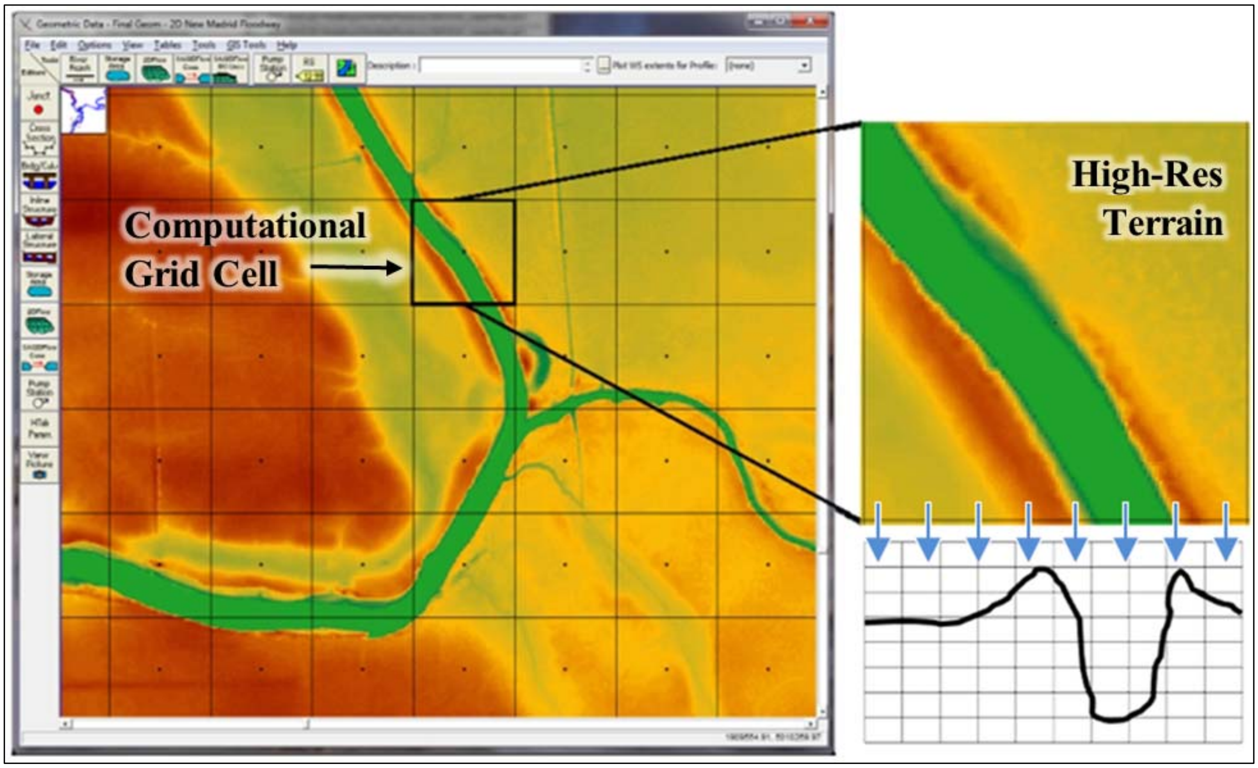



**Figure A-1. Hydraulic Computations in RAS 5 Utilize the Underlying, Higher Resolution Terrain Data**

### A1.2 Data Sources

Modeling software used for 2-D hydrologic and hydraulic engineering analysis requires input data sources. These data sources should provide adequate coverage for the area of study being prepared. Mapping Partners should review all data sources and perform appropriate quality assurance procedures for data compiled from external sources.

The following cited datasets have broad coverage for the Region 6 and larger United States and have been deemed appropriate for studies performed in FEMA Region 6:

- Precipitation Data: NWS/NOAA Precipitation Frequency Data Server
  https://hdsc.nws.noaa.gov/hdsc/pfds/
- GIS Precipitation Data: PFDS in GIS format (including confidence limits)
  https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html
- Soils Data: USDA/NRCS Web Soil Survey
  https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- Soils Data by State: USDA/NRCS Geospatial Gateway
  https://gdg.sc.egov.usda.gov/GDGOrder.aspx?order=QuickState
- Land Use Data: National Land Cover Database 2011 (NLCD)
  https://data.nal.usda.gov/dataset/national-land-cover-database-2011-nlcd-2011
- Terrain Data (3DEP): 3DEP Download Tool
  https://viewer.nationalmap.gov/basic/
- Terrain Data Availability: Contact information for the partners active in 3DEP program are available

Studies in areas that are not covered by these data sources must be supplemented with other, best available, data. Additionally, State, Regional, and Local source data that is more recent, more refined, and available may be utilized or paired with these larger datasets to provide the necessary source data for 2D model preparation. In all cases, the source data should be reviewed for completeness and applicability. CTPs should coordinate with their technical contractors to review and approve source data, as necessary or required. Mapping Partners may also coordinate approval of source data with FEMA Regional staff.

## A-2 2-D Base Level Engineering Approach

The following chapter discusses the 2-D BLE approach for developing a hydraulic model in Region 6 which leverages the rain-on-grid capabilities of RAS5. This includes sections on the following:

- Preparation of model inputs notably terrain data, apportioning roughness based on land use, boundary conditions and the application of excess rainfall hyetographs.
- Appropriate model controls when developing the 2-D computational mesh including representation of key hydraulic controls, selecting an appropriate timestep, computational approach and establishing internal 2-D mesh connections.
- Verification to ensure the robustness of model results using engineering judgement and comparison of computed results with gaged data where available for the 1% AEP event.
- Once the model is deemed to be representative, the remaining return periods are run, namely the 10%, 4%, 2% and 0.2% annual chance events.
- Errors associated with Curve Number selection to derive excess precipitation are assessed using the lower and upper (16% and 84% respectively) confidence limits of Bulletin 17B.
- Mapping outputs for depth, WSEL and velocity model results are prepared for each flood event analyzed.
- Post-processing to produce seamless deliverables spanning the entire study area; and,

- Validation of the effective Zone A polygons using 2-D flood extents

## A2.1 Inputs

The primary model inputs for a RAS5 2-D BLE analysis are detailed below, including terrain, land use and surface roughness, and boundary conditions.

### A2.1.1 Terrain

A terrain model is the key dataset required for initiating a RAS5 rain-on-grid model. The *HEC-RAS 6.0 2-D Modeling User's Manual* lists more than one hundred file formats that can be imported into RAS Mapper. A GeoTIFF (.tif) is generally recommended for creating a BLE terrain model. The highest-resolution FEMA-approved terrain data should always be used. The spatial projection must be specified in RAS Mapper before creating a terrain model. RAS5 has the capability to combine multiple terrain sources into a single terrain layer by mosaicking the layers following assigned priority. When using multiple terrain sources, RAS5 will project a terrain file if it is in a spatial projection other than that specified for the model. It is currently recommended all terrain processing be performed prior to importing to RAS5, particularly mosaicking of terrain grids with non-factorable cell sizes.

A unique feature of RAS5 is the sub-grid detail of a 2-D mesh cell. For each 2-D grid cell, RAS5 calculates a volume-elevation relationship with a 2-D mesh cell. RAS5 uses elevation relationships with area, wetted perimeter, and roughness to calculate the movement of flow from cell to cell. Due to this computational method, it is recommended that terrain grids no coarser than $10ft^2$ (1/9 arc second) be used, except where this level of precision is unavailable.

### A2.1.2 Land Use and Surface Roughness

The USDA/NRCS Web Soil Survey and the National Land Cover Dataset (NLCD) can be leveraged to develop Manning's n-value coverage, as well as Soil Conservation Service (SCS) Curve Numbers (CN), and other data supporting rainfall-runoff simulations. All Base Level Engineering studies should utilize the NLCD 2016 dataset for creating RAS5 roughness/Land Cover grids, unless local, or otherwise more accurate data, are available. Typical 1-D Manning's n-values for land use are appropriate for RAS5 2-D modeling.

### A2.1.3 Boundary Conditions

The following section discusses boundary condition considerations for any application of RAS5 rain-on-grid for BLE efforts in Region 6.

#### A2.1.3.1 Initial Conditions

Initially wet conditions may need to be considered for areas of standing water, especially for significant flood control structures. This is required where the terrain model captures significant bathymetry that should be considered unavailable for flood storage during a significant event. Performing a broad scale simulation, with a coarse (longer) timestep, that is long enough in duration for volume remaining in the RAS5 mesh to empty (unless it ought to remain "trapped" in depressions, or otherwise), could then be used as a restart file for a refined simulation. This restart file approach can be particularly useful for beginning a simulation flood control structures at capacity.

#### A2.1.3.2 Precipitation

When using a simple rainfall-runoff model (such as HEC-HMS) for Base Level Engineering analyses, the objective is to develop an excess precipitation hyetograph that is appropriate for input into the 2-D model. This is because the simple rainfall-runoff model does not need to take into consideration the attenuation of flood waves propagating through the topography of the area. The HEC-HMS simulation (or other rainfall-runoff model) is used to generate a hyetograph for the RAS5 Precipitation boundary condition that considers losses (infiltration). RAS5 does not currently have the capability to model infiltration losses in the 2-D domain.

A single precipitation boundary condition can be specified for any RAS5 2-D area, and a single 2-D computational mesh is generally recommended for any automated engineering application of RAS5 rain-on-grid modeling. Precipitation data from NOAA's Precipitation Frequency Data Server (PFDS) *can* be used directly for the precipitation hyetograph boundary condition in RAS5, though doing so assumes all rainfall is converted to runoff. This data can also be used as the meteorological input for a rainfall-runoff simulation in order to derive an excess precipitation hyetograph for the precipitation boundary condition of a RAS5 2-D mesh. GIS format of PFDS data, including confidence limits, is available and should be used where appropriate for 1% plus and minus events as detailed in Section 2.5 below.

The following outlines the rainfall-runoff approach for developing excess rainfall hyetograph time-series for areas modeled by a 2-D mesh:

1. Develop simple rainfall-runoff model (HEC-HMS) with area and CN, or some other loss methods, specified for contributing areas to the RAS5 2-D mesh.
2. Determine a precipitation depth (from PFDS) and use a NOAA, SCS, or another regionally appropriate storm distribution in the rainfall-runoff model (HEC-HMS). Generally, 24-hour storms are recommended, though other duration storms should be considered when matching up flooding along large main stem reaches and incoming tributaries.
3. Use the simulated excess rainfall time-series as the Precipitation boundary condition for the 2-D computational mesh.

Point precipitation values or GIS polygons for recurrence interval rainfall durations, can be obtained from the PFDS. These should be used to determine recurrence interval rainfall for modeling within HEC-HMS. Areal reduction factors should be considered and can be determined using the Rainfall Frequency Atlas of the United States (US Department of Commerce, 1961), better known as TP-40, or another approved or more appropriate methodology for Region 6 study areas. The areal reduction applied can also be considered in the reasonability and verification process described in Section 2.3.

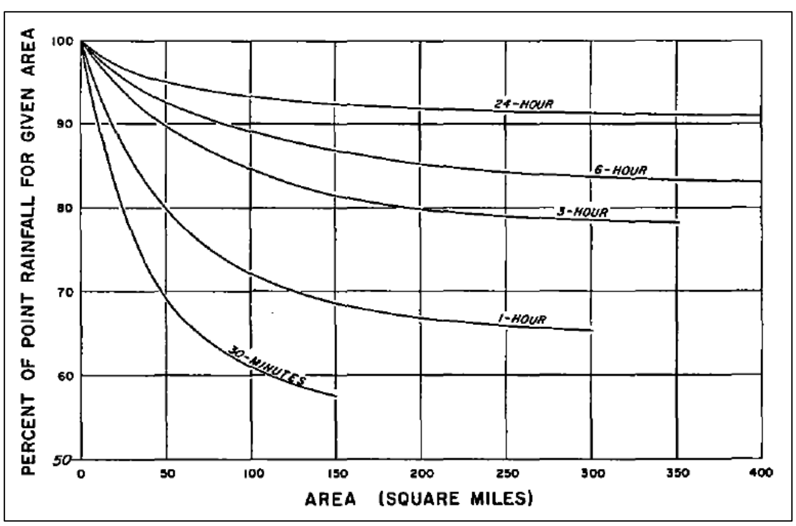



**Figure A-2. Area Depth Curves (Hershfield, 1961)**

Statewide soils coverages in gridded format, for developing initial CN's, should be obtained if the study area is large enough to require a prohibitive amount of individual county soil coverage downloads. Statewide soils coverages can also be obtained from USDA/NRCS Web Soil Survey at this link:

https://gdg.sc.egov.usda.gov/GDGOrder.aspx?order=QuickState

A land use-soils-CN matrix can be used to determine CN's for a particular study area. Table 1 details a typical matrix for determining CN's for the intersection of soils, land use, and drainage areas, to develop a weighted CN for a drainage area. The CN values are sourced from the NRCS's TR-55 (USDA 1986). This matrix is intended as a general guide and should be adjusted based on engineering judgment for a given study area.

Table 2: Typical Land Use-Soils-CN Matrix

| 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 |

### A2.1.3.3 Upstream

The overall shape of a 2-D mesh will depend on the study area (e.g. within a watershed or county), the topography, and the extent of the terrain model. Ideally, models will be setup on an entire watershed to fully utilize the benefits of a rain-on-grid approach and to capture all the contributing runoff within the study area. It may be appropriate or necessary to reduce the size of the 2-D mesh and to use inflow hydrographs for particular flooding sources extending beyond the mesh boundary. In these cases, inflow hydrographs should be developed, as described below, using rainfall-runoff modeling or applying the unit hydrograph approach to gage data, and then input into the RAS5 model.

Contributing drainage areas can be modeled in several ways. Rainfall-runoff modeling (e.g. HEC-HMS) is an acceptable method for computing excess precipitation and inflow hydrographs. USGS gage analysis discharges, paired with dimensionless unit hydrographs, provides another method, with the added benefit of supporting verification of hydraulic model results. Upstream boundary conditions, such as an inflow hydrograph, should be developed based on the procedures outlined below. Figure 3 displays a typical situation where inflow hydrographs were derived and applied to the computational 2-D mesh, shown in blue. The 2-D area, shown in red, covers the study area, county boundary in grey, for which an excess precipitation should be applied.

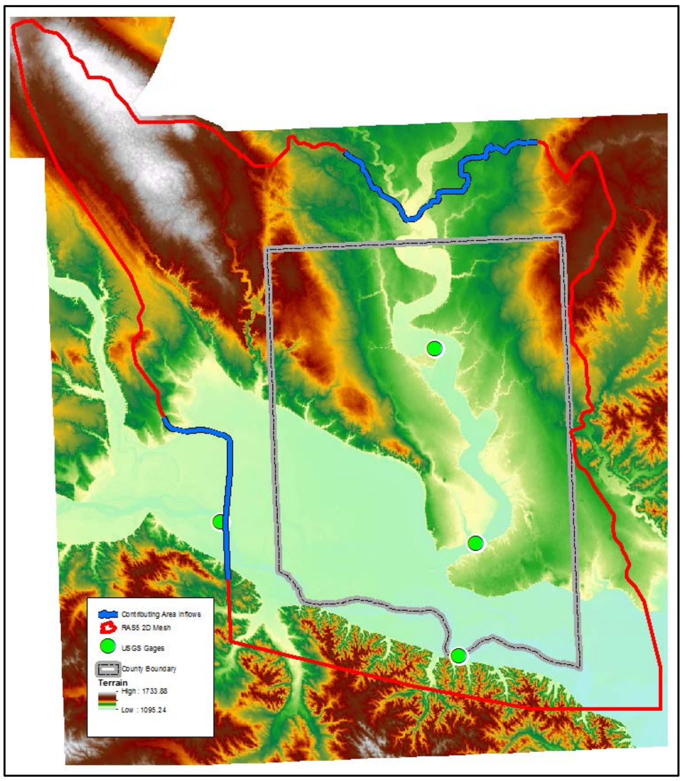



**Figure A-3. Applying Inflow Contributions**

Like the approach defined in Section 2.1.3.2 for developing excess rainfall hyetograph, the following outlines the rainfall-runoff approach for developing an inflow hydrograph for areas upstream of modeled 2-D mesh:

1. Develop simple rainfall-runoff model (HMS) with area, CN, and lag, or some other loss and transformation methods, specified for a sub-basin that represents the upstream watershed.
2. Determine a precipitation depth (from [PFDS](PFDS)), select a reasonable areal reduction to the rainfall total(s), and use a NOAA, SCS, or other reasonable storm distribution in the rainfall-runoff model.
3. Use the computed runoff hydrographs for inflow hydrograph boundary conditions to the 2-D flow area.

__**Inflow Hydrographs**__

*Unit Hydrograph*

The unit hydrograph approach for inflow locations with sufficient peak streamflow and observed historical record should be used in lieu of a rainfall-runoff simulation. This approach involves the following procedure:

1. Perform a flood frequency analysis, using the procedures outlined in the [USGS Guidelines for Determining Flood Flow Frequency - Bulletin 17C](https://pubs.er.usgs.gov/publication/tm4B5) (or other approved methods) to determine the magnitude of recurrence interval discharges of interest. Bulletin 17C is available at https://pubs.er.usgs.gov/publication/tm4B5
2. Utilizing observed event record, several large events should be selected, with preference given to relatively simple, single-peak hydrographs.
3. Convert the observed event hydrographs to dimensionless hydrographs by computing the time and discharge ordinates as t/tp and q/qp (where tp is time to peak, qp is peak discharge), and align the dimensionless hydrographs.
4. Determine an average q/qp and t/tp to derive an average dimensionless hydrograph which can be used for developing scaled hydrographs for recurrence interval discharges determined in the gage analysis.
5. Use these gage-derived outflow hydrograph(s) for upstream inflow hydrograph boundary conditions to the 2-D flow area.

*Balanced Hydrograph*

Similar to the unit hydrograph method, inflow hygrographs can be generated from USGS gages using the Balanced Hydrograph approach. Using HEC-SSP a peak flood flow frequency analysis can be computed using gages with sufficient peak stream flow utilizing Bulletin 17C. Once the desired peak flows have generated for the standard synthetic events the balanced hydrograph method uses observed data, flow, and volume-frequency curves to create a hypothetical hydrograph that “balances” the flow and/or volume across multiple durations.

When modeling very large areas, multiple 2-D models may be necessary. Outflow hydrographs from upstream rain-on-grid models as inflows for downstream adjacent models should be used. If gage information is available for reasonability checks and verification, use these locations as 2-D flow area boundary locations.

#### A2.1.3.4 Downstream

At a minimum, all 2-D meshes should have an outlet for flow to leave the system. In some cases, the outlet boundary condition line(s) can extend around a very large portion of the mesh but ideally should be split into smaller sections depicting obvious individual flow outlets. All 2-D meshes should have at least a single outlet boundary condition, such as normal depth, which does not create any artificial backwater. A gage rating curve at or near the downstream boundary of the model is recommended for use as the model downstream boundary condition, whenever available.

## A2.2 Model Controls

The following sections provide discussion and recommendations for RAS5 model controls.

### A2.2.1 Mesh Area

RAS5 2-D meshes can be developed by leveraging GIS to simplify and smooth the extents of 2-D domains. This reduces the need for edits within RAS5 to resolve errors associated with mesh creation. The size and orientation of each 2-D model mesh should be designed to best represent the area modeled using the rain-on-grid approach. Emphasis should be given to the location of flow and level gages.

Due to the limitations of RAS5 2-D meshes should be limited to less than one million computational cells. It is recommended that when defining a mesh area, complex shapes are avoided or smoothed to avoid triangulation issues and problematic model results. One method to define a suitable mesh area is to digitize a polygon in a GIS package and paste the polygon coordinates directly into the storage area outlines table which creates a storage area in the RAS5 geometry editor. The storage area outline boundary is then converted to the 2-D mesh boundary using the “covert to 2-D area” function.

If irregular edges are present in a 2-D mesh, boundary mesh triangulation issues are likely and further modifications will be required. These issues can be avoided by smoothing and simplifying a jagged-edged polygon before converting feature vertices to points. Localized mesh errors following smoothing can be addressed by manually modifying the mesh cells using inbuilt geometry modification tools in the geometry editor.

#### A2.2.2 Cell Size Selection

For accurate rain-on-grid modeling, the underlying terrain model must adequately represent the topography of the study area. In RAS5, 2-D mesh cell faces are represented as cross-sections, with hydraulic area-elevation tables computed and stored for each cell in the 2-D domain.

Differences between digital terrain data resolution and 2-D mesh cell size is driven by the purpose of the modeling, size of the study area and computational limitations. For applications of RAS5 for Base Level Engineering analyses in Region 6, a 200-FT by 200-FT mesh cell size is a reasonable starting point from which the mesh can be further refined based on initial runs. Specific watershed topography, flood flow routes and gage locations should inform both 2-D mesh orientation and cell size.

Due to computational limitations in RAS5, generated 2-D meshes should be limited to less than one-million cells. Determining a mesh cell size involves striking a balance between modeling and mapping accuracy requirements, the resolution of the underlying topography, model run times, hardware and software limitations and model stability at a specific timestep.

The specified mesh cell size should be a sufficiently high resolution to accurately capture flood flow routes within the study area and produce stable computations. A number of model iterations should be run during the development process to ensure the most robust and accurate results are produced.

#### A2.2.3 Time Step Selection

The RAS5 User’s Manual states that Courant number values should be less than or equal to 1.0, although values as high as 3.0 can be allowable when using the Full Momentum equations. When using Diffusion Wave equations, Courant number values should be less than or equal to 2.0, while values as high as 5.0 can provide sufficient accuracy in certain situations. Generally, the computation timestep should be small enough such that the time required for water to move through any cell exceeds the timestep. Most importantly, the timestep used must be sufficient to produce stable results, which can be assessed quickly by viewing stage and discharge hydrographs within a 2-D mesh. Any numerical noise in either the stage or discharge across a 2-D cell is indicative of instability within the model.

When undertaking 2-D Base Level Engineering analyses in RAS5, a computational timestep that balances computational efficiency and produces stable model results should be selected. A suitable timestep should be selected using the equation detailed below. The computational time step ($\Delta T$) should be determined using the average cell spacing, $\Delta X$, and the flood wave velocity, V. It should not exceed 0.15

multiplied by the nominal 2-D mesh cell size (e.g. for a 200ft nominal cell size, this equates to a simulation interval of 30 seconds).

$$\Delta T \leq \frac{2\Delta X}{V}$$

Saint Venant Equations (Full Momentum):

$C = \frac{V\Delta T}{\Delta X} \leq 1.0\ (with\ a \max C = 3.0)$

Or

$\Delta T\ \leq \frac{\Delta X}{V}\ (with\ C = 1.0)$

The Diffusion Wave equations:

$C = \frac{V\Delta T}{\Delta X} \leq 2.0\ (with\ a \max C = 5.0)$

**Equation 1**

Or

$\Delta T\ \leq \frac{2\Delta X}{V}\ (with\ C = 2.0)$

**Equation 2**

Where: C = Courant Number

V = Flood wave velocity (wave celerity) (ft/sec)

ΔT = Computational time step (sec)

$\Delta X$ = Average cell size (ft)

Striking a balance between model accuracy and computational time is an important requirement of the RAS5 2-D modeling process. Whilst reducing the 2-D timestep may improve model stability in problematic areas of the 2-D domain, this may be to the detriment of model run times. The modeler should seek to refine the 2-D model mesh in areas of instability rather than simply reducing the timestep which can cause more serious or widespread issues to be masked. Localized stability problems can usually be mitigated by improving mesh representation through the addition of breaklines in areas of rapidly undulating topography.

A2.2.4 Equation Selection and Other Computation Settings

Once a suitable terrain has been generated using RAS Mapper, a 2-D mesh can be created within the Geometry Editor. In addition, boundary conditions, and initial conditions can be set and a RAS5 rain-on-grid simulation can be undertaken. A balance must be struck between 2-D mesh resolution and computational runtime. Six significant factors should be considered when striking this balance. These are:

1. The 2-D mesh computational area;
2. The 2-D mesh cell size;

3. Computational timestep;
4. Simulation duration;
5. Output intervals and variables; and,
6. Equation selection

It is recommended that a broad scale model run be undertaken utilizing a coarse timestep to determine the time at which the flood peak on the outflow hydrograph has passed through downstream extent of the model. This will govern the simulation duration to be set up in the higher resolution model. The start of a simulation should coincide with either inflow entering the 2-D mesh at the model boundary or the excess rainfall hyetograph being applied to a 2-D mesh.

As previously discussed, a simplified set of equations, known as the Diffusion Wave equations, are typically leveraged where inertial forces dominate frictional and other forces. Where results prove unsatisfactory and flow regimes transition from subcritical to supercritical conditions, the Saint-Venant equations (also known as the Full-Momentum equations) should be utilized.

The RAS5 User's Manual states that the simplified equation set is usually sufficient for purposes such as flood inundation applications. Overall, the Diffusion Wave equations are considered to provide a sufficient balance between model stability and runtime. If the Saint-Venant equations for shallow flow are selected for use in 2-D computations, then significant increases in model runtimes are likely. Overall a volume percentage error of less than 1% is considered acceptable.

Within RAS5, HDF files are generated for each simulation. It is recommended that the interval for hydrograph outputs be set large enough to minimize unnecessary hard drive data writing, while fine enough to capture useful stage and flow hydrographs. An output interval of 60 minutes or more may be suitable for initial coarse simulations. *Output Options* can be accessed from the *Options* menu of an Unsteady Flow Analysis Plan window. Ultimately, the final *Hydrograph-* and *Mapping Output Intervals* become part of the 2-D product, so all these settings should be considered before post-processing.

#### A2.2.5 Internal 2-D Mesh Connections

Stage and discharge hydrograph time-series data at various locations within a 2-D mesh are valuable for comparing RAS5 rain-on-grid results with gaged data and anecdotal evidence. In order to provide locations for reporting stage and discharge hydrographs, RAS5 breaklines should be created and converted to 2-D internal connections. Terrain profiles along internal connections can be informed by either underlying terrain information or topographical survey.

Breaklines can be defined by importing georeferenced polyline shapefiles via the GIS Tools of the Geometry editor. These breaklines can be converted to Internal Connections by selecting the "convert this Break Line into a new internal SA/2-D Area Connection" function. The number of internal connections should be sufficient for validating the rain-on-grid results. As discussed previously stream gages in the study area are optimal locations to add internal connections. It is good modeling practice to include one internal connection for every 50 square miles of model area. The 2-D internal connections created in this process are essentially 1-D cross-sections conveying flow between 2-D mesh cells.

Internal connections should also be generated for significant reservoirs within a 2-D mesh. Spillway geometries can be obtained from terrain data or as built information where available. Storage behind an embankment that would not be available during a flood event should be excluded from any model considerations. A restart file can be used to establish initial water levels in a 2-D domain for large open water bodies.

Where 2-D results at dams and reservoirs appear unrealistic, gate and culvert openings can be included as internal connections to help improve model performance

A2.3 Reasonability and Verification Checks for the 1%-Annual-Chance Event

The following section provides an overview of the approach for checking the robustness of results derived from a RAS5 rain-on-grid simulation. Although this procedure is suggested for BLE application of RAS5, it is also recommended for the Regulatory Approach for converting to Zone A SFHAs. It should be noted that the Base Level Engineering approach may not warrant more than a single iteration or two to reach satisfactory reasonability based upon the project specifics.

The hydrologic input in the RAS5 2-D Base Level Engineering analysis is rainfall. When using a simplified rainfall-runoff model for Base Level Engineering analyses, the objective is to develop an excess precipitation hyetograph that can be applied directly to the 2-D domain as opposed to trying to match simulated recurrence interval peak discharges to those computed from a gage analysis. This is because the simplified rainfall-runoff model does not take into consideration the attenuation of flood waves propagating through the watershed. The HEC-HMS simulation (or other rainfall-runoff model) is performed to generate a hyetograph for the RAS5 Precipitation boundary condition that considers losses (infiltration), since RAS5 does not have this functionality in its current version.

Important reasonability checks involve comparing the WSELs and flood boundaries from the 2-D model with the following:

- Associated stage and discharge from a gage analysis;
- Observed data from previous flood events;
- Existing/effective WSELs and boundaries (primarily from model-backed Zone AE and Zone A studies);
- Other anecdotal information that may be available

The 2-D model results may not compare favorably with effective Zone A boundaries, due to the outdated methodology associated with many historic/effective Zone A studies. The 2-D BLE analysis represents a more sophisticated and credible approach, and as such should be expected to vary from many of the legacy effective Zone A floodplains. Model-backed Zone A studies can be used for verification of model results and efforts should be made to tie into effective, model-backed floodplain boundaries.

When assessing the suitability of gaged estimates for verification, consideration must be given to the unregulated or regulated nature of the record. This is also true for using verification locations which are considered unregulated and downstream of regulated gage records. Care must be taken to ensure proper comparisons are being made between gage estimates and 2-D model results.

All reservoirs, particularly those providing significant flood controls, should be considered for points of verification. Embankments and spillways commonly have gaged data with significant record lengths.

Also, it is common that LiDAR-based terrain models capture the normal retention level of a significant reservoir, depending on the operation of the reservoir and time during which the LiDAR was collected. Consideration should be given to how water bodies are represented within a 2-D domain, particularly if they are designed to offer flood protection during a significant event.

When effective data is not available for use in verification, regression equation estimates can be used as a guide for determining if further adjustments are needed to improve verification results. Specifically, the range of discharges computed using the standard error range of applicable regression equations can be compared with 2-D model results at verification locations.

However, it will not be uncommon for discharges to vary wildly, while actual WSELs would not. If effective detail data is available (i.e. effective Zone AE information), then these WSEL's and boundaries should generally take precedence over all other measures. The only exception being gaged estimates with sufficient record length of at least 10-years and preferably 20 or more years.

The following reflects the minimum approach that will be followed to perform checks to verify that the results from the 2-D RAS5 model are reasonable:

1. Compare resulting RAS5 1%-annual-chance WSELs, flood extents, and peak discharges with best available data at the stage and discharge comparison lines discussed in Section 2.2.5.
2. Using engineering judgment, adjust curve numbers within the HEC-HMS model and regenerate an excess precipitation time-series for use as the precipitation boundary condition in RAS5. If the unit hydrograph approach is employed for deriving inflow hydrographs, the timing of these can be adjusted based on engineering judgment.
3. Evaluate if any significant features are not accounted for in cell wall locations. Breaklines may need to be added or adjusted to appropriately account for storage within the 2-D mesh area.
4. Rerun the RAS5 model with the updated variables.
5. Repeat Step 1.
6. Proceed until RAS5 elevations (and peaks) are reasonably close to the best available data (engineering judgment shall always be weighed more than general recommendations).

It is worth noting another option for adjusting RAS5 results is to use Manning's n Land Cover data, though this has proven to be relatively ineffective.

### A2.4 Multi-Frequency Analyses

Once the 1%-annual-chance event RAS5 results have been verified, as described in Section A2.3, precipitation values corresponding to the 10%, 4%, 2%, and 0.2% events should be developed. These datasets should then be applied to the rainfall-runoff model resulting from the 1% verification exercise, without adjustment to other parameters (i.e. CN). The outputs from the rainfall-runoff run for these frequency events should then be applied directly to the RAS5 model, as previously described.

If the gage-based unit hydrograph approach is used for inflow hydrographs, the scaled hydrographs should be used directly for all percent-annual-chance events.

It should be noted that ratios can be applied, within both HEC-HMS and RAS5, to determine the precipitation input into HEC-HMS (and therefore excess precipitation for a 2-D mesh directly) and hydrograph (for an incoming drainage area) inputs into RAS5.

### A2.5 1% Plus and Minus Analysis

Procedures for estimating the discharge for the 1%-annual-chance plus and minus events for a gage analysis or using regional regression discharge estimates are well-defined. However, procedures for quantifying uncertainty for deterministic models, such as rainfall-runoff or rain-on-grid methods are not well-defined.

When using rainfall-runoff models such as HEC-HMS, the USACE's EM 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies* offers the most definitive guidance. Procedures described in EM 1110-2-1619 quantify uncertainty in predictions using Bulletin 17B guidelines for a gage analysis. Discharge estimates, including the 50% event are used, and an "equivalent years of record" value -selected by the user is also required. The table defines these values by different levels of rainfall-runoff-routing model complexity and agreement with observed data. These are generally in increments of 10 years, with 10 years being the smallest value.

The rainfall-runoff modeling defined for 2-D BLE in this guidance is a simplification of a rainfall-runoff (no routing) simulation to address the lack of infiltration modeling functionality in the current version of RAS5. No routing or attenuation is considered, and model parameters are often revised significantly during the RAS5 model reasonability and verification process. For 2-D BLE in Region 6, Antecedent Runoff Condition (ARC) II CN's should be used for the 1% event and ARC III CN'S for 1% plus rainfall-runoff event estimate. The 1% minus event should be computed using CN's assuming ARC 1.5 conditions, halfway between ARC I and ARC II conditions as shown in Figure 4 below).

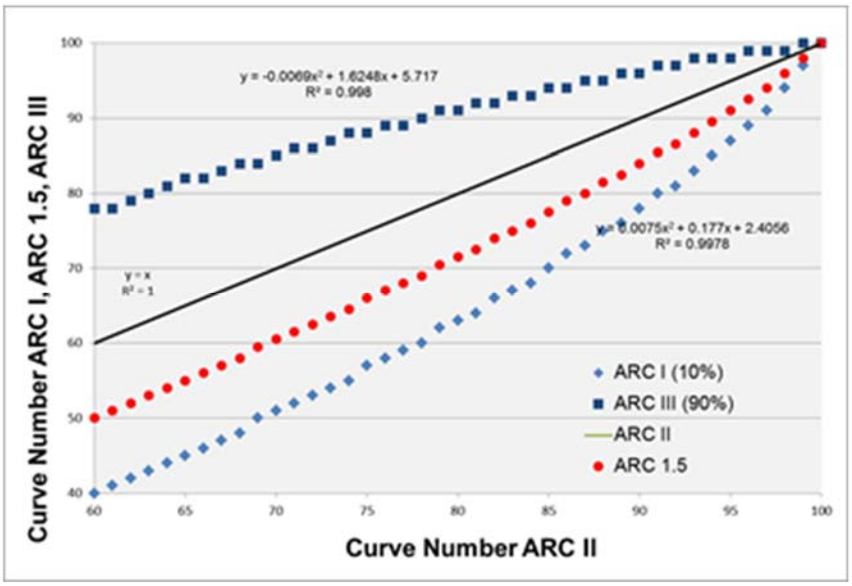



**Figure A-4. Plot of ARC I, ARC 1.5, and ARC III versus ARC II**

A review of previous studies indicated the 1% minus event is generally of lower magnitude than the 10%-annual-chance event **using hydrologic methods other than a gage analysis**; therefore, it is recommended that ARC 1.5 be used for the 1% minus event. It is also recommended that the discharge estimates simulated (via rainfall-runoff modeling) for the 1% minus event should be based on the combination of the rainfall and CN adjustments. These should not exceed the simulated estimate for the 10%-annual-chance event. Engineering judgment should also be part of final determination for the CN adjustment, and deviations from the recommendations documented. The unit hydrograph approach involves gage analyses, for which CN and rainfall adjustments do not apply.

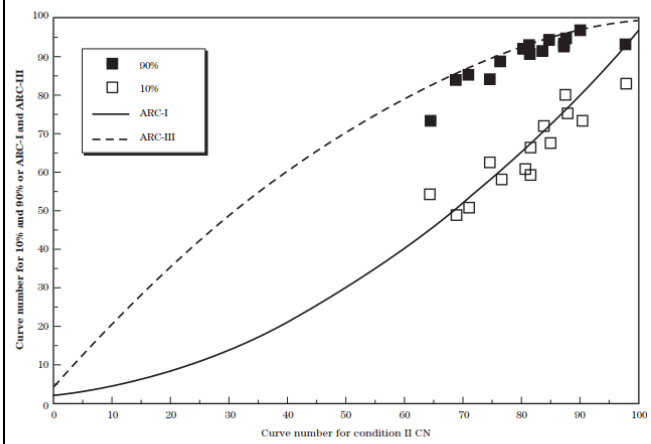
The conversion from a normal Antecedent Runoff Condition (ARC II) to a wet (ARC III) or dry (ARC I) condition is provided in Table 10-1 of the Hydrology section of the NRCS's National Engineering Handbook, and included in Figure 5, below. The same information is also provided in graphical form in Figure A-5 below.

**Table 10–1** Curve numbers (CN) and constants for the case $I_a = 0.2S$

| 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|
| CN for ARC II | - - CN for ARC - - I | III | S values* (in) | Curve* starts where P = (in) | CN for ARC II | - - CN for ARC - - I | III | S values* (in) | Curve* starts where P = (in) |
| 100 | 100 | 100 | 0 | 0 | 60 | 40 | 78 | 6.67 | 1.33 |
| 99 | 97 | 100 | .101 | .02 | 59 | 39 | 77 | 6.95 | 1.39 |
| 98 | 94 | 99 | .204 | .04 | 58 | 38 | 76 | 7.24 | 1.45 |
| 97 | 91 | 99 | .309 | .06 | 57 | 37 | 75 | 7.54 | 1.51 |
| 96 | 89 | 99 | .417 | .08 | 56 | 36 | 75 | 7.86 | 1.57 |
| 95 | 87 | 98 | .526 | .11 | 55 | 35 | 74 | 8.18 | 1.64 |
| 94 | 85 | 98 | .638 | .13 | 54 | 34 | 73 | 8.52 | 1.70 |
| 93 | 83 | 98 | .753 | .15 | 53 | 33 | 72 | 8.87 | 1.77 |
| 92 | 81 | 97 | .870 | .17 | 52 | 32 | 71 | 9.23 | 1.85 |
| 91 | 80 | 97 | .989 | .20 | 51 | 31 | 70 | 9.61 | 1.92 |
| 90 | 78 | 96 | 1.11 | .22 | 50 | 31 | 70 | 10.0 | 2.00 |
| 89 | 76 | 96 | 1.24 | .25 | 49 | 30 | 69 | 10.4 | 2.08 |
| 88 | 75 | 95 | 1.36 | .27 | 48 | 29 | 68 | 10.8 | 2.16 |
| 87 | 73 | 95 | 1.49 | .30 | 47 | 28 | 67 | 11.3 | 2.26 |
| 86 | 72 | 94 | 1.63 | .33 | 46 | 27 | 66 | 11.7 | 2.34 |
| 85 | 70 | 94 | 1.76 | .35 | 45 | 26 | 65 | 12.2 | 2.44 |
| 84 | 68 | 93 | 1.90 | .38 | 44 | 25 | 64 | 12.7 | 2.54 |
| 83 | 67 | 93 | 2.05 | .41 | 43 | 25 | 63 | 13.2 | 2.64 |
| 82 | 66 | 92 | 2.20 | .44 | 42 | 24 | 62 | 13.8 | 2.76 |
| 81 | 64 | 92 | 2.34 | .47 | 41 | 23 | 61 | 14.4 | 2.88 |
| 80 | 63 | 91 | 2.50 | .50 | 40 | 22 | 60 | 15.0 | 3.00 |
| 79 | 62 | 91 | 2.66 | .53 | 39 | 21 | 59 | 15.6 | 3.12 |
| 78 | 60 | 90 | 2.82 | .56 | 38 | 21 | 58 | 16.3 | 3.26 |
| 77 | 59 | 89 | 2.99 | .60 | 37 | 20 | 57 | 17.0 | 3.40 |
| 76 | 58 | 89 | 3.16 | .63 | 36 | 19 | 56 | 17.8 | 3.56 |
| 75 | 57 | 88 | 3.33 | .67 | 35 | 18 | 55 | 18.6 | 3.72 |
| 74 | 55 | 88 | 3.51 | .70 | 34 | 18 | 54 | 19.4 | 3.88 |
| 73 | 54 | 87 | 3.70 | .74 | 33 | 17 | 53 | 20.3 | 4.06 |
| 72 | 53 | 86 | 3.89 | .78 | 32 | 16 | 52 | 21.2 | 4.24 |
| 71 | 52 | 86 | 4.08 | .82 | 31 | 16 | 51 | 22.2 | 4.44 |
| 70 | 51 | 85 | 4.28 | .86 | 30 | 15 | 50 | 23.3 | 4.66 |
| 69 | 50 | 84 | 4.49 | .90 | 25 | 12 | 43 | 30.0 | 6.00 |
| 68 | 48 | 84 | 4.70 | .94 | 20 | 9 | 37 | 40.0 | 8.00 |
| 67 | 47 | 83 | 4.92 | .98 | 15 | 6 | 30 | 56.7 | 11.34 |
| 66 | 46 | 82 | 5.15 | 1.03 | 10 | 4 | 22 | 90.0 | 18.00 |
| 65 | 45 | 82 | 5.38 | 1.08 | 5 | 2 | 13 | 190.0 | 38.00 |
| 64 | 44 | 81 | 5.62 | 1.12 | 0 | 0 | 0 | infinity | infinity |
| 63 | 43 | 80 | 5.87 | 1.17 | | | | | |
| 62 | 42 | 79 | 6.13 | 1.23 | | | | | |
| 61 | 41 | 78 | 6.39 | 1.28 | | | | | |

* For CN in column 1.

**Figure 10–4** Comparison of 10 and 90 percent extremes with ARC I and ARC III values from table 10–1 (adapted from Hjelmfelt 1991)




10–8 (210-VI-NEH, July 2004)

**Figure A-5. Table 10-1 and Figure 10-4, Chapter 10 of NRCS's NEH-4**

It is recommended that rainfall inputs be adjusted, whether directly on a 2-D mesh or within HEC-HMS over a sub-basin, to model 1% plus and minus events. When using a rainfall-runoff simulation to develop an excess precipitation hyetograph or inflow hydrographs for upstream boundary conditions, adjustments to CN's should also be considered. These adjustments should seek to achieve ranges in rainfall-runoff simulated peak discharges like that of a gage analysis or regression equations used in the study area.

As RAS5 can only use a single precipitation value for each 2-D flow area, point rainfall values from the NOAA PFDS can be applied (either directly from the PFDS or via an area-weighted determination from PFDS GIS data). In addition to recurrence interval precipitation estimates, NOAA Atlas 14 provides 90% confidence intervals of reported precipitation values, as shown in Figure 6.

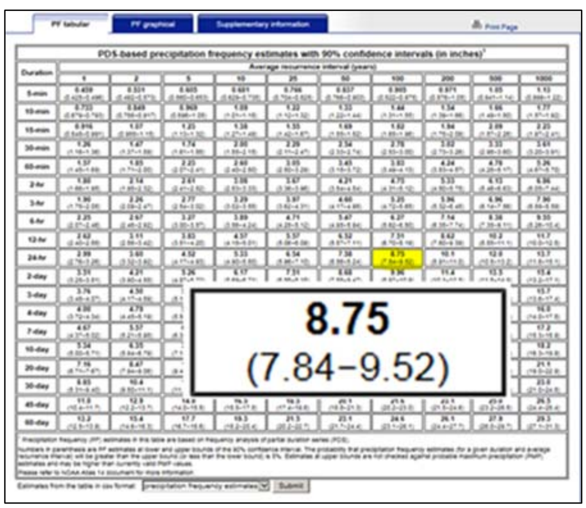



**Figure A-6. NOAA Atlas 14 Precipitation Values**

On a normal distribution curve, 90% confidence intervals correspond to +/- 1.645 standard deviations (i.e. 5% on each tail). The 1% plus and minus events are defined to be one standard deviation above and below the 1%-annual-chance event. It should be noted that the error bands for the selected rainfall depth should be applied to the precipitation value used in modeling post-areal reduction. An example of the calculation process for a point depth of 5.56 inches is provided in Table 2 below.

**Table 3: Point Depth Calculation Example**

| 1% Precipitation: | 5.56 in |
|---|---|
| 90% Upper Limit: | 7.02 in |
| 90% Lower Limit: | 4.34 in |
| Difference (3.29 st. dev.): | 2.68 in |
| 1 st. dev.: | 0.81 in |
| 1% Plus Precipitation: | 6.37 in |
| 1% Minus Precipitation: | 4.74 in |

The 1% plus and minus event precipitation totals can be determined using PFDS data, specifically of confidence limits. Using GIS data instead of point rainfall totals differs only in that GIS data provides a spatial understanding and area-weighted determination for a point depth estimate.

- Precipitation Data: NWS/NOAA Precipitation Frequency Data Server
- GIS Precipitation Data: PFDS in GIS format (including confidence limits)

### A2.6 Model and Mapping Outputs

Geometry and plan run data are stored in the .g##.hdf and .p##.hdf files, respectively. The size of the plan .hdf file depends on the computation settings, as described in Section 2.2.4. These include the hydrograph, mapping, and detailed output intervals. Additional considerations and information related to model packaging and delivery is included in the BLE Submittal Guidance document.

For the Base Level Engineering Approach, the hydrograph output interval should be frequent enough to capture any model stability issues associated with stage profiles and discharge hydrographs produced during the simulation. The mapping output interval is used for dynamic mapping (animating in RAS Mapper) of model results. This interval must be equal to or larger than the hydrograph output interval, and the interval to use depends primarily on the visualization requirements of the study. The detailed output interval for a Base Level Engineering approach can be set to a very large interval, unless detailed information of the computations is important for the study.

In the 2-D component of HEC-RAS, a single water surface elevation is modeled in each computational cell (generally 200 ft. x 200 ft.). Interpolation between these modeled cell values is required to create usable water surface elevation (WSEL) rasters. Depth and WSEL grids for the 10%, 4%, 2%, 1%, 0.2%, 1% plus, and 1% minus annual-chance events should be exported, and included within the default model subfolders, for any multi-frequency RAS5 rain-on-grid model.

Previously the “sloping” interpolation method in HEC-RAS 5.0.3 was used to extract mapping outputs. However, through sensitivity testing it has been determined that the “sloping” interpolation method allowed neighboring mesh cells to adjust model results. These adjustments produce depth and WSEL grid rasters that do not reflect water volumes computed by the RAS 2-D engine. This known bug has been documented by the USACE. More information can be found in their release notes (http://www.hec.usace.army.mil/software/hec-ras/documentation/HEC-RAS_5.0.3_Release_Notes.pdf)

Figure A-7 below illustrates the variance between the HEC-RAS 5.0.3 "sloping" and the TIN interpolation methods. While flatter areas of terrain match the model closely in both methods, steep locations can have larger flooding extents and variances from the model using the "sloping" method.

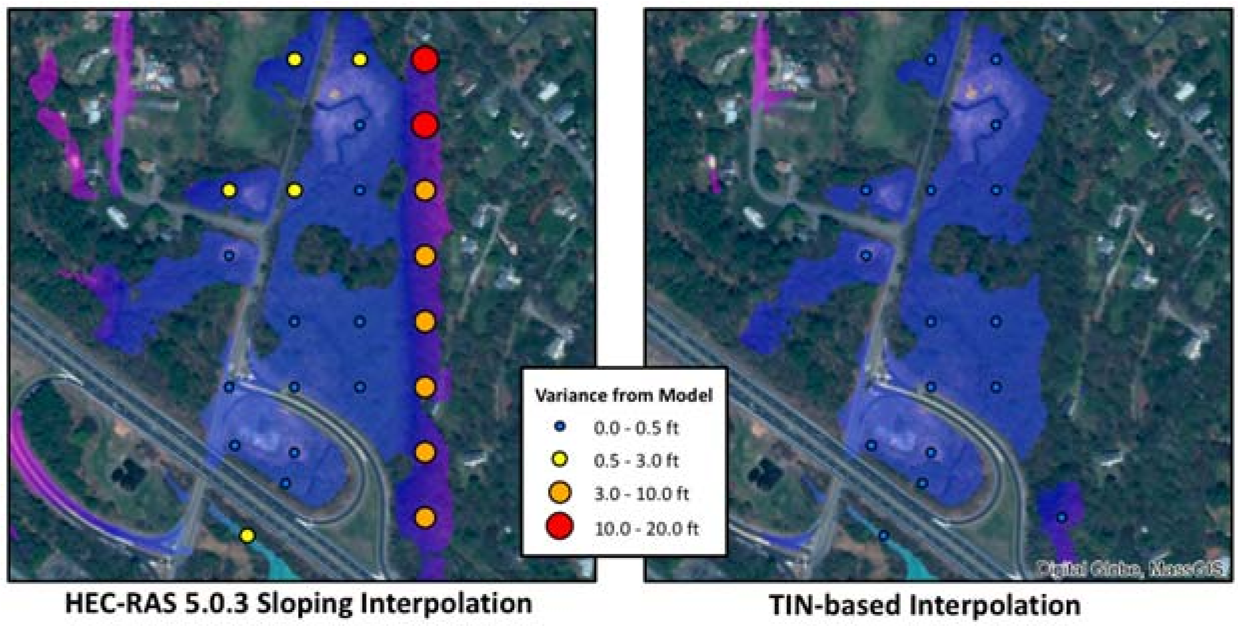



**Figure A-7. Comparison between HEC-RAS Sloping and TIN-Based Interpolation Methodologies**

To mitigate this issue an alternative mapping approach has been developed. This involves using an interpolation method which leverages Triangulated Irregular Networks (TINs) and preserves the computed values in the generated raster.

This method includes the following steps:

1. Open RAS Mapper after a simulation has completed.
2. Set the Render Mode Options to 'Horizontal' with a plot tolerance of -1,000. This ensures that the exported depth and WSEL values are as true to the computational results as possible. The-1,000 plot tolerance forces the dry cells to have the same elevation as the underlying terrain. The result is that every point that falls within the 2-D mesh cell center has an elevation value attributed to it.
3. Expand the geometry data tree and right click on '2D Flow Areas' and export a point shapefile for each 2-D cell. Assign a unique name to the shapefile which will be automatically loaded into the Map Layers section of RAS Mapper.
4. Right click on the event under the results library and select 'Manage all map layers'.
5. Select the 'Add New Map' option.
6. Under Map Type select 'Water Surface Elevation' or 'Depth' as appropriate.
7. Under Unsteady Profile select 'Maximum'.

8. Under Map Output Mode select ‘Point Feature Layer’ under the ‘Stored (saved to disk)’ section.
9. Click the folder icon and select the point shapefile created in Step 3 above. Leave the ‘Base Elevation Source’ as the default ‘Terrain Layer’ and click OK.
10. Click ‘Add Map’.
11. Highlight the recently added map layer and click ‘Compute/Update Stored Maps’ to output a point shapefile with attributed 2D depths or WSELs (as appropriate).
12. Generate a TIN based on the shapefile created in Step 11 using a GIS package such as ArcMap.
13. Convert the TIN to a raster dataset using the Natural Neighbor interpolation method taking care to ensure the cell size and spatial reference of the raster match the study area DEM.
14. Subtract the depth raster created in Step 13 from the DEM and extract all values greater than zero. This will create the final depth grid.
15. Use the final depth grid created in Step 14 to clip the WSEL raster created in Step 13 to create the final WSEL grid.

### A2.7 Mapping Post-Processing

Rain-on-grid 2-D modeling produces a product that calculates a depth at nearly every cell. While there may be depths associated with numerous raster cells, they may not all necessarily be deemed as a floodplain. These broad overview steps will help filter the raw results down to the proposed flood risk areas. The flood risk polygons will be based off existing CNMS features and effective floodplains.

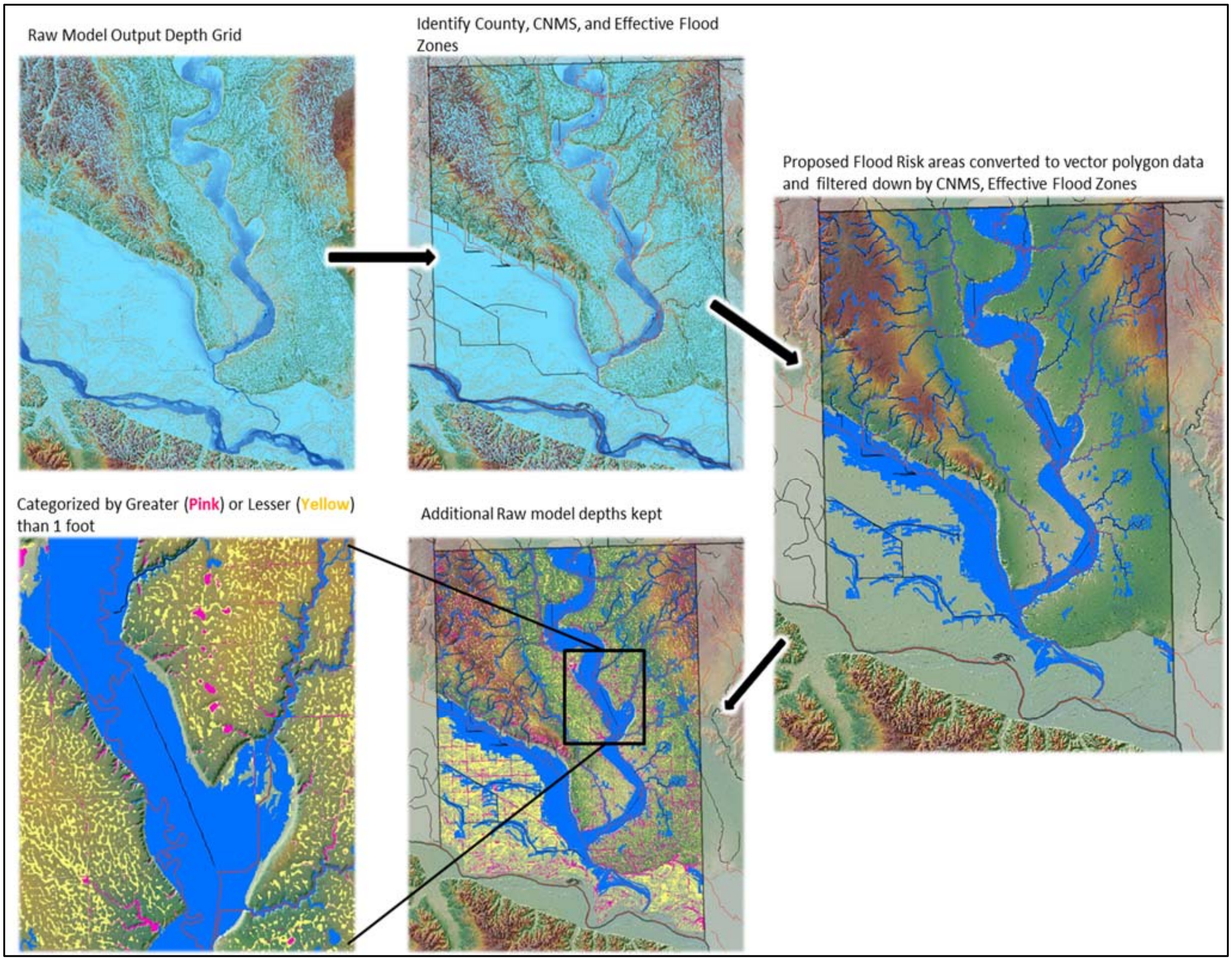



**Figure A-8. Boundary Creation Workflow**

Initial Automated Mapping Cleanup steps:

1. Convert Depth Raster to polygon feature class or shapefile
    a. *Simplify polygons* – removes extraneous bends while preserving essential shape
    b. *Smooth polygons* – smooths sharp angles in polygon outlines to improve aesthetic or cartographic quality; Suggested Smoothing Tolerance = 2.5x input raster cell size (i.e. 10ft raster = 25ft Smoothing Tolerance)
2. Create a “scope” layer that will be used to identify our extents of proposed flood risk areas
    a. CNMS Unknown, Unverified, and Unmapped
    b. Effective flood zones from NFHL or FEMA Q3 digital data
3. Use a minimal buffer to select raw model polygons that intersect our “scope” layer
4. All Additional flood polygons should be retained in a separate layer and should contain a categorization of Greater Than or Less Than 1 foot

**Manual Mapping Considerations:**

At this point, the floodplain mapping cleanup becomes much more of a manual process rather than automated. The 2-D results can vary from study area to study area due to several reasons, and a one-size-fits-all approach cannot always be taken.

For example, areas that are extremely flat, have low velocities, and have very shallow depths can create unique challenges. In these situations, if setting the initial depth threshold to 0.1ft can remove a significant amount of 'noise' in a floodplain while retaining the CNMS identified features, then that step can be taken. Floodplain results for the 1% and 0.2% annual-chance events shall not include flood depths between 0.0 and 0.5ft.

When the selection of data for the proposed flood risk areas does not capture a portion of the floodplain, a manual selection and incorporating into the proposed flood risk dataset is needed. Typical GIS mapping cleanup processes will be undertaken to address these situations on a case-by-case basis. Aerial imagery will also be used as needed to help support these activities. Within FEMA Region 6 process areas, islands within the mapped floodplain shall not be filled in, doing so will result in floodplain areas indicating high flood risk where the flood depth and water-surface elevations will not indicate flooding.

The Producer Tips and Tricks section in the BLE Submittal Guidance identifies other manual floodplain review and update procedures that have been identified by Mapping Partners throughout the creation, testing and initial application of the Base Level Engineering approach.

**Tie Ins:**

Since the modeling is not done at county wide level, the mapping of work areas will need to be reviewed for proper tie-ins. The floodplain data will ultimately be submitted as a county-wide layer but should be a seamless feature that will connect across political boundaries. The use of the same county boundary shapefile for these submittal extents should be used. Floodplains from adjacent work areas will need to be checked as well for connectivity and to create the seamless layer.

All CNMS Valid Zone AE studies will be identified, and the proposed Zone A flood risk areas will tie into those areas. The data to tie into will come from NFHL as the top priority, but if not available in that dataset, the FEMA Q3 data should be used.

## A2.8 CNMS Zone A Validation

**When the 2-D BLE assessment data has been compiled, the following procedures should be used for completing the Zone A validation assessment check A5 (Refined Zone A Engineering Comparison). Additional Zone A validation assessment steps and CNMS integration procedures are required for all BLE studies and are described in the CNMS Database Section of R6 BLE Submittal Guidance.**

To validate the effective Zone A polygons using 2-D outputs, the required datasets are:

- Ground Elevation Grid
- 1%(+) Water Surface Elevation Grid OR 2-D mesh with centroid representation
- 1%(-) Water Surface Elevation Grid OR 2-D mesh with centroid representation
- Effective Zone A Polygons
    - Use NFHL Data if available. If not, use Q3 or best available digital representation of effective Zone A boundaries

The fundamental evaluation procedure is to create a "confidence band" by using the 1%(+) and 1%(-) values and determining if the effective boundary is mapped within it. Simply put, if the effective Zone A floodplain boundary falls in that range, it passes. If it does not fall within it, it fails. In keeping with the approach outlined in the Automated Engineering Guidance document (May 2016), an allowable horizontal offset tolerance is applied to help in these checks.

**Details:**

*Create Test points*

Create Test points along effective Zone A boundary lines spaced at an interval of 500-ft.

*Create the Confidence Band*

To create the minimum value of the band, extract the minimum elevation from the 1%(-) grid. To account for an allowable vertical tolerance, the minimum value should be lowered by that amount. For Region 6 specifically, a vertical tolerance of 2.5-ft was used based on assumed effective topological data.

To create the maximum value of the band, extract the maximum elevation from the 1%(+) grid. To account for an allowable vertical tolerance, the minimum value should be lowered by that amount. For Region 6 specifically, a vertical tolerance of 2.5-ft was used based on assumed effective topological data.

*Assign Effective Zone A Boundary Elevation*

If we assume that the boundary is the same as where the 1% WSE meets the ground, we can use the value from the ground to equal our tested 1% WSE.

Extract Ground values and populate that value into the test point.

*Perform Validation on the Test Points*

Determine if each test point ground elevation is within the confidence band that was created earlier.

If point value is within the band, it passes. If it is not within the band, it fails.

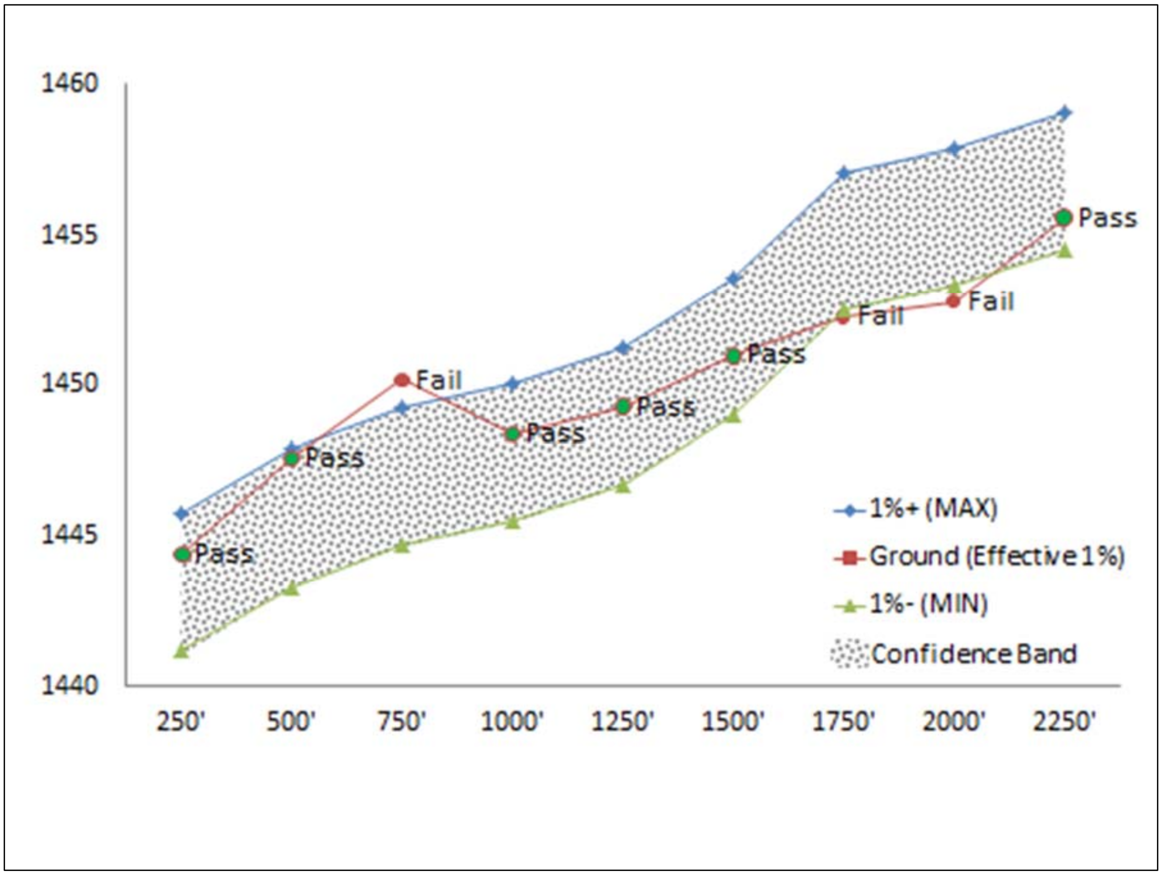



**Figure A-9. Profile Example of Validation Results**

*Report Validation results*

The spatial test points pass/fail rates can be aggregated and reported on a stream basis for reporting in CNMS.

The spatial test points pass/fail rates can also be aggregated and reported on a County basis or a HUC-12 basis for reporting measures (or perhaps HUC-10 or HUC-8 levels). **See the CNMS Database Section of R6 BLE Submittal Guidance for additional instructions on integrating results into CNMS, including A1-A4 validation checks, unmapped line integration, populating BLE tracking fields, and Status Type updates.**

## A-3 Additional Considerations

This section discusses pertinent enhancements to the models developed in the Base Level Engineering approach that should be considered, primarily in the context of 2-D BLE efforts, in order to produce products suitable for regulatory purposes. However, the modeling and reviewing engineers retain the final decision on the extent to which applying these enhancements will result in a noticeable improvement in model results.

Currently, the greatest limitation of RAS5 rain-on-grid is its inability to model infiltration of rainfall for any given condition. The base level and regulatory approach each address this limitation, via rainfall-runoff modeling for determining excess precipitation resulting from a recurrence interval flood event. For large scale modeling, the use of a rainfall-runoff model, simple or complex, should be in response only to the current lack of infiltration modeling in RAS5. There are, however, opportunities for extending the understanding of runoff response for any watershed that is not covered here.

Greater engineering detail of specific areas within a RAS5 BLE model is a likely interest of stakeholders. Of course, more detailed models can be produced for these areas. However, the BLE approach can be maintained by refining a 2-D mesh in RAS5, for example, using breaklines, internal connections, internal structures, and manual cell configurations at targeted locations. Improving the definition of risk for particular areas within a work area model seems an appropriate measure for upgrading a 2-D BLE model to a product suitable for regulatory purposes.

### A3.1 Topographic Conditions

This section identifies five distinct regions with significantly different hydraulic behavior and provides the Mapping Partner guidance to perform 2-D Base Level engineering (BLE) hydraulic analyses for these regions.

#### A3.1.1 Lowlands/Mississippi River Delta Region

One of FEMA Region 6's most prominent hydrologic features is the Mississippi River. The river drains approximately one third of the area of the nation's 48 contiguous states. As such, over a long period of time, the Mississippi River has carved a wide, low-lying, changing floodplain which empties in the Gulf of Mexico. Roughly along the Illinois and Missouri state line begins what is also known as the Mississippi River Lowlands or Mississippi Embayment. The Lowlands extend south through Arkansas and into Louisiana until they become the Mississippi River Delta. Large flows of water and sediment changed the Mississippi River Lowlands and Delta regions until flood control structures were built that kept the river's main channel in a fixed location.

##### A3.1.1.1 Mississippi Lowlands

The Mississippi River Lowlands are a low-lying, generally flat topographical feature formed over geologic times and can measure over 100 miles across. In 1927, the Mississippi River flooded a significant portion of the lowlands. To prevent another flood of such magnitude, the federal government built a system of levees that prevent the Mississippi River flow from reaching the Lowlands directly. However, the Mississippi River Lowlands maintain many of the features that result from fluvial geomorphology. These features are the result of sinuous and meandering rivers and bayous that once discharged into the Mississippi River. Populated areas often follow "high ground" formed by sediment deposited over geologic times, but the overbank areas are often barely higher than the water level in the channel. As such, when these systems overflow, the result is shallow, lateral flow that can extend for long distances.

As such, the main modeling assumption in the Mississippi River Lowlands is storage. Given an accurate representation of the ground elevations, a two-dimensional model is well equipped to handle storage and compute depths. However, the accuracy of the topographic data is paramount to the accurate calculation of water depths or water surface elevations because slight deviations on ground elevations can result in significant storage calculation differences. Given the flatness of the terrain, the model mesh resolution may remain coarse. The modeler should use engineering judgment to determine where breaklines should be placed to best represent key obstructions to flow in the 2-D domain. The development of the terrain model and model mesh are described in Sections 2.1.1 and 2.2.1 of the BLE Submittal Guidance document.

#### A3.1.1.2 Mississippi River Delta

Much of the guidance provided for the Mississippi River Lowlands applies to the Mississippi River Delta region. In the Delta region, stream flow tends to split and spread in different directions which a two-dimensional model can replicate given an accurate topographic data.

As in the Lowlands, many of the channels and ditches have water year-round. However, in the Delta region, tides may affect the hydraulics of the channels. To this end, the modeler may apply a tidal boundary condition in this location. A value higher than the mean high-water tide may help incorporate the effects of storm surge, which may occur simultaneously with a runoff event.

Of note, coastal floodplains in the Delta region may see flooding from rainfall runoff as well as coastal surge elevations. If calculated independently from each other, a flood frequency elevation analysis should incorporate coastal and riverine flood events by adding them statistically through the combined rate of return approach. Use of a joint probability analysis is also appropriate.

### A3.1.2 Coastal Regions/Combined Probability

FEMA Region 6 has a long coastline with the Gulf of Mexico along Texas and Louisiana. Characteristic topographic features in these coastal watersheds include low gradients and interior bays (particularly in Texas).

Coastal watersheds often lack a single, defining stream that drains the watershed. Instead, coastal watersheds (including USGS's HUC-8 watersheds) often include multiple streams that run relatively parallel to each other (i.e., do not accumulate flow from the entire watershed) before discharging into the ocean or bay. Some of these rivers and bayous may experience inter-basin flow transfers, which a two-dimensional model can simulate well, if the terrain is accurate. As such, the development of a terrain model (described in Section 2.1.1) must show this drainage pattern.

Coastal watersheds are highly influenced by tides and coastal surge levels. The modeler should choose a boundary condition consistent with other FEMA Guidance that considers tides and storm surge. The modeler may use a mean high water tidal datum or a value between the 50- to 10-percent annual chance elevations as a downstream boundary condition. The choice of boundary condition should be carefully considered. Of note, a value higher than the mean high-water tide may help incorporate the effects of storm surge, which may occur simultaneously with a runoff event.

### A3.1.3 Playas/Endoheric Basins

Playas are found in the Southern High Plains of Texas, Oklahoma, and New Mexico. Since playas are typically shallow, circular-shaped wetlands, they are best modeled using 2-D methods as the models lend themselves well to more accurately dealing with the storage and attenuation impacts. Special attention should be paid to those playas that have gravity drainage systems. If significant, drainage system capacity/inflow should be modeled to account for the storage in the 2-D model. Playas that are simply recharge basins (recharge for the aquifer) do not need to include infiltration information as the 2-D analysis will suffice for a BLE study.

### A3.1.4 Arid Southwest

Although the hydraulic approach in an arid area would be consistent with the approach described in this document, the hydrology would vary. Due to a lack of extensive gage record, flood frequency analysis is rarely an option. Additionally, regression equations have large standard errors. The approach most favorable is rainfall runoff modeling.

In some locations Drainage Design Manuals have been published which contain area specific methods to be used in areas of arid hydrology. In areas where a drainage design manual is not available, those from nearby areas may contain useful guidance. Within Region 6, Drainage Design Manuals have been published by New Mexico State Highway and Transportation Department and the City of El Paso, TX. Although not in Region 6, Drainage Design Manuals or Hydrologic Modeling Guidelines have been published by Arizona Department of Transportation; Arizona Department of Water Resources; Coconino County, AZ; Yavapai County, AZ; and Flood Control District of Mohave County, AZ.

It should be noted that areal reduction of precipitation is more important in an arid region. The above-mentioned resources and Depth-Area Ratios in the Semi-Arid Southwest United States (Zehr and Meyers, 1984) can be used to develop the best approach to areal reduction.

#### A3.1.5 Urban Areas

Terrain model development in urban areas should follow the same procedures outlined in previous sections which require incorporating the main hydrologic features. Urbanized topography often includes roads, railroads, man-made channels, and numerous culverts and bridges, which determine flow movement. A 2-D BLE study should not incorporate every single hydraulic structure. However, the modeler should assess the overall flow patterns and include the main hydraulic features only (for example, sharp embankments and man-made channels) These features can be identified by undertaking a coarse model run and locating area of flow attenuation. Offset breaklines may also be used as an alternative to explicitly modeling the structure in 1-D.

If a LiDAR dataset that includes buildings is available, the modeler may leave the buildings in the terrain model. A hydraulic model with buildings included as part of the terrain will display flow moving on the streets exclusively and not “through” the buildings. Given that a hydraulic model with bare earth terrain (i.e., without buildings and tree canopy) simulates flow resistance with the aid of Manning’s n values, the modelers should adjust these values accordingly, if the terrain includes buildings.

### A3.2 Non-levee Features

Non-levee features, such as road or railroads embankments, should not be allowed to simply act as natural high ground or accredited levees within the terrain. The base flood should be allowed to pass through these structures, as appropriate, using either modifications to the terrain or incorporation of hydraulic structures through the feature. Refer to Levee Guidance (2020) for additional information.

### A3.3 Levees/Floodwalls

A levee is an embankment or wall built to contain rising water. Throughout FEMA Region 6, levees of many sizes and conditions exist. Levees or floodwalls with documentation that meets the 44CFR65.10 criteria can be accredited, with the FIRM panels showing a reduced flooding risk.

To certify a levee or floodwall, the owner is responsible for complying with the requirements included in 44CFR65.10. To show reduced risk in areas protected by levees or floodwalls, FEMA must perform a completeness check on the certification package to verify that the certification package is adequate. This section addresses levees modeled for riverine flood sources only, as BLE approaches for coastal are not considered in this guidance.

Refer to Levee Guidance (2020) for additional information.

### A3.3.1 Accredited Levees

Accredited levees/floodwalls represent significant drainage features because they constrict flow and direct it elsewhere. Accredited levees/floodwalls have certified data that the levee/floodwall is designed to withstand at least the 1-percent annual chance flood.

Accredited levees/floodwalls must be included in the terrain model used to develop a hydraulic 2-D BLE study. A modeler can accurately describe a levee's alignment and crest elevation using three-dimensional breaklines. For a 2-D BLE study, a detailed cross section geometry of the embankment is not necessary. The modeler must ensure that the levee/floodwall connects seamlessly upstream/downstream tie-ins and hydraulic road crossings. If a tie-in includes a non-levee feature, rather than high ground, the modeler must take into consideration non-levee feature approaches, as described in the Fall 2017 guidance.

Results of the 2-D BLE should be compared against the effective to evaluate how the levee/floodwall accreditation may be affected by the new analysis. The community should be asked to provide the confirmation that their levee/floodwall system is still considered accredited against the new base flood elevations that would eventually come into effect from the 2-D BLE, which may necessitate a revised certification package.

Accredited levees/floodwalls must also be evaluated for residual flood risk and interior drainage. If not part of the 2-D BLE scope, interior drainage may be carried over from the certification package.

### A3.3.1 Non-Accredited Levees

Non-accredited levees are those which have not been shown by the community or levee owner to meet the requirements outlined in 44CFR65.10. FIRM panels should not show non-accredited levees as providing full protection from a 1-percent annual chance flood.

Before initiating special modeling considerations, non-accredited levees should be evaluated for hydraulic significance. There are many small levees in Region 6, usually designed for high frequency events in agricultural areas that do not have significance to the 1-percent-annual-chance flood. These can simply be left in the terrain model as they are. However, the Mapping Partner should communicate their presence and the modeling plan for them to project monitor and to the stakeholders, to check for any objections to considering any specific levees as not hydraulically significant.

The development of a 2-D BLE study with non-accredited levees should include the collection of best available data and an evaluation of known deficiencies. Non-accredited levee systems may be broken into reaches, based on shared characteristics of available data, deficiencies (or lack thereof), and hydraulic conditions. Each levee system must, at a minimum, be analyzed for both natural valley and for the levee held in place. Available data and/or discussion with the community may lead to the need to perform analysis by overtopping or structural-based inundation (breach).

Performing analyses of a non-accredited levee requires close coordination with FEMA Region 6's Project Monitor and Levee Lead and local floodplain administrators to identify what makes the levee non-accredited and how the map can more accurately depict the flood risk. The final reach analysis and mapping decision should be made only after engaging the levee stakeholders. Minimal coordination may consist of a concurrence to simply proceed with natural valley. Otherwise, a Local Levee Partnership Team (LLPT) should be formed to determine if the levee system has reaches that are to be considered for structural-based inundation, overtopping, freeboard-deficient, or sound reach. Some procedures require a high level of data to be submitted by the community to show that some conditions of 44CFR65.10 are met. If a levee requires formation of an LLPT and a procedure other than natural valley is being considered, the Mapping Partner should consider if it may be appropriate to rescope the leveed reach from 2-D BLE to instead be a detailed study and discuss that option with the FEMA Region 6 Project Monitor.

To model the necessary levee scenarios, including with-levee and natural valley, a 2-D BLE study may develop more than one terrain for use in the hydraulic model, where the only difference is the levee. The terrain can incorporate the levee alignment and crest elevation using three-dimensional breaklines. The availability of multiple terrain datasets may help quickly incorporate levees into a study.

Alternatively, two-dimensional models can incorporate levees as model features, which is an option in some types of 2-D software. This approach may prove a more efficient modeling method than creating multiple terrain datasets. As with terrain breaklines, the lines that define a levee should incorporate an accurate crest elevation and alignment. In HEC-RAS 5.x, the modeler may create different plans (i.e., simulation “scenarios”) that include the different levee alternatives.

The landward area should also be evaluated for interior drainage conditions and, if necessary, modeled and mapped for interior drainage.

### A3.4 Other Flood Control Structures

The goal of flood control structures is to guide or regulate flow and, thus, should be included in a 2-D BLE study. Other than levees previously discussed in this guidance document, flood control structures include, but are not limited to, dams, weirs, and gates.

2-D BLE studies include dams and levees in a similar way. Modelers may include dams in a hydraulic model by including the embankment or concrete structure into the terrain. Incorporating the exact dam cross section geometry is not necessary in a 2-D BLE study.

Unlike levees, dams create enclosed reservoirs. Without an outlet, the water would back up behind the dam until the structure becomes overtopped. However, dams have regulated or free flow discharging mechanisms that allow dam operators to control the water level and prevent overtopping of the design flood event. These mechanisms include weirs, spillways, and gates of varying designs. These structures’ rating curves are often available and should become part of the 2-D BLE study as a downstream or internal boundary condition.

A 2-D BLE study should not incorporate complex dam operational procedures. For example, a BLE simulation should not try to incorporate operation rules that dam operators follow during flood events. Simply, the BLE simulation should include rating curves of fully open gates and uncontrolled spillways. If rating curves are unavailable, the modeler may modify the terrain to allow for uncontrolled flow or include weir structures that allow the model to calculate outflow. RAS5 allows the inclusion of weir structures in its geometry module.

Other weirs, inline or lateral, should be included as part of the BLE analysis, if they represent a significant flow regulator at the 1-percent annual chance level.

## A-4 2-D Base Level Engineering Hydraulic Review QC Checklist

This section provides a detailed list of questions relating to each aspect of the model build process and the outputs produced. It is essential that these sensibility checks are undertaken to ensure the robustness of model results. Where the model development methodology or input parameters differ from the recommended approach provided in Section A-2, the Mapping Partner should engage the model team to understand the reasoning for such discrepancies.

Each hydraulic model is bespoke and deviation from recommended model build approaches can be warranted to produce stable and representative results. Adequate justification must be provided to ensure parameters such as the computational timestep have not been altered to mask instabilities.

**General**

- Is the product scalable? (i.e., can the model be upgraded to meet regulatory requirements?)

**Terrain/Topographic Data**

- Is the model hydrology based on a DEM with an appropriate resolution? (HUC 10 or smaller should use 10-meter or better. Larger than HUC 10 should use 30-meter or better.)
- Does the model use terrain data at least as current as the current effective study and meet FEMA topo standards?
- Is the input topography reasonably dense? (Cell size should be 10-foot or less.)
- Have topographic abnormalities been corrected? (No extreme undulation due to underlying data errors.)

**Hydrographs (HEC-HMS and/or gage based)**

- Are the basin delineations reasonable?
- Are the curve numbers reasonable and sufficiently documented?
- Are the precipitation depths reasonable and sufficiently documented?
- Is the time of concentration determination reasonable for all HEC-HMS subbasin elements?
- Was a reasonable temporal storm distribution used?
- Was the appropriate areal reduction factor used for any contributing drainage area inflow modeled using rainfall-runoff?
- If PeakFQ is used, was the correct confidence interval used? (Should be 0.84 instead of default 0.95)
- Is gage-based hydrology reasonable? Does the gage-analysis follow identified best practices for this project? (If USGS report is available for the gages in this area, the same methodology should be applied to this project, or reasons for deviation should be documented.)

**Excess Precipitation**

- Does the model include all frequencies? (10%-, 4%- , 2%- , 1%- , and 0.2%-acf)
- Does the model include the 1%-plus and 1%-minus flood events?
- Was the appropriate areal reduction factor used for the 2-D mesh?
- Are curve numbers reasonable, and sufficiently documented?
- Are the incoming hydrographs being applied properly? (location, shapes, timing, etc.)
- For hydrographs transferred from one RAS model to a downstream RAS model, are the incoming and outgoing hydrographs being applied a coincident location?
- If applicable, does the peak discharge compare favorably to gages or effective studies? If not, have attempts been made to calibrate? (This applies to both the study area and incoming hydrograph models.)
- Does the model account for any significant flow-regulating dams?

**Hydraulics**

- Does the model use public domain software?
- Is the 2-D mesh reasonably sized to limit cell count and obtain reasonable velocities?
- Is the timestep appropriate for the mesh size and calculated velocities?

- Is the source of the roughness coefficients or criteria for selecting default roughness coefficients documented in the report?
- Are significant hydraulic structures and embankments accounted for? (i.e., placing breaklines, 2-D structures, terrain processing, etc.)
- Are comparison points/lines (i.e., internal 2-D connections) captured and compared against applicable benchmarks? (gage, high water mark, effective BFE, etc.)
- Are the boundary conditions established, documented, and reasonable?
- If applicable, is the transfer line between this model and a downstream model well away from any boundary condition effects?
- Are the initial conditions and final conditions reasonable?
- Is the mass balance/volume conservation reasonable? (Generally, this is less than 1.0% for RAS5.)
- Was the model simulation long enough to pass the entire hydrograph(s) through the model?
- Have instances of significant crossing profiles or adverse slopes been investigated for modeling errors?

**Mapping Outputs**

- Do the boundaries appear reasonable?
- Has the correct TIN-based interpolation approach been leveraged?

## A-5 Resources

FEMA guidance may be updated twice yearly. As such, the FEMA Library should always be checked for updates. The following documents provide useful information that should be considered when developing Base Level Engineering products.

- Automated Engineering (May 2016)
- General Hydrologic Considerations (May 2016)
- Elevation (May 2016)
- General Hydraulics Considerations (November 2016)
- Hydraulics: One-Dimensional Analysis (November 2016)
- Hydraulics: Two-Dimensional Analysis (November 2016)

## A-6 References

ADOT, 2014, Arizona Department of Transportation Highway Drainage Design Manual, Hydrology, 2nd Edition.

ADOT, 1993, Arizona Department of Transportation Highway Drainage Design Manual Hydrology, Final Report, March 1993, Report Number FHWA-AZ93-281.

ADWR, 2007, State Standard for Hydrologic Modeling Guidelines, SS10-07, prepared by Stantec and JE Fuller for Arizona Department of Water Resources, Flood Mitigation Section, August 2007.

Bruner, Gary and CEIWR-HEC. February 2016. HEC-RAS River Analysis System, 2D Modeling User's Manual Version 5.0. Davis, CA.

City of El Paso, 2012, Drainage Design Manual, draft, City of El Paso Engineering Department, June 2012. Never adopted.

City of El Paso, 2008, Drainage Design Manual, City of El Paso Engineering Department, June 2008.

FCDMC, 2013, Drainage Design Manual for Maricopa County, Arizona, Hydrology, 4th Edition, dated August 15, 2013, publication of the Flood Control District of Maricopa County, Phoenix, Arizona.

FCDMC, 2012, Drainage Design Manual for Mohave County, Arizona, Hydrology, 2nd Edition, dated December 12, 2012, prepared by Arid Hydrology & Hydraulics, LLC for Flood Control District of Mohave County, Kingman, Arizona.

Hershfield, D. M., May 1961. Technical Paper No. 40. Rainfall Frequency Atlas of the United States. U.S. Weather Bureau. U.S. Department of Commerce. Washington, DC. Figure 15. Page 6.

NMSHTD, 1995, New Mexico State Highway and Transportation Department Drainage Manual, Volume 1, Hydrology, December 1995.

U.S. Department of Agriculture. Natural Resource Conservation Service. "Chapter 2 Estimating Runoff." Technical Release 55: Urban Hydrology for Small Watersheds. 2nd ed. 1986. Table 2-2a. Page 2-5.

U.S. Department of Agriculture. Natural Resource Conservation Service. National Engineering Handbook Hydrology. Chapter 10: Estimation of Direct Runoff from Storm Rainfall. July 2004. Table 10.1. Page 10-6.

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U. S. Water Resources Council. March 1976. Guidelines for Determining Flood Flow Frequency. Bulletin 17B of the Hydrology Subcommittee. Washington, DC.

Zehr, R.M. and Myers, V.A., 1984, Depth-Area Rations in the Semi-Arid Southwest United States, NOAA Technical Memorandum NWS HYDRO-40, Office of Hydrology, Silver Spring, MD.

# Appendix B – MIP Validation Checklists

Terrain Data Capture

Hydrology Data Capture

Hydraulics Data Capture

Flood Risk Products Data Capture

Terrain Data Capture

| Validation Inventory Checklist - XX-06-XXXXS - Terrain - Study Name | | | | | | |
|---|---|---|---|---|---|---|
| Directory Structure / Path | Description of Data Files / Acceptable Formats / Data File Name or Type | Required | Fulfilled | Reviewer Approval | Reviewer Comments | Production Team Response |
| **Task Documentation** | | | | | | |
| | - Project Narrative – Word | | | | | |
| | - Certification of Completeness (if applicable) – .PDF | | | | | |
| | - Terrain Metadata – .XML | | | | | |
| **Correspondence** | | | | | | |
| | - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF | | | | | |
| **Final*** | | | | | | |
| **Breaklines** | | | | | | |
| | - 3D Breaklines – .SHP/.PGDB/.fGDB/.DXF | | | | | |
| | - 3D Breakline Tile Index – .SHP/.PGDB/.fGDB | | | | | |
| | - 2D Breaklines – .SHP/.PGDB/.fGDB/.DXF | | | | | |
| | - 2D Breakline Tile Index – .SHP/.PGDB/.fGDB | | | | | |
| | - Mass Points – .SHP/.PGDB/.fGDB/.DXF | | | | | |
| **Bare_Earth_DEM** | | | | | | |
| | - DEMs – Esri grid/GeoTIFF/ASCII grid | | | | | |
| | - DEM Tile Index – .SHP/.PGDB/.fGDB | | | | | |
| **Contours** | | | | | | |
| | - Contours – .SHP/.PGDB/.fGDB/.DXF | | | | | |
| | - Contour Tile Index – .SHP/.PGDB/.fGDB | | | | | |
| | - Bathymetric Data – .SHP/.PGDB/.fGDB/.DXF | | | | | |
| | - Bathymetry Tile Index – .SHP/.PGDB/.fGDB | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **TIN** | | | | | | |
| | - Uncorrected TIN Files – Esri ArcGIS | | | | | |
| | - Terrain – Esri ArcGIS - TIN Tile Index – .SHP/.PGDB/.fGDB | | | | | |
| **HDEM** | | | | | | |
| | - Hydrologically Corrected DEMs – Esri grid/GeoTIFF/ASCII grid | | | | | |
| | - Terrain – Esri ArcGIS | | | | | |
| | - HDEM Tile Index – .SHP/.PGDB/.fGDB | | | | | |
| **Spatial_Files** | | | | | | |
| | - FIRM Database files as described in the FIRM Database Technical Reference Table 2* – .SHP/.PGDB/.fGDB/.GML | | | | | |
| | - Source Index – .SHP/.PGDB/.fGDB/.GML | | | | | |
| **Supplemental_Data** | | | | | | |
| | - Any additional elevation data collected for use in the preparation of this Flood Risk Project – Format as received | | | | | |

* Study teams will always create all listed sub-folders but will only upload a readme file if none of the listed items are applicable to the submittal.

Hydrology Data Capture

| Validation Inventory Checklist - XX-06-XXXXS, - Study Name | | | | | | |
|---|---|---|---|---|---|---|
| **Directory Structure / Path** | **Description of Data Files / Acceptable Formats / Data File Name or Type** | **Required** | **Fulfilled** | **Reviewer Approval** | **Reviewer Comments** | **Production Team Response** |
| **Task Documentation** | | | | | | |
| | - Hydrology Report – Word and .PDF | | | | | |
| | - Draft FIS Section 5.1 – Word and .PDF | | | | | |
| | - Project Narrative – Word | | | | | |
| | - Certification of Completeness (if applicable) – .PDF | | | | | |
| | - Certification of Compliance (if applicable) – .PDF | | | | | |
| | - Hydrology Metadata – .XML | | | | | |
| **Correspondence** | | | | | | |
| | - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF | | | | | |
| **Watershed_Name** | | | | | | |
| **Simulations** | | | | | | |
| | - Model input and output files – Native format | | | | | |
| | - Readme file explaining contents of each named file – .TXT | | | | | |
| **Supplemental_Data** | | | | | | |
| | - Database file(s) and/or spatial files such as data and analyses for stream and rainfall gages and computations for regional regression equations such as output from USGS PeakFQ, NFF or NSS computer programs – Native format | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | - Any additional Hydrology data collected for use in the preparation of this Flood Risk Project – Format as received | | | | | |
| **Spatial_Files** | | | | | | |
| | - FIRM Database files as described in the FIRM Database Technical Reference Table 2* – .SHP/.PGDB/.fGDB/.GML | | | | | |

*Note that Hydrology data submitted for Large Scale Automated Engineering, Base Level Engineering, or Levee analyses may not include all FIRM Database files listed in the FIRM Database Technical Reference Table 2.

| Validation Inventory Checklist - XX-06-XXXXS, Study Name | | | | | | |
|---|---|---|---|---|---|---|
| Directory Structure / Path | Description of Data Files / Acceptable Formats / Data File Name or Type | Required | Fulfilled | Reviewer Approval | Comments | Production Team Response |
| **Task Documentation** | | | | | | |
| | - Hydraulics Report (BLE Report) – Word and .PDF | | | | | |
| | - Draft FIS Section 5.2 – Word and .PDF | | | | | |
| | - Project Narrative – Word | | | | | |
| | - Certification of Completeness (if applicable) – .PDF | | | | | |
| | - Certification of Compliance – .PDF | | | | | |
| | - Hydraulics Metadata – .XML | | | | | |
| **Correspondence** | | | | | | |
| | - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF | | | | | |
| **Hydraulic Models** | | | | | | |
| **HUC10-1 Name (or Number)** | | | | | | |
| **Mainstem** | | | | | | |
| | - Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format | | | | | |
| | - Readme file explaining contents of each named file – .TXT | | | | | |
| **Tributary 1** | | | | | | |
| | - Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format | | | | | |
| | - Readme file explaining contents of each named file – .TXT | | | | | |
| **Tributary 2** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | - Model input and output files for all flood frequencies (required) and floodway analysis (if applicable) – Native format | | | | | |
| | - Readme file explaining contents of each named file – .TXT | | | | | |
| **Profiles** | | | | | | |
| | - Profiles – RASPLOT .MDB/.DXF/.DWG | | | | | |
| **FWDT** | | | | | | |
| | - Floodway Data Tables – .MDB/.XLS/.XLSX/.DBF | | | | | |
| **Supplemental_Data** | | | | | | |
| | - Database file(s) and/or spatial files such as high water mark data for model calibration – Native format | | | | | |
| | - Zone A backup files – Native format | | | | | |
| | - Any additional Hydraulics data collected for use in the preparation of this Flood Risk Project – Format as received | | | | | |
| **Hydrology**** | | | | | | |
| | - Back up tables, model, gage analysis used to develop BLE flows – Format as received | | | | | |
| **Spatial_Files** | | | | | | |
| | - FIRM Database files as described in the FIRM Database Technical Reference Table 2* – .SHP/.PGDB/.fGDB/.GML | | | | | |

*Note that the submitted FIRM Database files must match the model output with respect to floodplain boundaries, cross sections, and water surface elevations and their precision. Unlike in the regulatory data submittals, floodplain boundaries and cross sections should not be cartographically modified, and the data may not necessarily agree exactly with the regulatory FIRM, FIRM Database, flood profiles, and Floodway Data Tables.

Note also that Hydraulics data submitted for Large Scale Automated Engineering, Base Level Engineering, or Levee analyses may not include all FIRM Database files listed in the FIRM Database Technical Reference Table 2.

**** 2D BLE studies only**

| Validation Inventory Checklist - XX-06-XXXXS, Study Name | | | | | | |
|---|---|---|---|---|---|---|
| **Directory Structure / Path** | **Description of Data Files / Acceptable Formats / Data File Name or Type** | **Required** | **Fulfilled** | **Reviewer Approval** | **Reviewer Comments** | **Production Team Response** |
| **Draft*** | | | | | | |
| **Task Documentation** | | | | | | |
| | - Project Narrative – Word | | | | | |
| | - Certification of Completeness (if applicable) – .PDF | | | | | |
| | - Large Scale Automated Engineering Report or Base Level Engineering Report (if applicable) – Word and.PDF | | | | | |
| **Correspondence** | | | | | | |
| | - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF | | | | | |
| **Flood_Risk_Datasets** | | | | | | |
| **CSLF** | | | | | | |
| | - Input and output data associated with the Changes Since Last FIRM (CSLF) dataset (not the actual CSLF dataset which is submitted with the FRD) – Native format | | | | | |
| **FDAG** | | | | | | |
| | - Input and output data associated with the Flood Depth and Analysis Grids (FDAG) dataset (not the actual grids which are submitted with the FRD) – Native format | | | | | |
| **FRA** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | - Input and output data associated with the Flood Risk Assessment (FRA) dataset, which include Hazus data (not the actual Risk Assessment dataset which is submitted with the FRD) – Native format (.hpr files for Hazus data) | | | | | |
| **Flood_Risk_Products** | | | | | | |
| **FRD** | | | | | | |
| | - .ZIP file containing FRD and accompanying metadata file – SHP, DBF and .XML | | | | | |
| | - .ZIP file containing FRD and accompanying metadata file – fGDB and .XML | | | | | |
| | - .ZIP file containing Flood Depth and Analysis rasters and accompanying metadata file – GeoTIFF and .XML | | | | | |
| **FRR**** | | | | | | |
| | - Flood Risk Report (if applicable) – Word and .PDF or readme file with hyperlink to the location of the digital file if alternate format is prepared (i.e., Story Map) | | | | | |
| **FRM** | | | | | | |
| | - Flood Risk Map (if applicable) - .PDF and .MXD or readme file with hyperlink to the location of the digital file if alternate format is prepared (i.e., Story Map) | | | | | |
| **Supplemental_Data** | | | | | | |
| | - Input and output data associated with the FRD (not the actual FRD which is submitted with the final mapping data) – Native format | | | | | |
| | - Any relevant input and output data associated with the Flood Risk Report (not the actual FRR which is submitted with the FRD), if applicable – Native format | | | | | |
| | - Any relevant input and output data associated with the Flood Risk Map (not the actual FRM which is submitted with the FRD), if applicable – Native format | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | - Any additional data used to assist in the preparation of this Flood Risk Project – Native format | | | | | |
| **Final** | | | | | | |
| **Task Documentation** | | | | | | |
| | - Project Narrative – Word | | | | | |
| | - Certification of Completeness (if applicable) – .PDF | | | | | |
| | - Large Scale Automated Engineering Report or Base Level Engineering Report (if applicable) – Word and.PDF | | | | | |
| **Correspondence** | | | | | | |
| | - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes – Word/.PDF | | | | | |
| **Flood_Risk_Datasets** | | | | | | |
| **CSLF** | | | | | | |
| | - Input and output data associated with the Changes Since Last FIRM (CSLF) dataset (not the actual CSLF dataset which is submitted with the FRD) – Native format | | | | | |
| **FDAG** | | | | | | |
| | - Input and output data associated with the Flood Depth and Analysis Grids (FDAG) dataset (not the actual grids which are submitted with the FRD) – Native format | | | | | |
| **FRA** | | | | | | |
| | - Input and output data associated with the Flood Risk Assessment (FRA) dataset, which include Hazus data (not the actual Risk Assessment dataset which is submitted with the FRD) – Native format (.hpr files for Hazus data) | | | | | |
| **Flood_Risk_Products** | | | | | | |
| **FRD** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | - .ZIP file containing FRD and accompanying metadata file – SHP, DBF and .XML | | | | | |
| | - .ZIP file containing FRD and accompanying metadata file – fGDB and .XML | | | | | |
| | - .ZIP file containing Flood Depth and Analysis rasters and accompanying metadata file – GeoTIFF and .XML | | | | | |
| **FRR**** | | | | | | |
| | - Flood Risk Report (if applicable) – Word and .PDF or readme file with hyperlink to the location of the digital file if alternate format is prepared (i.e., Story Map) | | | | | |
| **FRM** | | | | | | |
| | - Flood Risk Map (if applicable) - .PDF and .MXD or readme file with hyperlink to the location of the digital file if alternate format is prepared (i.e., Story Map) | | | | | |
| **Supplemental_Data** | | | | | | |
| | - Input and output data associated with the FRD (not the actual FRD which is submitted with the final mapping data) – Native format | | | | | |
| | - Any relevant input and output data associated with the Flood Risk Report (not the actual FRR which is submitted with the FRD), if applicable – Native format | | | | | |
| | - Any relevant input and output data associated with the Flood Risk Map (not the actual FRM which is submitted with the FRD), if applicable – Native format | | | | | |
| | - Any additional data used to assist in the preparation of this Flood Risk Project – Native format | | | | | |

* Note that an identical folder structure is provided for Draft and Final Flood Risk Products data submittals. Draft data uploads are only required if applicable.

** If not provided during Discovery