Guidance for Flood Risk Analysis and Mapping

Mapping Base Flood Elevations on Flood Insurance Rate Maps

February 2019

FEMA

Requirements for the Federal Emergency Management Agency (FEMA) Risk Mapping, Assessment, and Planning (Risk MAP) Program are specified separately by statute, regulation, or FEMA policy (primarily the Standards for Flood Risk Analysis and Mapping). This document provides guidance to support the requirements and recommends approaches for effective and efficient implementation. Alternate approaches that comply with all requirements are acceptable.

For more information, please visit the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage (www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping). Copies of the Standards for Flood Risk Analysis and Mapping policy, related guidance, technical references, and other information about the guidelines and standards development process are all available here. You can also search directly by document title at www.fema.gov/library.

Document History

Affected Section or Subsection	Date	Description
Sections 1, 2, and 3	February 2019	Revisions made to address considerations associated with data accuracy and data confidence relative to BFE placement, and to address considerations associated with cross-section placement and alignment with the use of supplemental BFE lines.

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1.0 Background

Water-surface elevations of the 1-percent annual chance (base) flood are called Base Flood Elevations (BFEs). These BFEs may be designated on the Flood Insurance Rate Map (FIRM) using BFE lines or at Cross Section lines with the appropriate elevation labels. BFEs are placed on the FIRM to assist users in determining the elevation of the 1-percent-annual-chance flood elevation anywhere within the floodplain. For more detailed information on BFE determinations, users should reference the base flood profile in the Flood Insurance Study report, where applicable.

For the purpose of this guidance, the term BFE refers to:

- The 1-percent-annual-chance elevation shown on cross section lines, as noted in the FIRM Database <WSEL_REG> field and as shown at cross-section L in Figure 1, or,
- The 1-percent-annual-chance elevation shown on BFE lines as noted in the FIRM Database <BFE> field and as demonstrated by elevation 462.2 in Figure 1. These BFEs may be shown as whole foot rounded values or to the tenth of a foot (decimal), depending on stream slope and map scale. See Section 2 for more information on the use of decimal BFEs vs. whole-foot rounded elevations.

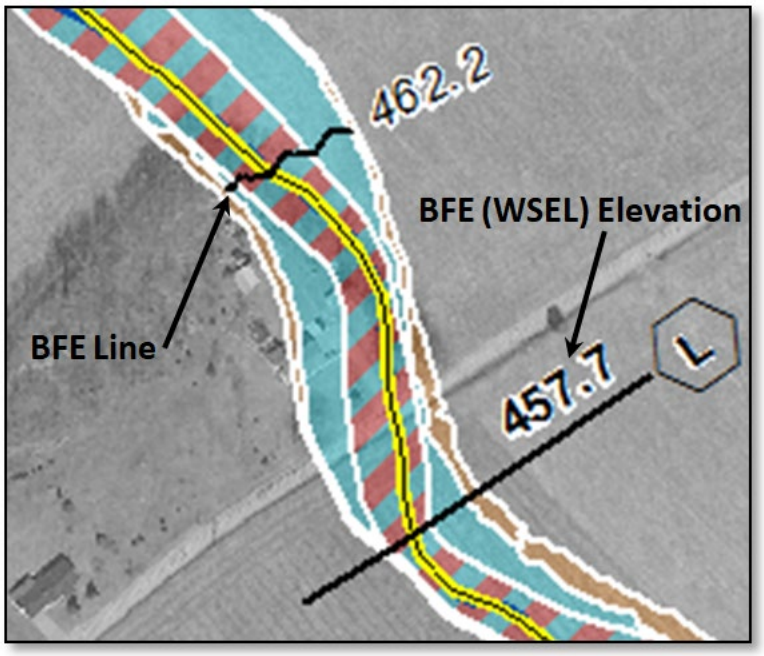

Figure 1: Two BFE depictions on a FIRM

- BFE lines (such as shown in Figure 1 for elevation 462.2) will be placed along the profile baseline at inflection points not already captured by cross sections, or as needed in areas of backwater, ponding, complex flow areas, overflow areas off the profile baseline, at node areas of Interconnected Channel and Pond Routing (ICPR) and similar models in very flat areas of Florida, or other areas needed per engineering judgment.

FEMA Risk MAP standards require that BFEs (i.e., cross-section values supplemented with BFE lines where needed) must be shown at appropriate locations to allow map users to accurately interpolate flood elevations both horizontally and vertically.

Because this requirement is results-focused, there is no specific or prescriptive requirements associated with map spacing or flood elevation rise between BFEs. The intent is that map users can accurately interpret flood elevations on the FIRM and that BFEs are placed strategically and

at reasonable intervals to enable this intent. See Section 3.0 of this guidance document for more information on cross-section placement relative to the plotting of BFEs on the FIRM.

The remainder of this guidance document is devoted to providing guidance on the use of decimal BFEs vs. whole foot rounded elevations; cross-section considerations; examples; and guidance that enables SID 374 to be reasonably met. This include examples of poor BFE mapping for context, backwater BFEs, converting effective unrevised BFEs (riverine, ponding and lacustrine) to tenth foot (decimal) values; and coastal BFEs.

2.0 Use of Whole-Foot Rounded BFEs vs. Decimal Value BFEs

While FEMA standards allow for the use of decimal BFEs to supplement cross-section BFEs, there are a few considerations that must be accounted for in this decision. The first and most important consideration is relative accuracy. The question that needs to be answered is if the hydraulic data supports the implied accuracy of plotting BFEs to the tenth of a foot. To help answer this question, it is recommended that mappers read Technical Paper 114 from the USACE that addresses multiple uncertainties as well as methods to test the accuracy of Flood Profiles using such techniques as a Monte Carlo Analysis.

- http://www.hec.usace.army.mil/publications/TechnicalPapers/TP-114.pdf

If decimal BFEs are used to supplement whole foot BFEs on the FIRM, they may be used in any sequence (0.5 foot, 0.2 foot, or 0.1 foot) as determined by the appropriate accuracy needed to replicate the flood profiles using reasonable intervals of BFE lines and BFE labeled cross-sections on the FIRM. These sequences will be dictated by the stream slope and map scale; and may vary from stream to stream, and even along a stream reach.

3.0 Cross-Section and BFE Considerations

Because cross-sections from the hydraulic model are now used as the primary flood elevation communication tool on the FIRM, it is critical that mappers understand the importance of cross-section placement and alignment. In situations where there are no traditional BFE lines, the location and alignment become critical for proper interpretation of flood elevations and must be double-checked after the modeling is completed. This issue is critical to determining the flood elevations for properties at the fringes of the floodplains.

When cross-sections are not sufficient to enable proper interpretation of flood elevations, they must be supplemented with BFE lines (either as whole foot rounded elevations or decimal BFEs depending on data confidence as noted in Section 2.0 of this guidance document). In general, BFEs lines are shown on the FIRM, by modeler's experienced in hydraulic floodplain analyses, using the model results (output), the profile, the DEM (topography), and familiarity with the floodplain and hydraulic conditions, and using their experience and expertise to map supplemental BFEs (whether by using BFE lines to supplement cross-sections or decimal BFEs as noted above).

The important thing to note, for 1D steady flow models, is that cross-section orientation in the outer portions of the cross-sections where very little flow conveyance is found are not significant

in determining the base flood profile, as long as the mapper is using the profile, cross-section, topographic data, and engineering judgment to plot the BFEs.

4.0 BFE Plotting

As implied in the FEMA standard, the goal in BFE plotting is to enable the map user to make an accurate flood elevation determination. To enable this standard to be met, it is important to note that applying a rules-based mapping protocol where one-size fits all may yield undesirable results. As such, Mapping Partners must evaluate map scale, stream slope and proximity to development when determining the best approach for plotting BFEs on the FIRM. BFE lines should be placed only "where needed" for new or revised riverine floodplains and to an appropriate level of precision based on the stream slope and map scale.

4.1 Plotting BFEs on New or Revised Riverine Study

For all new or revised riverine flood elevations, riverine BFEs lines should be placed only "where needed" both horizontally and vertically to enable accurate interpretation of the water surface elevations, and those BFEs should be expressed as values either in a sequence (0.5 foot, 0.2 foot, or 0.1 foot) as determined by the appropriate accuracy needed to replicate the flood profiles using reasonable intervals of BFE lines and BFE labeled cross-sections on the FIRM, or as whole-foot rounded values (without a decimal place shown) depending on the stream slope and map scale. In areas of significant stream slope, where precision in BFE mapping would be problematic, the BFEs may be best expressed as whole foot rounded values, while in areas of gentle stream slope BFEs may be best expressed as tenth foot values. It is encouraged that lakes and ponding areas be expressed as tenth foot values if they have been calculated to that level of precision.

Where possible and accuracy and map scale allow, it is further recommended that BFEs shown on individual flooding sources all follow the same protocol with limited exceptions. Many streams will tolerate whole foot BFEs near the mouth where stream slopes are mild; however, using the same whole-foot interval upstream where slopes are steep can create confusion for map users (more so than would changing the sequence of BFE lines). Some flexibility in applying BFEs may be necessary along a single stream depending on slope and stream characteristics.

The notable exception is to show backwater arms similar to what is shown in Figure 2 as whole foot rounded values if sufficient confidence in the true backwater elevation is not present. Likewise, if a flooding source is determined to not support the accuracy implied by showing BFEs to a certain sequence (i.e., 0.5 foot, 0.2 foot, or 0.1 foot) due to map scale or stream slope, then it is recommended that all BFEs for the entire flooding source be shown as whole foot rounded values without the decimal shown (i.e., 423, not 423.0).

Following this approach will enable a level of precision to be represented on the FIRM when that level of precision is supported by the mapping and associated data. All new studies must map base flood elevations (whether on cross sections or supplemental "BFE") at their true location. Therefore, selection of the cross-sections used for labeling on the FIRM is critical to proper representation of BFE data. Lastly, it is encouraged that the need for additional BFE lines added to the FIRM be reduced whenever possible. Correct selection of cross sections should suffice in most straightforward riverine situations.

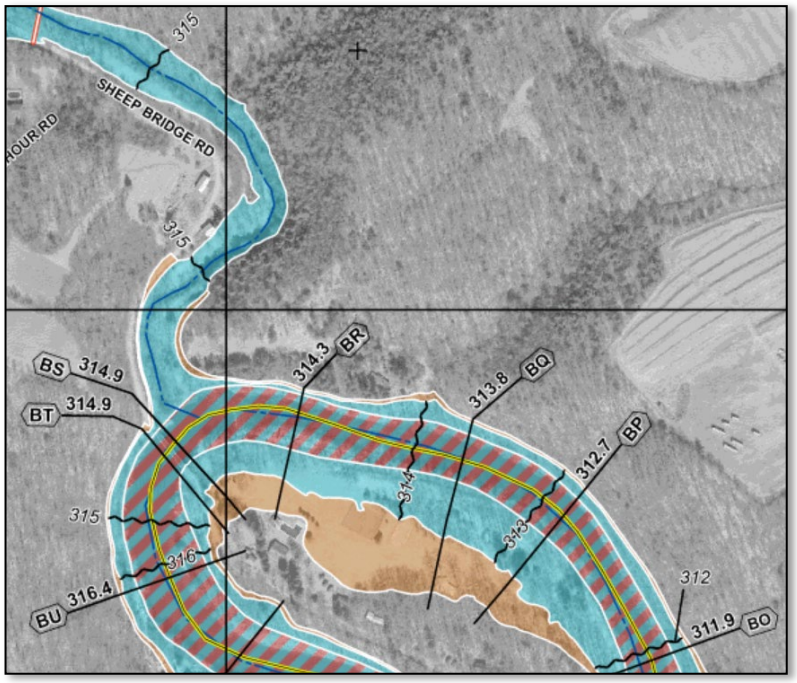

Figure 2: Area of rounded backwater BFEs

4.1.1 Other Considerations

The following are additional considerations for riverine BFEs.

- Streams that are only experiencing redelineation based on new terrain data would not be considered new or revised flood elevations.
- Showing flood elevations on backwater tributaries in a sequence (0.5 foot, 0.2 foot, or 0.1 foot) as determined by the appropriate accuracy needed to replicate the flood profiles is optional and will be based on the relative accuracy of expressing the backwater elevation to the tenth of a foot value. The relative accuracy will be dependent on the accuracy of the available topographic data, profile and map scale, and stream slope. If sufficient confidence in representing the backwater elevation to the tenth of a foot is not present, then the backwater BFE should be shown as a whole foot rounded elevation, without the tenth of a foot decimal shown.
- For small floodplain segments that are not able to graphically "carry" a BFE line due to their small size, the BFE label should only be shown to the tenth of a foot if there is sufficient confidence in the flood elevation at that location. Otherwise it should be shown as a whole foot rounded elevation without the decimal.

4.2 Plotting BFEs in Areas of Complex Overbank Flow

Figure 3 demonstrates an area of complex overbank flow that would benefit from additional BFEs "bent" using available terrain data and engineering judgment to reflect flow patterns in overbank areas and to ultimately enable an accurate representation of flood elevations at all points within the floodplain. These BFEs must traverse the entire floodplain to reflect the consistent 1-percent-annual-chance annual chance water surface elevation in the overbank

areas with the BFEs drawn perpendicular to the flow path. Care should be taken with the depiction of these BFEs as a mechanism to enhance clarity of the changing water surface elevations in relation to other features represented on the FIRM. Placement and orientation of cross-sections and use of BFEs should be evaluated to ensure that water surface elevations are accurately and clearly conveyed.

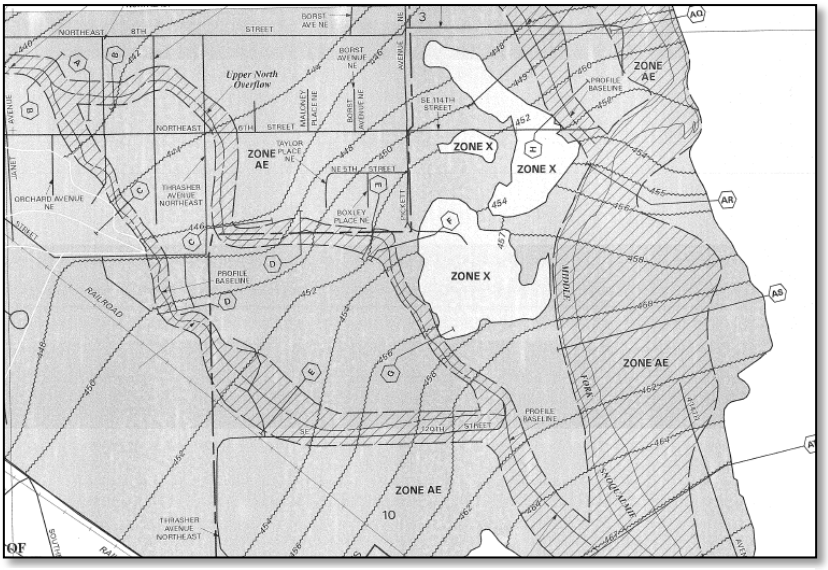

Figure 3: Area of complex overbank flow patterns

4.3 Avoiding Overcrowding of BFEs

FEMA standards regarding BFE plotting was focused on a specific allowable rise between BFEs and stream gradient. While these are important considerations, it is important to note that mandating (for example) a one foot rise maximum between plotted BFEs could result in overcrowding on the FIRM as demonstrated in Figure 4, which shows an extreme crowding effect caused by placing BFEs at every whole foot in an area of significant stream slope. Figure 5 demonstrates an area of regular stream slope with sufficient cross-sections to represent flood elevations but with several unnecessary BFE lines placed to meet the prior standard of showing whole foot BFEs at every foot of vertical rise.

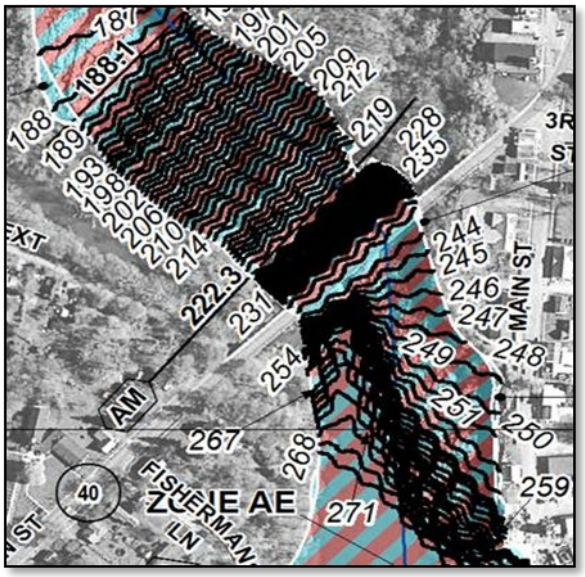

Figure 4: BFEs Plotted at every whole foot on a stream with significant slope

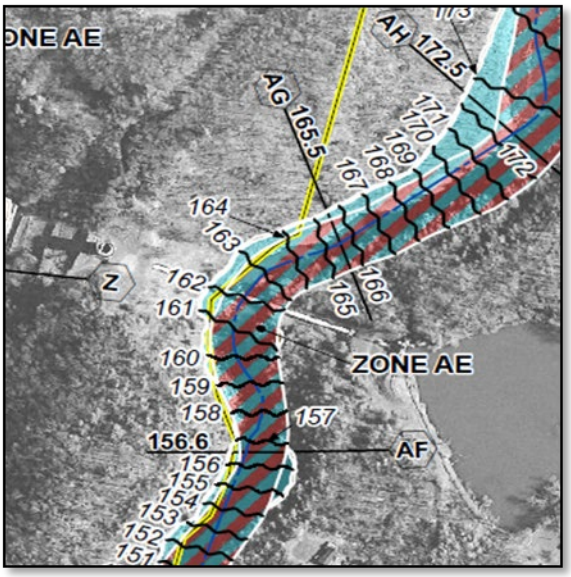

Figure 5: Several Unnecessary Whole-Foot Elevations

4.4 Ponding, Lacustrine and Coastal BFEs

FEMA standard 106 requires that BFEs for ponding and lacustrine areas must be expressed to the tenth of a foot if they have been calculated to that level of precision; otherwise they should be shown as whole-foot rounded elevations. Unrevised lake and ponding elevations may be converted to tenth foot elevations if supported by technical data on a project-by project basis in coordination with the FEMA Project Officer. BFEs for coastal flood zones must be shown as whole foot elevations.

Care must be taken in the decision to convert unrevised ponding and lake elevations. If the hydraulic analysis used to derive the elevations shown on the prior FIRM supports this level of precision, and as such, a conversion of this sort, then the Mapping Partner may proceed. When in doubt, it is recommended that the Mapping Partner consult with the FEMA Project Officer.

4.4.1 Coastal BFEs

Coastal BFEs will be shown as whole foot rounded values for new studies and unrevised coastal flood elevations will normally not be updated to tenth foot values. There are specific exceptions that may be granted through coordination with the FEMA Project Officer and via the FEMA Guidelines and Standards Exceptions Process.

4.5 BFEs for Unrevised Flooding Sources

Unrevised BFE lines may be converted to tenth of a foot values as a project-specific option, based on Regional discretion. For example, if 90 percent of the streams are being revised, a decision may be made to convert the remaining BFEs to tenth of a foot values, if this level of precision is determined to be warranted and justifiable.

Before converting unrevised BFEs, a decision must be made regarding the ability to derive accurate flood elevations from the FIRM. For example, if the flood elevations are not attributes of the profile baseline (i.e., older studies) and the Flood Profile is shown at a vertical scale of 1 inch = 20 feet, it may not be possible or reasonable to convert the unrevised flood elevations with a high degree of accuracy. The test for this would be that the accuracy of the converted BFEs should enable recreation of the Flood Profile to within ½ foot at any location. For many unrevised flooding sources this may require the addition of more BFE lines to meet this accuracy requirement.

Effective (unrevised) lake elevations may be shown to the tenth of a foot only if supported by a Summary of Stillwater Elevations table in the Flood Insurance Study (FIS) report (and as noted earlier) the hydraulic analysis used for the prior FIRM.

Figures 6 and 7 demonstrate how an unrevised stream with BFEs converted from whole foot rounded values to the tenth of a foot value may appear.

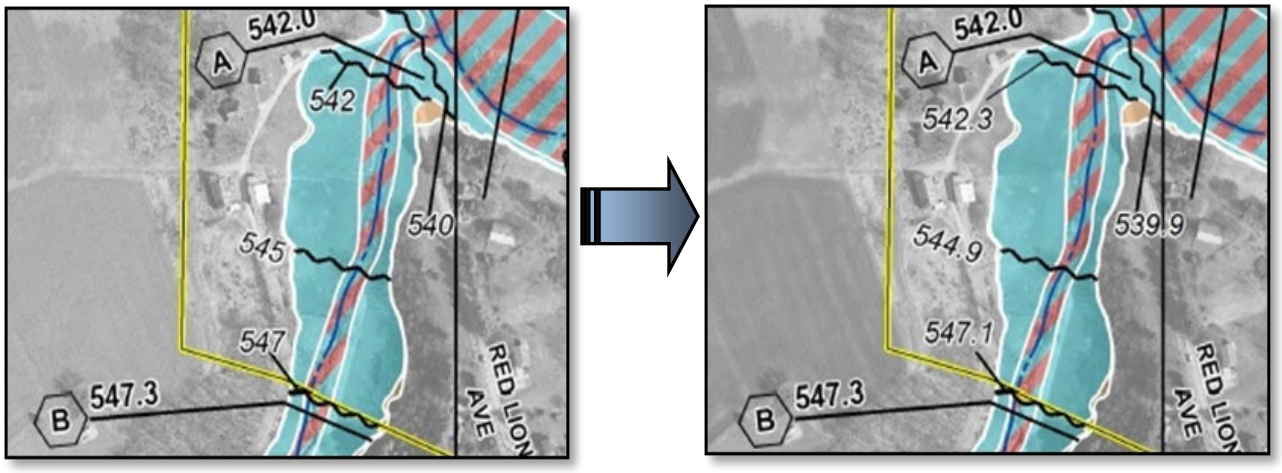

Figure 7: Unrevised BFEs

Figure 7: Unrevised BFEs Converted to tenth foot values

Unrevised BFE lines may, with Regional discretion, be converted to the tenth of a foot values if it is determined that stream slope and map scale enable accurate interpretation of the effective flood elevations. When making a decision to convert unrevised flood elevations to the tenth of a foot value, the following factors should be considered:

- Cost: How many flooding sources (and stream miles) contain unrevised BFEs on FIRM panels being revised is an important factor.
- Consistency: Having all BFEs on a FIRM shown to a consistent sequence (0.5 foot, 0.2 foot, or 0.1 foot) as determined by the appropriate accuracy needed to replicate the flood profiles to minimize end-user confusion. If 90% of the streams on a FIRM are being revised, it may be worth converting the unrevised flood elevations as well. Note: Since

accuracy of the BFE information on the FIRM is dependent on stream slope and map scale, the conversion of all streams to this standard may not be reasonable or realistic in all cases.

- Accuracy: The perceived or relative accuracy of the conversion. If the flood elevations are not attributes of the profile baseline (i.e., older studies) and the Flood Profile is shown at a vertical scale of 1 inch = 20 feet, it may not be possible to convert the unrevised flood elevations with a high degree of accuracy.

Each Region will need to make individual decisions on the conversion of unrevised flood elevations based on the perceived value of doing so and the actual benefit to map users.