Guidance for Flood Risk Analysis and Mapping

Flood Profiles

December 2020

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/flood-maps/guidance-partners/guidelines-standards). 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/multimedia-library.

Table of Revisions

The following summary of changes details revision to this document subsequent to its most recent version in November 2016.

Affected Section or Subsection	Date	Description
Sections 2.3, 3.1 and 4.0	December 2020	This guidance has been updated to add references to evaluation lines for 2D modeling.

Table of Contents

List of Figures

1.0 Introduction

This document provides guidance to support the production of flood profiles for inclusion in Flood Insurance Study (FIS) Reports. Flood profile standards and technical specifications required to achieve the minimum level of consistency are found in the Standards for Flood Risk Analysis and Mapping and the FIS Report Technical Reference respectively. The purpose of this document is the practical application of those standards and requirements and the consistent development of the attributes not specifically addressed by those documents.

2.0 Study Types

Flood profiles are produced for riverine studies designated as Zone AE with Base Flood Elevations (BFEs) determined using a variety of modeling approaches including steady and unsteady one-dimensional (1-D) and two-dimensional (2-D). For more information on modeling approaches, please refer to the Hydraulics: One-Dimensional Modeling Analyses Guidance document and the Hydraulics: Two-Dimensional Modeling Analyses Guidance document.

2.1 1-D Steady State

For studies using steady state modeling, the model uses a constant flowrate. The model results will return one elevation for each flood recurrence interval at each cross-section. These elevations are plotted on the profile at their corresponding cross-section stations, and the water surface profile lines are interpolated by connecting these points.

2.2 1-D Unsteady

For studies using unsteady modeling, the model varies the flowrate over time as an event is routed through the modeled system. As such, the modeled water surface elevations will vary at each cross-section over the duration of the model run. In this case, the peak elevations are tabulated for each recurrence interval at each cross-section. These peak elevations are plotted on the profile at their corresponding cross-section stations, and the water surface profile lines are interpolated by connecting these points.

2.3 2-D Studies

Due to the fact that the water surface elevation varies laterally, profiles have limited utility in true 2-D study areas. The relevance of an elevation reported on a profile in a 2-D study area is limited to the profile baseline itself. In most instances, 2-D study areas can be more accurately represented by contoured BFEs on the Flood Insurance Rate Map (FIRM) which are based on the water surface elevation grid generated from the 2-D model. Contoured BFEs allow longitudinal and lateral variability in the water surface grid to be depicted, ultimately better capturing the resolution of the 2-D model. If BFEs are not sufficient to define an area, water surface elevation grids should be published as FIS inserts, or a profile can be included in the FIS.

In many cases, 2-D analysis of an area will include a 1-D component where 2-D methods are applied to overland flow and the overbanks and 1-D methods are applied to riverine flow in defined channels. When this is the case, the elevations reported on the profile are relevant for the full width of the 1-D channel. Profile production for these reaches is no different from profile production on other 1-D study reaches. Minor 1D reaches within 2D models, such as those that convey less than 20% of the floodplain flow or are less than 1000 feet long, may not require a separate profile for accurate representation of the BFE.

2-D analysis is particularly useful for the identification of shallow flooding hazards and their interaction with riverine flooding hazards. However, profiles are not produced for shallow flooding areas. Refer to the Shallow Flooding Analyses and Mapping Guidance document for additional information regarding shallow flooding hazards.

3.0 Profile Layout

Each profile page consists of a title block and a gridded area. The gridded area is the working portion of the flood profile page. Cross-section markers are placed toward the bottom of the grid. Above these markers are the profile lines for the various flood recurrence intervals and stream bed and the modeled structure symbols. Scale labels are placed outside the gridded area. Markers for confluences, road names at modeled stream crossings, and the divergence and convergence of split flows are placed above the profiles and hydraulic structure symbols. The gridded area contains extent notes across the top. All text on a profile sheet is capitalized. Specifications for profile formatting can be found in the FIS Report Technical Reference.

3.1 Cross-sections and Evaluation Lines

Cross-sections enable a profile user to quickly associate stations on the profile with locations on the Flood Insurance Rate Map (FIRM) and data in the Floodway Data Table (FDT). For stream segments for which no regulatory floodway is computed, selected sequentially labeled cross-sections may be shown on the profile. Cross-sections are symbolized with a vertical line at the cross-section station snapped to a hexagon that contains the cross-section letter or number. Hexagon wipeouts can increase the legibility of cross-section labels but are not required.

Lettering or numbering every cross-section can lead to crowding that makes both the profile and the FIRM difficult to use. Therefore, care should be taken to select lettered or numbered cross-sections that provide reasonable definition on the FDT without obstructing the visibility of the flood hazard layer and other features on the FIRMs. When two lettered or numbered cross-section labels are close together, the hexagons from the two cross-section markers should not overlap. If there is room, the markers can be staggered vertically to prevent overlap. Alternately, the vertical line can be dog-legged to move the hexagon horizontally so long as the upper portion of the marker’s vertical line remains at the correct station. This approach can also be useful when the cross-section station is near the left or right edge of the profile grid as shown in Figure 1. Refer to the Standards for Flood Risk Analysis and Mapping for details regarding the maximum tolerance of profile markers.

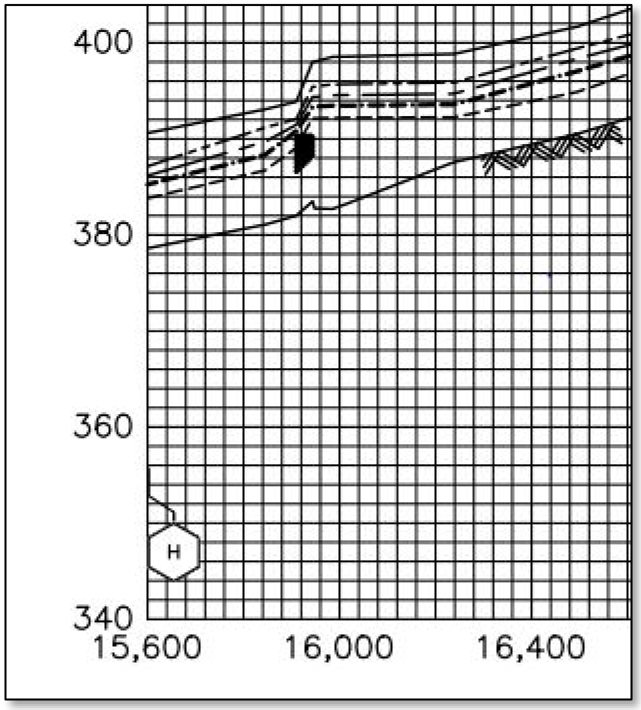

Figure 1: Cross-section Marker

Generally, cross-section markers are placed below the stream bed profile. However, if placing the cross-section marker below the stream bed profile would cause it to overprint the legend or pass outside the profile grid, the marker can be placed above the 0.2%-annual-chance profile.

Cross-sections outside of the study footprint are generally not included on the profile. For short stream segments that meander beyond the study limits, sequentially labeled cross-sections may be retained on the profile for clarity and continuity.

Evaluation lines should be placed on FIRMs where a detailed study included a floodway calculated based on 2D methods. Evaluation lines should also be used where a detailed study included a floodway calculated based a hybrid 1D, 2D model where the cross sections do not cover the entire floodplain. Where a 2D or hybrid 1D, 2D model was used but no floodway is calculated, evaluation lines should not be included. If a profile is created from a 2-D area where evaluation lines are used to present model results, the evaluation lines should be formatted in the same way as the cross sections. The specifications and additional details regarding evaluations lines can be found in the Floodway Analysis and Mapping Guidance Reference.

3.2 Profile Lines

Graphic specifications for profile line types can be found in the FIS Report Technical Reference.

3.2.1 Drawdowns and Crossing Profiles

When using the same geometric model data to determine flood elevations for a multiple profile analyses, drawdowns and crossing profiles are common challenges faced by profile producers. When efforts to correct drawdowns and crossing profiles within the model have been exhausted or the profile has been determined to be hydraulically accurate as-is (with accuracy emphasis to the 1.0%-annual-chance profile), then the removal of these features occurs in the course of profile production. In the case of a drawdown, the lower upstream inflection point should be raised until it equals the elevation of the next inflection point downstream for that recurrence interval. Likewise for crossing profiles, the inflection point for the lower recurrence interval event should be raised to equal the elevation of higher recurrence interval event. Correcting both of these cases by raising inflection points rather than lower other inflection points ensures a conservative approach to the representation of flood risk.

If a profile is created from a 2D model, drawdowns are expected, and the profile should match the FIRM.

3.2.2 Stream Bed Profile

Stream bed symbols should appear at least twice on a full page profile. If the stream bed profile extents are less than half a page, one symbol is sufficient. If the stream bed profile extents are less than the length of the stream bed symbol, the symbol may be truncated at the end of the profile line.

Dips in the stream bed are not drawdowns and do not need to be removed from the stream bed profile.

3.3 Stream Crossings

Structure symbols are placed on the profiles for all modeled structures. The specifications for bridge, culvert and dam structures can be found in the FIS Report Technical Reference. Additionally, most other hydraulic structures can be symbolized by one of the three defined structure symbols. For example, a weir can be represented on a profile using a dam symbol. For structures with top of road and low chord elevations that vary along the structure span, the values at the profile baseline are used to size the structure symbol on the flood profile. Very small structures may be difficult to display on the profile and especially so at smaller scales. In those cases, the structure symbol can be exaggerated so long as tolerance standards are maintained. Refer to the Standards for Flood Risk Analysis and Mapping for details regarding the maximum tolerance of structure symbols.

On occasion, an apparent stream crossing structure may appear in the base imagery or transportation layer that has not been modeled. These structures may be hydraulically insignificant, designed to break away during a storm or otherwise legitimately excluded through engineering judgment. No symbol is required on the profile for structures at stream crossings that have not been included in the model. Examples could include low water crossing, stream fords, foot bridges, or any other structure that would not create a significant impediment to flow and was therefore not considered in the modeling.

3.4 Stream Crossing Labels

In most cases, the name of structure is a road name. Many roads have multiple names as they represent federal, state, county and/or local routes that coincide. When this is the case, one road name is usually sufficient as long as it matches one of the road names labeled on the FIRM. If it is desired to include all road names, the road name label can be stacked above and/or below the marker line. Service roads, fire roads, logging roads and other unnamed roads may simply be labeled “Unnamed Road”. When an unnamed road is on private property, it may be labeled “Private Road” or “Private Drive”. Foot bridges or other similar structures not included in the hydraulic model may be labeled with only a location label.

3.5 Stream Connections

Split flow path convergences and divergences and stream confluences are only labeled for other streams with flood profiles. Incoming tributaries are labeled as “Confluence of…” When the downstream end of the stream profile represents a confluence with a receiving stream, the label should read “Confluence with…” Split flow divergences and convergences are labeled on the main stream profile as “Divergence of…” and “Convergence of…” respectively. Split flow divergences and convergences are labeled at the beginning and end of the split path profile as “Divergence from…” and “Convergence with…” respectively.

The label can be stacked above and/or below the marker line. It is not necessary to distinguish marker lines from major gridlines when they happen to be coincident.

No markers are required for tributaries that are unstudied or studied by Zone A methods. Splits or sloughs that are fully encompassed by the main stream cross-sections are not labeled.

3.6 Other Flooding Influences

The flooding hazard on a stream can be influenced by neighboring flooding sources through backwater, conjoined floodplains and coastal effects. When the flooding hazards from these influences exceed the flooding hazard of the stream itself, they are shown on the profile.

3.6.1 Backwater

Backwater occurs when ineffective flow pools at the downstream end of incoming tributaries. Backwater from the receiving stream or other water body is represented as a static elevation at the downstream end of a profile. The backwater elevation is represented as a horizontal line using the applicable line type for each recurrence interval. The backwater is projected upstream until it intersects the corresponding modeled profile. If the receiving water body does not have a regulatory BFE, backwater is not displayed on the profile and a limit of study label is placed at the downstream location on the tributary where the approximate 1%-annual-chance profile would be greater than the tributary stream 1%-annual-chance profile and identified with a note reading “1% annual-chance backwater effects from [name of main stream].”

3.6.2 Conjoined Floodplains

A conjoined floodplain occurs when the high ground between two flooding sources is insufficient to contain the flooding from one or both of the flooding sources. When the flooding hazard from the neighboring flooding source is greater than the flooding hazard from the profile stream, the water surface elevations of the neighboring flooding source are shown. The extent of this influence is noted on the profile along with a “Flooding Controlled By…” note identifying the source of the greater flood hazard as shown below.

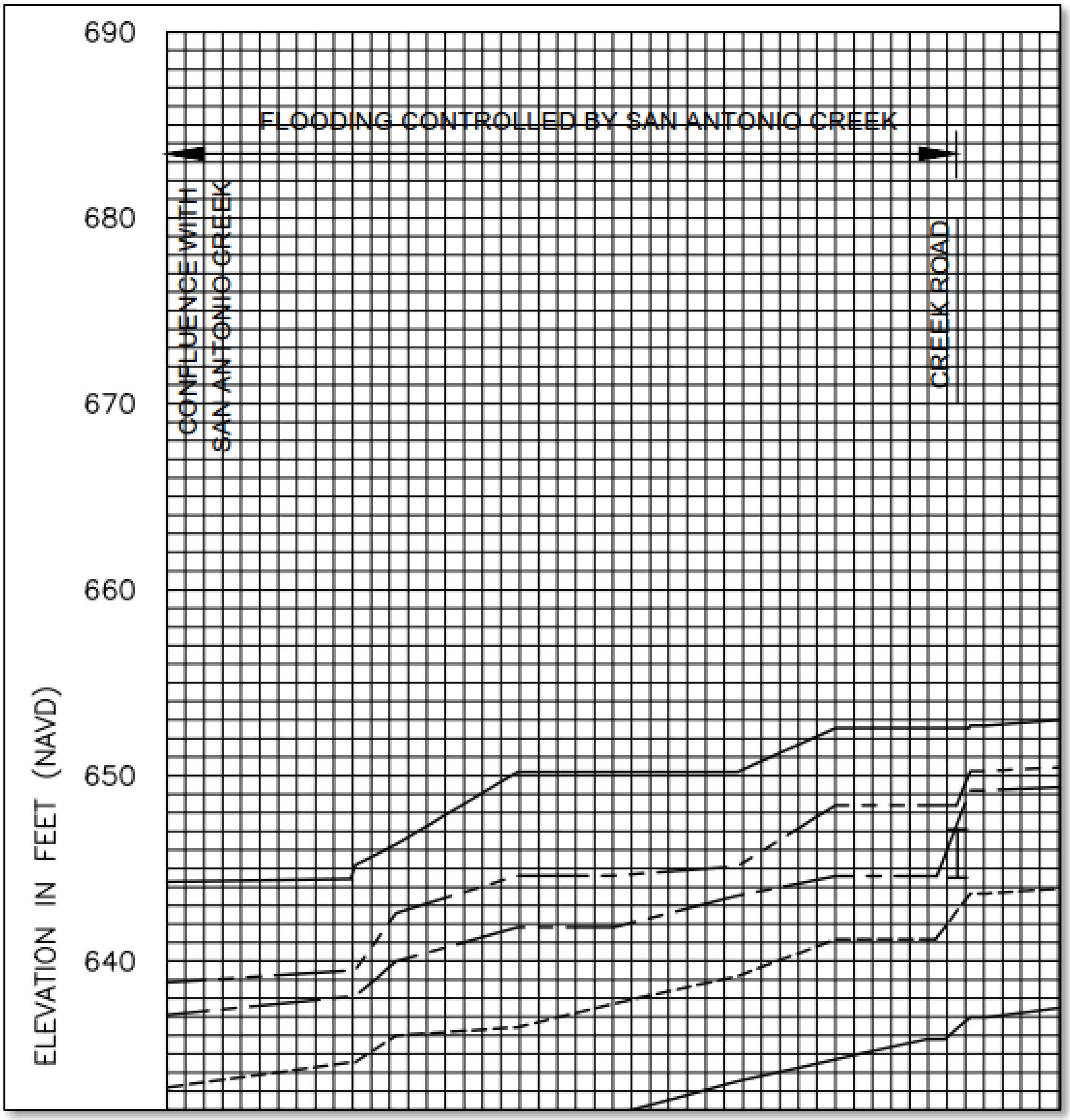

Figure 2: Flooding Controlled Note Example

3.6.3 Coastal Effects

For specifications related to the display of coastal effects, please refer to the FIS Report Technical Reference.

3.7 Levees

Unlike bridges, culverts and other stream crossings, levees, dikes, floodwalls and other flood protection structures parallel to the flooding source do not have a structure symbol on the profile. For levees that intersect the stream, as in the case of an interior drainage stream with a levee penetration, the levee and penetrating structure are symbolized on the profile of the intersecting stream in a manner similar to other stream crossings and labeled appropriately.

In certain situations, it may be necessary to present multiple profiles for a given stream reach to represent analysis that reflects various levee configurations. When this is the case, a description of the modeled levee configuration should follow the stream name in parenthesis in the name block. Examples: “[Stream Name] (Without Levees)” or “[Stream Name] (With Right Bank Levee Only)”. For more information on BFEs associated with levee analysis, please see the Mapping Base Flood Elevations on Flood Insurance Rate Maps Guidance document.

3.8 Data Gaps

When data for one of the profiles symbolized in the legend is not available for the entire profile page, that profile will be footnoted as exemplified in the FIS Report Technical Reference. However, when the data is unavailable for only a portion of the stream reach represented on the profile page, an extents marker should be placed on the profile along with a note identifying the profile(s) for which data is not available.

3.9 Scales

The horizontal scale provides profile users with the units and values needed to associate the profiles with the FDTs and the FIRMs. The vertical scale provides profile users with the units and values to determine the water surface elevations. The horizontal and vertical scales should be consistent among all profiles pages for each flooding source, unless changes in stream slope make it impractical to produce an easily-interpreted profile with a uniform scale. If the effective scale for a profile is determined to be inadequate to display the flood hazard and a new scale is chosen, the new scale should be applied to all profile pages for that stream and not just the revised reach. Refer to the Standards for Flood Risk Analysis and Mapping for details regarding acceptable horizontal and vertical scales.

The accuracy of the BFE information should be taken into account before a decision of what accuracy to show the BFEs on the lettered XS on the FIRM. In the interest of precision, a vertical scale of 1 inch equals 20 feet should only be used for extreme cases. For example, major rivers may exhibit such significant flood depths that the profiles and labels can only be displayed within the profile frame at a vertical scale of 1 inch equals 20 feet. In these situations, using a break in the vertical scale may help to minimize the need for this approach on major rivers. Also, in some instances steep stream channels may be difficult to represent on the flood profiles by adjusting the horizontal scale alone. For more information on BFEs, please see the Mapping Base Flood Elevations on Flood Insurance Rate Maps Guidance document.

4.0 FIS Inserts for 2D modeling

If the water surface elevation is not adequately captured by the published BFEs and evaluation line elevations on the FIRM, an insert will be added to the FIS to better convey the results of 2D modeling. One option is the annotated grid, where water surface elevations are published at set locations throughout the modeled 2D area. The water surface elevation at an area of interest can be determined by measuring the distance from known landmarks.

The figure below provides an example of an annotated grid presented in place of a profile in the FIS Report. Currently other options to better define the water surface elevations and replace the flood profile requirement are being evaluated. The appropriate FIS grid insert should be discussed with community officials and the FEMA Project Officer. If a different option besides those defined here, The FEMA Project Officer must concur prior to development.

The page format of the FIS grid insert can be 11” x 17” format and an index can be included if more than one page is needed to capture entire 2D area.

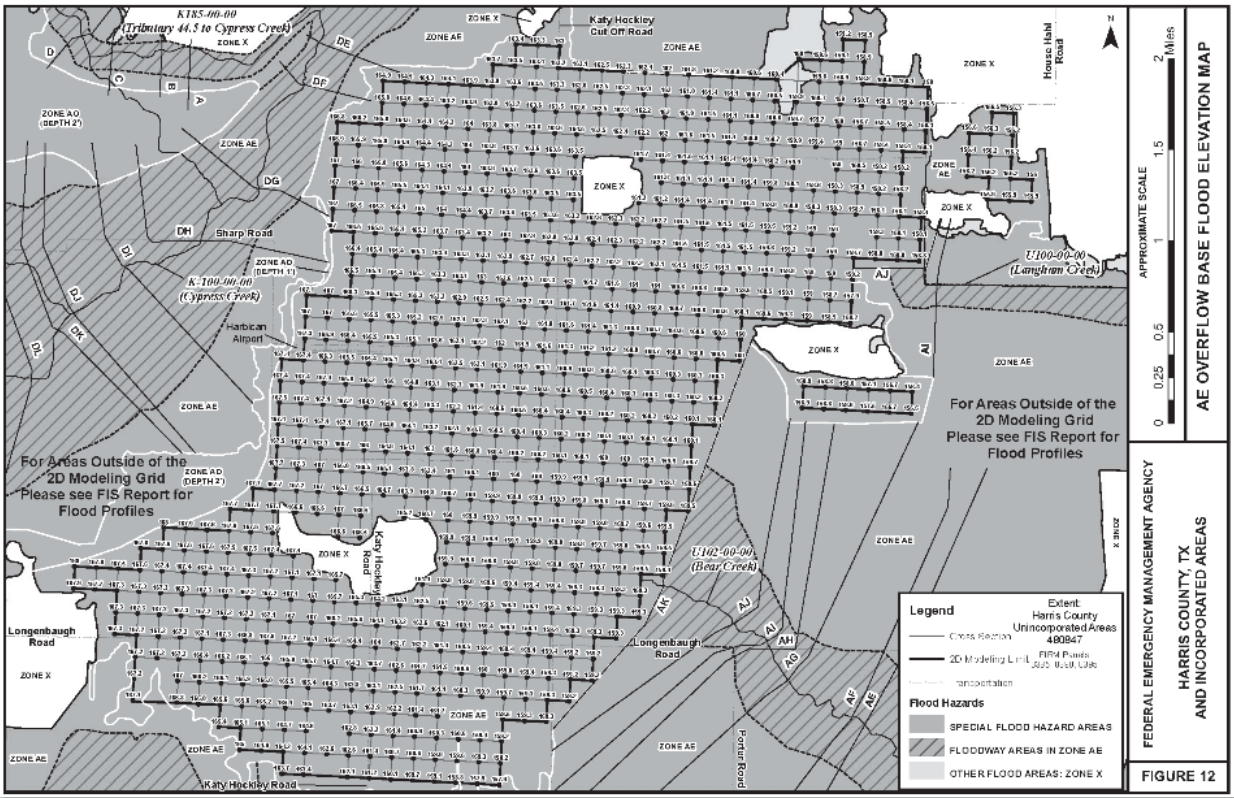

Figure 3: Annotated grid presented in place of profile in FIS report

5.0 Unrevised Profiles

It is often the case that digital source files are unavailable for effective profiles. For various reasons, these otherwise unrevised profiles may need to be renumbered, have the title block updated or require other text edits. Many of these edits can be accomplished within .PDF editing software.

6.0 Delivery

Profiles are a required deliverable for Hydraulics, Alluvial Fan and Final Mapping Data MIP submittals. For Floodplain Mapping, Preliminary Mapping Data and Final Mapping Data MIP submittals, the profiles will also be embedded in the .PDF of the FIS Report. Refer to the Data Capture Technical Reference for more information regarding required deliverables.