

Guidance for Flood Risk Analysis and Mapping

First Order Approximation

November 2015



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
First Publication	November 2014	Initial version of transformed guidance. The content was formalized from draft guidance previously developed and is being published separately from the standards.
Section 2.4 Submittal Guidelines	November 2015	Moved content to <u>Data Capture Guidance – Workflow Details</u> document.

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1.0 Introduction

Recent innovations and efficiencies in floodplain mapping have allowed FEMA to develop a process called First Order Approximation (FOA), which can be used to address current program challenges including the validation of Zone A studies and the availability of flood risk data in the early stages of a Flood Risk Project. The FOA process involves using best available data and automated techniques to produce estimates of flood hazard boundaries for multiple recurrence intervals. Although the cost for developing the data and estimates resulting from the FOA process should be lower than standard flood production costs, the FOA may be scalable for eventual production of regulatory and non-regulatory products.

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 floodprone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the Coordinated Needs Management Strategy (CNMS) Technical Reference. The CNMS Validation Checklist provides a series of critical and secondary checks to determine the validity of flood hazard areas studied by detailed methods (e.g., Zone AE, AH or AO). While the critical and secondary elements in CNMS provide a comprehensive method of evaluating the validity of Zone AE studies, a cost-effective approach for evaluating Zone A studies has been 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.

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the early stages of a Flood Risk Project. FEMA Program Standard ID (SID) #29 requires that *during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses must be shared and results must be discussed with stakeholders.* (Effective August 22, 2013)

An important goal of the FOA process developed by FEMA is the scalability of the results. Scalability means that the results of an FOA can not only be used for CNMS evaluations of Zone A studies but also leveraged throughout the Risk MAP program. The large volume of data resulting from an FOA can be used for the eventual production of regulatory and non-regulatory products, outreach and risk communication and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

Currently, a standard methodology and guidance has not been formally developed for areas of coastal flooding conditions and it should be noted that this document strictly provides guidance and best practices for non-coastal areas. This FOA Guidance document presents FOA best practices in the following three sections:

Section 2.0 – Process and Methodology for First Order Approximation, presents the hydrologic, hydraulic and floodplain mapping techniques for conducting an FOA and defines the deliverables and submittals.

Section 3.0 – Validation Procedure for Zone A Studies, presents the methodology used to establish whether an effective Zone A should be designated as “valid” or “unverified” in the CNMS inventory and how FOA data can be leveraged in the Zone A validation process.

Section 4.0 – First Order Approximation Scalability, presents additional ways in which FEMA and stakeholders can use FOA results, including the production of regulatory and non-regulatory products, outreach and risk communication and MT-1 processing.

2.0 Process and Methodology for First Order Approximation

This section provides guidance for the hydrologic, hydraulic and floodplain mapping steps required to create an FOA.

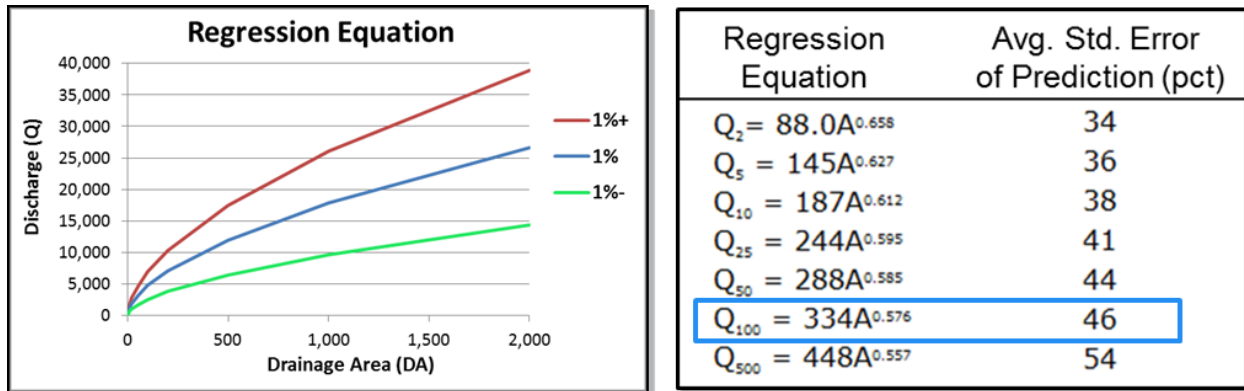
The FOA process leverages the best available data and methods and uses automated techniques to mass produce estimates of flood hazard boundaries for multiple flood recurrence intervals. The following sections provide minimum requirements but are intentionally meant to provide flexibility, as the best available data may vary among Regions. In addition, advances in programming and modeling tools may allow for future automation of tasks that are currently time consuming or manual. Regardless of the individual techniques used to perform these steps, the goal of a scalable product should be adhered to throughout the entire FOA process.

2.1 Hydrology

The primary hydrologic considerations are selecting the terrain and the methodology for establishing appropriate flood discharges for the recurrence intervals that are being studied. To support efficiency in leveraging the FOA data for future phases, all frequencies should be included in the analysis. The typical frequencies are the 10%-, 4%-, 2%-, 1%- and 0.2%-annual-chance floods. One or more of these frequencies may be excluded as necessary, such as cases where the published regression equations for the area do not include certain frequencies. Also, the 1%+ (“plus”) and 1%- (“minus”) flood events should be computed, which are calculated to help provide a confidence range within which the actual 1%-annual-chance discharge at a location is likely to fall, given the uncertainty that often exists with estimating discharges. Figure 1 helps illustrate what this means, as it relates to discharges estimated by regional regression equations.

Each regression equation reports an “average standard error of prediction” or “average standard error of estimate” percentage to define its statistical 68% confidence interval (+/- one standard deviation). Generally, this standard error percentage shows the average measure of accuracy of the regression equation. For example, the 46% percent shown in the table below is used to define the upper (regression equation plus the standard error) and lower (regression equation minus the standard error) confidence limits of the 1% annual chance discharge, which are used to compute the 1%+ and 1%- events, respectively.

Figure 1: 1%+ (Plus) and 1%- (Minus) Discharge Curves



Preparation of hydrology will vary depending on the complexity of the analysis. For FOA, hydrology preparation will vary more by State than by any other factor. Because the most common type of hydrology used for FOA is a U.S. Geological Survey (USGS) regression equation, it is reasonable to assume that the more complex the equations are for any given State, the longer the hydrology will take to prepare. In the 19 States where USGS regression equations are solely a function of contributing drainage area, the hydrology analysis should be simple and fast for almost any scale. The watersheds should be divided by the zones for the regression equations in the State. However, in States with many parameters or with complex parameters that do not have easily available Geographic Information System (GIS) data for the calculations, hydrology may require considerably more effort. As always, the statistical limitations of the USGS regression equations are critical in the application and careful attention should be paid to the upper and lower ends of drainage area applicability in particular.

The USGS StreamStats program (<http://water.usgs.gov/osw/streamstats/ssonline.html>) is now available for about 30 States, with approximately 10 more States in process. The StreamStats program typically allows the bulk submission of hydrology for hundreds of points at a time. Mapping Partners should contact their States' USGS offices to determine whether larger scale requests can be made of the StreamStats server. If so, this can be a very helpful way to determine flow hydrology at more than enough points to properly discretize flows in the underlying models.

2.1.1 Terrain Source

Terrain for hydrologic computations is used primarily to delineate watersheds. The 10-meter USGS Digital Elevation Model (DEM) or better should be used for smaller watershed study areas, defined as Hydrologic Unit Code 10 (HUC-10) or smaller. The 30-meter USGS DEM or better should be used for steeper areas or larger watershed study areas such as HUC-8 watersheds.

Terrain data may also be required to estimate some regression parameters. The terrain datasets used to estimate regression parameters should be consistent with those used to develop the regression equations.

2.1.2 Regression Estimates

The appropriate regression equations for the region being studied should be chosen based on availability, their dates of publication, and their suitability to the region. More recent equations are generally superior, because flow estimates improve with the length of record. More than one set of regression equations may be available. For example, both “urban” and “rural” regression equations may cover the same urban area. The best-suited set of regression equations should be selected for each watershed.

If a study area is very large, it may be acceptable for the FOA to use rural equations for the entire study area, even if urban equations are available. The decision to do this should be based on the level and extent of urbanization in the study area.

The National Inventory of Dams should be reviewed to help identify potential flow regulation by dams. For watersheds intersecting only a limited number of counties, reviewing the Flood Protection Measures section of the applicable effective Flood Insurance Study (FIS) Reports can help users determine whether and where any other significant flow-regulating dams exist. Locations where flow is regulated should be noted, because flow regulation may make the regression equations invalid. It is also beneficial to check for any levees, floodwalls or other flood-control structures when reviewing the FIS Reports; this information will be useful later, when conducting the hydraulic analyses.

2.1.3 Basin Model Setup and Flow Calculation

2.1.3.1 Watersheds

The first step is to set up basin break points, at least at stream junctions. Additional locations may be added, if they are judged to potentially result in a significant variation in sub-basin flows. Hydrologic tools should be run to create other hydrologic layers, calculate basin parameters and calculate the flow for the specified frequencies.

2.1.3.2 Parameter Checks

Parameters outside the range of regression equation tolerances should be noted but the results can be accepted for the FOA, unless deviations are judged to be extreme enough to be a concern even at the FOA level. For example, when the calculated 1%-annual-chance flood for a small stream is significantly larger than that of a nearby larger river, engineering judgment should be applied.

2.1.3.3 StreamStats

Where available, USGS’s StreamStats can be used to reduce time. StreamStats is a GIS application that provides stream flow statistics for gage sites and uses regression equations, typically developed for individual States, to compute flood discharges. These are generally the same equations discussed in Section 2.1.2.

2.1.3.4 Gage Analysis

In general, incorporating gage analyses, where possible, can contribute to more accurate flow information. In some instances, such as large study areas, gage analyses can be omitted. Otherwise, the gages in the study area that have sufficient records (at least 10 years of data)

and are not overly regulated should be identified and an appropriate statistical analysis (e.g., using Bulletin 17B) of the gages should be used to determine the flow for the different recurrence intervals.

Once the appropriate statistical analysis has been performed at the gages, standard methods can be used to calculate discharges at the break points, where applicable and to weight the results of the gage and regression analyses, where required.

2.2 Hydraulics

2.2.1 Model Selection

If possible, models should be compiled and run in public-domain software that is open to manipulation by other non-licensed users (e.g., the Hydrologic Engineering Centers River Analysis System (HEC-RAS) or the U.S. Environmental Protection Agency (EPA) Storm Water Management Model (SWMM)). For model-based Zone A studies, if the original models were compiled and run in proprietary software, the end product should be provided in a free version (e.g., XPSWMM model exported to EPA SWMM 5.0).

FOA hydraulics will typically be prepared using HEC-RAS and the companion GIS mapping tools, such as HEC-GeoRAS and RAS Mapper. The amount of effort required for an FOA is highly dependent on several factors: placement of cross sections, representation of flow-altering structures and number of return periods run. Quality Control (QC) checks (which can be automated for FOAs) also affect hydraulics computation time. For more complex hydraulic environments, a simplified 2-dimensional approach may generate more accurate results compared to HEC-RAS and should be explored before selecting the appropriate model.

2.2.2 Model Preparation

2.2.2.1 Terrain Source

The source of the terrain should be at least as current as the current effective study and meet the applicable FEMA standards for topographic information. In areas where terrain data meeting the prior criteria are not available, use of best available data is encouraged; however, depending on the intended use of the FOA outputs, it may be acceptable to use lower resolution data (e.g. USGS DEM) for FOA and upgrade to best available data during a future phase if warranted. If the FOA is to be used for CNMS validation of an effective Zone A study, the FOA must use the best available topographic information.

2.2.2.2 Terrain Preparation

Topographic data preparation is needed for all types of FOAs. FOAs performed on the USGS 10-meter DEM require the least amount of preparation, while FOAs performed on layers of overlapping, unprocessed Light Detection and Ranging (LiDAR) data require the most preparation. In general, preparing topographic data for an FOA is not much different from preparing such data for a normal watershed-scale Zone A production study. The major difference is in the sheer scale of the topographic data and the need to tile the data or split the analysis to allow for efficient computational operations. This will vary by the system used for the FOA.

2.2.2.3 Cross-Section/Node Spacing and Alignment

Cross sections/nodes (hereafter referred to collectively as cross sections) should be placed in an automated fashion and should be placed close enough to provide a reasonable approximation of the flooding source's invert profile based on available terrain. Additional cross sections should be placed at major changes in the width of the 1%-annual-chance-floodplain. Cross sections do not have to be placed to consider the hydraulic impacts of in-stream structures, such as low head dams.

Placement of cross sections is critical to the accuracy of one-dimensional flow models. Typically, cross sections are placed perpendicular to the stream centerline. This approach generally works well and produces reasonable results, except where streams are highly sinuous or have multiple branches. Some sinuosity can typically be handled by the programs that place cross sections; however, at a certain point, manual intervention or acceptance of some inaccuracy in sinuous reaches will be required. Manual intervention in the FOA production process rapidly degrades the cost efficiency and thus, decision to manually refine results should be considered with intended use of the outputs in mind. Placement of cross sections without manual intervention requires a well-prepared stream network, ordered consistently from downstream to upstream. The preparation of this layer is comparable to typical flood study production efforts in terms of time per mile. The amount of time needed to place cross sections using automated methods can range from minutes per HUC-8 to hours, depending on the complexity and degree of iteration. Generally, more complexity and iteration is preferred in refining automated cross section placements and in making critical manual adjustments. It is wise to invest sufficient time in the placement of cross sections, as this has a significant impact on the quality of the FOA outputs.

2.2.2.4 Overtopped Cross-Sections

In general, flow should be contained within the cross section, unless the section ends in an area that would not be conveying flow.

2.2.2.5 Roughness Coefficients

If land use data is available to leverage or if sub-watersheds can be generalized with a low level of effort, using more detailed land use data to determine local roughness may enhance the model accuracy. The source of the roughness coefficients should be well documented (e.g., National Land Cover Data (NLCD), a locally available land cover dataset or aerial imagery). Where the source data are not publicly available, all supporting documentation should be included (e.g., photographs, effective detailed studies in the area, calculations). If the data are publicly available, the source of the data should be explicitly stated (e.g., URL, date accessed). If a default roughness is used, a brief narrative should be included in the report discussing the determination and selection criteria for the roughness coefficients used.

2.2.2.6 Flow Regimes

The flow regimes should be based on sound engineering judgment, based on the watershed scale.

2.2.2.7 Flow Profiles

Because both the hydrology and hydraulics are intended to be highly automated profiles for the frequencies described in Section 2.1, all frequencies should be calculated in most situations. If only USGS topography is available for hydraulics, it may be appropriate to eliminate the more frequent events, because the limited definition of the channel/valley shape may cause the 10%- and 4%-annual-chance flood profiles to be over-predicted.

2.2.2.8 Boundary Conditions

Boundary conditions for FOA can be assumed to be normal depth, except for conditions where other boundary conditions (known water-surface elevation, tidal conditions, etc.) are known and significant to the approximate floodplain.

2.2.2.9 Structures

The use of bridges and culverts in FOA can be very difficult. First, in order to properly model hydraulic structures, cross sections must be placed immediately upstream and downstream of the structure. This can be complex, especially in sinuous reaches. Second, it is rare to have a good database of bridges and culverts for the entire study area. Even good databases maintained by State highway departments may only capture one-third to one-half of the structures, because of limitations on the type of structures actually measured (only those exceeding a certain size, such as 48 inches in diameter). Structures may be represented as weirs (i.e., no roadway opening) in the FOA but this leads to very conservative results and may degrade the ability of the product to be used, especially for regulatory mapping.

Because of these challenges, bridges and culverts do not need to be included in the FOA. However, if automation is possible, cross sections should be placed to facilitate the future addition of bridges and culverts, which will accommodate efforts to scale up the FOA in the future.

The representation of major flow-altering structures such as dams is very similar to that of bridges and culverts. Rarely are the data available in usable digital form to insert these features into the FOA model without manual intervention. However, because there are typically far fewer flow-altering structures in an FOA area than bridges and culverts, it may be feasible to insert them manually with minimal compromise to overall efficiency. Cross sections should be placed to capture the large change in slope caused by these large hydraulic structures. This can be accomplished by cutting a section through the dam with additional sections upstream and downstream of the embankment. If published elevations are readily available for large reservoirs, they can be used in lieu of an FOA. Use of published elevations should be documented in the FOA submittal.

Because the FOA is meant to be a first look and an approximation of the potential flood hazard, levees are not required to be accounted for or included in the FOA. Most areas with levees, especially in urban areas, will already have detailed studies that would supersede any FOA. The default approach should be to allow flow behind the levee during the FOA.

2.2.2.10 Channel Banks

Automated channel bank placement is acceptable for the FOA. Potential methods for automating the placement of bank stations include setting them at a standard distance from the stream centerline or at the more frequent event, such as the 2-year flood, if that information is available.

2.2.2.11 Profile Baselines

Final hydraulic profile baselines should nearly always be contained by the 1%-annual-chance flood inundation boundaries but this will be largely dependent upon the source of the baseline information. The baselines should be based on the best available dataset. Possible sources of profile baselines include LiDAR-derived hydrography and the USGS's National Hydrography Dataset (NHD) information.

2.2.2.12 Crossing Profiles and Adverse Slopes

There are no requirements to correct crossing profiles or adverse slopes in the streambed or water surface profiles in the FOA models. However, instances of significant crossing profiles and adverse slopes should be examined to verify that they are not a result of model errors that are easily corrected.

2.2.2.13 Ineffective Flow Areas

There is no requirement to evaluate ineffective flow areas in the FOA study. Ineffective flow areas could be added later as an enhancement to further refine the modeling.

2.2.3 Hydraulic Model Quality Control

The QC for an FOA generally should be entirely automated to be practical. Because of the scale of the FOA, manually checking each cross section or stream would be prohibitively time consuming. Thus, QC will rely heavily on statistical comparisons to known layers, such as an existing FEMA detailed study (categorized as valid in CNMS). With some early effort, results can be "tuned" to these enhanced floodplains for the entire watershed by altering information such as the Manning's "n" value. Automated tools like CHECK-RAS can be employed to check for a range of common errors and warnings in the hydraulic model, and those results can be summarized and attributed to cross sections for visualization by reviewers. Likewise, simply looking for large jumps in parameters, water surface elevations (WSELs) or floodplain widths in an automated manner can be very helpful. The QC process should be less time consuming than a manual QC process, on the order of a few minutes per mile of study.

2.3 Floodplain Mapping

Floodplain mapping generally comes directly from the model output but it may require processing after the QC checks are run or it may require some limited re-runs of models in areas with tighter cross section spacing. Both floodplain mapping and depth grid output are computationally intensive and may take many hours to actually process, although these processes require relatively little human oversight.

2.3.1 Profiles to Map

Before beginning the FOA, the Mapping Partner will work with the FEMA Project Officer and other stakeholders to determine which flood event profiles will be mapped. Because limited cleanup of the floodplains is required, the recommended default approach is to map all profiles that are computed.

2.3.2 Cleanup and Smoothing

In general, raw output of floodplain mapping is acceptable. Areas that the initial floodplain mapping shows as inundated but that are clearly hydraulically disconnected from the floodplain should be removed from the mapping. Automated smoothing techniques can be applied to smooth the floodplain edges.

2.3.3 Merging Floodplains

The final floodplains should be merged into a single watershed-wide (e.g., Statewide/countywide) layer. The Mapping Partner should check to make sure that the boundaries from less frequent flood events are larger or coincident with the boundaries from more frequent flood events.

2.3.4 Water Surface Elevation and Depth Grids

In some instances, depending on the methods used to produce the models and mapping, water surface elevation and depth grids may be produced as a by-product. Although these products may not meet all requirements of the [Flood Risk Database Technical Reference](#), they still may be useful products for communicating flood risk.

2.4 Submittal Guidelines

See the [Data Capture Guidance – Workflow Details](#) document for information about submitting FOA data to the MIP.

3.0 Validation Procedure for Zone A Studies

FEMA determines the validity of detailed riverine flood hazard studies by evaluating the critical and secondary elements in the CNMS Validation Checklist (Appendix A of the [CNMS Technical Reference](#)); however, determining the validity of Zone A studies requires a modified approach.

The large number of stream miles (more than 900,000) in FEMA's national inventory of Zone A studies that are subject to the required 5-year assessment cycle underscores the need for efficient yet technically sound procedures for validating Zone A studies. Determining the validity of historic Zone A studies (prepared prior to Map Modernization) is often further challenged by a lack of technical data and information about the original methods used to develop the effective flood hazard boundaries. These historic Zone A flood studies are collectively referred to as "non-model-backed" studies.

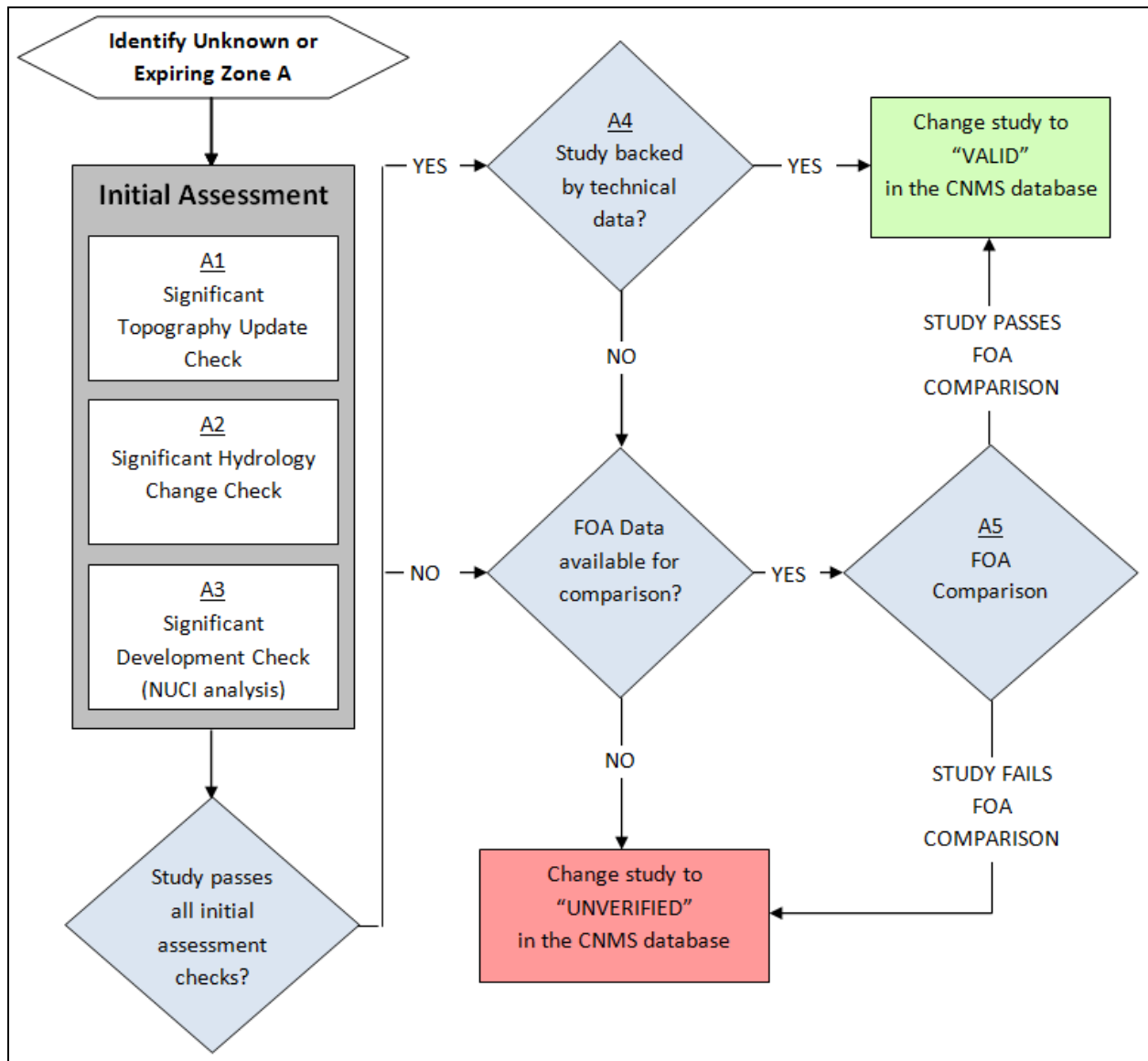
Procedures for evaluating the validity of both model-backed and non-model-backed studies of Zone A flood hazards are presented and described in the sections below.

The Zone A validation process begins with an initial assessment of three checks. These checks serve as an initial screen by which to efficiently categorize some Zone A studies as “Valid” or “Unverified” in the CNMS Inventory. As shown in Figure 2, the initial assessment checks will result in one of the following scenarios, which calls for one of the steps listed below.

1. If the effective Zone A study fails one or more initial assessment checks, then:
 - a. If an FOA dataset is available, proceed with an FOA comparison for further evaluation, OR
 - b. If no FOA dataset is available, categorize the study as “Unverified” in the CNMS inventory.
2. If the effective Zone A study passes all initial assessment checks and the study is backed by technical data, then:
 - a. Categorize the study as “Valid” in the CNMS inventory.
3. If the effective Zone A study passes all initial assessment checks but no technical data backing exists, then:
 - a. If an FOA dataset is available, proceed with an FOA comparison for further evaluation, OR
 - b. If no FOA dataset is available, categorize the study as “Unverified” in the CNMS inventory.

The initial assessment checks, technical data criteria and FOA comparison methods are described in the following sections.

Figure 2: Validation Procedure for Zone A Studies



3.1 Initial Zone A Assessment Checks

The initial assessment checks and all procedures in Figure 2 are only for Zone A studies (Zone A). These checks do not apply to detailed studies, which must comply with Zone AE validation criteria (17 elements), as described in the [CNMS Technical Reference](#).

3.1.1 Check for Significant Topography Updates

This check involves determining whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. To conduct this check, a new topographic data source for the study area of the effective Zone A must be available that meets or exceeds the requirements for vertical accuracy described in FEMA Standard ID (SID) 43. These requirements are illustrated in Table 1. For complete

definitions of Fundamental Vertical Accuracy (FVA) and Consolidated Vertical Accuracy (CVA), refer to SID 43.

Table 1: SID 43 – Vertical Accuracy Requirements

Level of Flood Risk	Typical Slopes	Specification Level	Vertical Accuracy: 95% Confidence Level FVA/CVA	LiDAR Nominal Pulse Spacing (NPS)
High (Deciles 1,2,3)	Flattest	Highest	24.5 cm / 36.3 cm	≤ 2 meters
High (Deciles 1,2,3)	Rolling or Hilly	High	49.0 cm / 72.6 cm	≤ 2 meters
High (Deciles 2,3,4,5)	Hilly	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Flattest	High	49.0 cm / 72.6 cm	≤ 2 meters
Medium (Deciles 3,4,5,6,7)	Rolling	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Hilly	Low	147 cm / 218 cm	≤ 5 meters
Low (Deciles 7,8,9,10)	All	Low	147 cm / 218 cm	≤ 5 meters

Zone A studies fail this check if the topographic data used for the effective study does not meet the specifications in SID 43 AND new topographic data is available for the study area that meets or exceeds the SID 43 requirements. If both the effective and the new topographic sources meet the SID 43 requirements, then the effective Zone A study may pass this check.

Data required:

- Streamline from the effective Zone A CNMS inventory (used for documenting results of this assessment). Record or estimation of the topographic data source used for the effective Zone A study.
- National Digital Elevation Program status polygon. Consideration of local sources for new topography meeting the SID 43 requirements is encouraged but may be cost prohibitive for some Regions.

3.1.2 Check for Significant Hydrology Changes

This check involves first determining whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1%-annual chance flow. The determination of significance can be made by contacting the local USGS Field Office. For example, if a new regression equation

was revised solely because of StreamStats compatibility, then the change may not be significant enough to affect flow. However, communication with the local USGS Field Office is important, as some regions of the United States suggest that there may be a +/-30% change between StreamStats and the previous regression equations. If the results of communicating with the USGS are inconclusive, some suggested approaches for determining significance are provided below.

Method 1:

1. Using the old regression equation, the range of acceptable values for the various parameters is used to determine both the maximum and minimum discharges for a representative sub-basin.
2. Using the new regression equation for a representative sub-basin, the maximum and minimum discharges are determined by using the range of acceptable values for the various parameters that are used to determine the maximum discharges for a representative sub-basin.
3. The standard error in the old equation is determined based on documentation.
4. The maximum discharges calculated in steps 1 and 2 are compared and the minimum discharges calculated in steps 1 and 2 are compared. If the comparisons show that the new discharges are outside the standard error of the old equations, then the equations are significantly different.

Method 2:

If newer regression equations exist, another way to test for significance is to determine whether predictions from the new regression equations fall outside the standard error of the estimates in the original equations. To reduce costs, this may be checked on a county basis, rather than a stream segment basis. In general, if newer equations produce discharges different enough from the original equations to make the results invalid, the problem is more likely to be a more basin-wide problem than a stream-segment-by-stream-segment issue.

A check at the basin level may be accomplished by establishing discharges using the new equations at a sample of sites, rather than at all stream segments, through the following process:

- Find parameters of interest in the latest version of the regression equations (e.g., drainage area, stream slope, basin elevation).
- Establish the 1%-annual-chance flood event discharge using these parameters for extreme cases (e.g., largest and smallest drainage areas, steepest and mildest slope).
- Establish the acceptable range of effective 1%-annual-chance flood event discharges from error estimates provided in USGS reports for the original equations and determine whether the hydrology remains valid.
- Assume that if the 1%-annual-chance flood event discharges are acceptable at the extremes, they will be acceptable between extremes.

- Designate Zone A hydrology for all stream reaches in the basin as acceptable or not on this basis. (This is not 100% foolproof; if the 1%-annual-chance flood event discharges are unacceptable at the extremes, there is still a minimal chance that some will be acceptable away from the extremes.)

Data required:

- Stream line for the effective Zone A CNMS inventory (used for documenting the results of this assessment)
- Date (actual or estimated) of the effective Zone A study
- List of the most recent USGS regression equations and effective dates

3.1.3 Check for Significant Development in the Watershed

This check involves using the National Urban Change Indicator (NUCI) dataset to assess increased urbanization in the watershed of the Zone A study. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15% or more and has increased by 50% or more since the effective analysis, the study would fail this check. Although the NUCI data provide year-to-year change in urbanization, the NLCD is also needed to establish a baseline of urban land cover for this analysis.

Data required:

- Stream line for effective Zone A CNMS inventory (used for documenting result of this assessment)
- NUCI data
- NLCD

3.2 Check of Studies Backed by Technical Data

Zone A studies that pass all initial assessment checks described above may be categorized as “Valid” in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If technical backing aside from model based data is determined to be sufficient for this check, it should be documented within the CNMS database and summarized in the deliverable report to FEMA for this assessment.

If the effective Zone A study passes all initial assessment checks but is not supported by modeling or if the original engineering method used is unsupported or undocumented, the FOA comparison described in Section 3.3 should be performed.

Alternatively, if FOA data are unavailable and the effective Zone A study passes all initial assessment checks but is not supported by modeling or if the original engineering method used is unsupported or undocumented, then the study may be categorized as “Unverified” in the CNMS inventory.

3.3 Comparison of First Order Approximation and Effective Zone A

When all other initial Zone A validation checks have been conducted as described in previous sections, Zone A studies may need to be compared to FOA results to determine their validation status. The comparison method described here presumes that the effective Zone A study is of a typical riverine geography and does not include significant areas of ponding, alluvial fans or excessively flat terrain.

The FOA/effective Zone A comparison method leverages the existing Floodplain Boundary Standard (FBS) certification procedures described in FEMA SID 113 but with a slight modification. This modified FBS comparison approach uses the 1%+ (“plus”) and 1%- (“minus”) flood profiles and horizontal and vertical tolerances described below.

Data Inputs:

- FOA cross section GIS layer attributed with the 1%+ WSEL
- FOA cross section GIS layer attributed with the 1%- WSEL
- Effective Zone A floodplain boundary
- FOA topographic data
- Vertical tolerance—one-half contour interval of the assumed effective topographic data source (e.g., vertical tolerance would equal 5 feet for a typical USGS 10-meter DEM derived from 10-foot contours or 10 feet for a USGS 10-meter DEM derived from 20-foot contours)
- Horizontal tolerance—75 feet (the average of 5% of a 1 inch = 1,000 feet Flood Insurance Rate Map (FIRM) and a 1 inch = 2,000 feet FIRM)

The following steps are used to perform this comparison:

1. Using the FOA cross section GIS layer attributed with the 1%+ WSEL, the effective Zone A floodplain boundary and FOA topographic data, run an FBS check using the tolerances listed above. FBS points with ground elevation values falling within the 1%- and 1%+ confidence bands receive an automatic pass.
2. Using the FOA cross section GIS layer attributed with the 1%- WSEL, the effective Zone A floodplain boundary and FOA topographic data, run a second FBS check using the tolerances listed above. FBS points with ground elevation values falling within the 1%- and 1%+ confidence bands receive an automatic pass.
3. Combine the FBS sample point results from steps 1 and 2 so that any sample point passing Step 1 or Step 2 is marked “pass” and sample points failing both Steps 1 and 2 are marked “fail.”
4. Tabulate the pass/fail results from Step 3 for each stream reach.
5. Categorize each stream reach as “Valid” or “Unverified” based on risk class at the county or watershed level, as defined in SID 113 and summarized in Table 1 and Table 2. The percentages in Table 2 are the percentage of FBS sample points that must be marked “pass” for the stream reach data to be called “Valid.”

Table 2: SID 113 – Flood Risk Class Characteristics

Risk Class	Characteristics	Floodplain Delineation Reliability¹: Zone A	Floodplain Delineation Reliability¹: All Other Zones
A	High population and densities within the floodplain and/or high anticipated growth	+/- 1/2 contour 95%	+/- 1.0 foot / 95%
B	Medium population and densities within the floodplain and/or modest anticipated growth	+/- 1/2 contour 90%	+/- 1.0 foot / 90%
C	Low population and densities within the floodplain, small or no anticipated growth	+/- 1/2 contour 85%	+/- 1.0 foot / 85%
D	Undetermined risk; likely subject to flooding	N/A	N/A
E	Minimal risk of flooding; area not studied	N/A	N/A

¹The difference between the ground elevation (defined from topographic data) and the computed flood elevation

Table 3: SID 113 – Floodplain Boundary Standards Pass Thresholds based on Risk Class

Risk Class	Characteristics	% Sample Points that Must “Pass” for Stream Reaches Called “Valid”
A	High population and densities in the floodplain and/or large amount of anticipated growth	95%
B	Medium population and densities in the floodplain and/or modest anticipated growth	90%
C	Low population and densities in the floodplain and little or no anticipated growth	85%

4.0 First Order Approximation Uses and Scalability

Floodplain boundaries generated through automated methods such as the FOA process that can be produced quickly and for large areas have many potential uses, including Zone A validation, eventual regulatory and non-regulatory product generation, outreach and risk communication and MT-1 processing.

FOA outputs are useful in informing the Risk MAP Discovery process but they can also be leveraged in other areas of the Risk MAP program. With the investments that FEMA will make in developing FOA analyses, it is in the program’s best interest to define these other applications for the FOA outputs.

This section provides guidance to FEMA Regional offices and other stakeholders on how to use FOA outputs. A framework is also provided for FOA outputs to be used by stakeholders outside the Risk MAP program.

FOA outputs are a valuable investment for the Risk MAP program that will enable the identification and validation of flood risks. Also, once they understand the characteristics of the inputs used to develop the FOA outputs, users can determine the level of effort required to “scale-up” the FOA.

4.1 Geographic Scale-up

FOA data may be generated at a variety of scales and can be generated periodically, based on need and the availability of funding. Therefore, an FOA database will be needed to store the newly created data in a central location, adhering to the current version of the FIRM Database Technical Reference as much as possible to facilitate future incorporation into the NFHL. Once the Mapping Partner has completed QC of the analysis and outputs, the FOA data should be delivered to FEMA in a manner consistent with the Submittal Guidelines in Section 2.4.

4.2 Program Scale-up

FOA outputs are useful for informing the Risk MAP Discovery process, and they can be leveraged in other areas in the Risk MAP program. Leveraging FOA outputs can reduce the costs of traditional program components, such as regulatory products and MT-1 processing, while still meeting production and quality standards. Moreover, FOA outputs can be used to produce non-regulatory products more cost effectively. They can also increase communities’ active engagement by improving risk communication and moving citizens to act to mitigate risks and increase their resiliency. The following are specific examples of uses for FOA outputs:

- *CNMS assessments.* As discussed in Section 3.0, FOA outputs can be used in the Zone A validation process. Using FOA outputs to assess expiring miles in the future will allow FEMA to avoid significant drops in the NVUE metric. FOA can also be used to validate Zone A miles currently categorized as “Unknown” in the CNMS inventory.
- *Regulatory products.* FEMA could elect to advance production of FOA outputs to regulatory products during the course of a Flood Risk Project. When the hydrologic and hydraulic analysis used for the FOA is refined to meet FEMA’s standards, this analysis can be used to produce the technical data for regulatory products at significantly lower cost than developing new technical data. In areas where FOA data is not constrained by limitations (regulated watersheds, alluvial fan areas, etc.), the data may be used for floodplain management purposes. Additional considerations may be present when developing regulatory products that include accredited or non-accredited flood control structures.
- *Non-regulatory products.* FEMA can also benefit from previous investments in FOA analysis by developing non-regulatory products at a reduced cost. The ability to generate non-regulatory products more efficiently and at a larger scale can allow FEMA Regions to better inform community officials and property owners about flood risks in areas where FOA data has been produced.

- *Outreach and communication.* FEMA can use FOA outputs to communicate risks in areas where regulatory products may have limitations or are unavailable. Availability of diverse informational products, such as the FOA outputs that visualize and inform risk, can greatly improve a community's ability to plan and act toward increasing its resiliency through local floodplain management and emergency planning.
- *Letter of Map Change processing.* Approximately 35% of the MT-1 applications FEMA receives are for properties in Zone A, where WSELs need to be developed using engineering methods. Leveraging FOA outputs will significantly reduce the level of effort required to develop the WSELs used in Letter of Map Amendment (LOMA) determinations. FOA outputs could also be used as a starting point for FEMA-initiated Letters of Map Revision to correct errors on effective maps.

4.3 Serving Data to External Stakeholders

External stakeholders can also use FOA outputs for planning and development purposes. It is recommended that the FOA data undergo a QC check similar to the process implemented for non-regulatory products, to ensure compliance with FEMA's standards before delivery and dissemination.

Results of the FOA should be delivered to stakeholders in such a way that the uncertainties and constraints of the analysis are appropriately qualified. Format of delivery should be strategically considered in serving the data externally. For example, FOA for use in the early stages of a Flood Risk Project is meant to be used as a starting point for Discovery discussions. Regions should use the most appropriate methods for offering and delivering data to stakeholders.

4.4 Business Requirements for First Order Approximation Data

This section lays out the business requirements for each of the potential uses listed below. One key business requirement is for all products to build off earlier products.

4.4.1 First-Pass Special Flood Hazard Approximation

FOA data must meet the following business requirements for first-pass special flood hazard approximations:

- *Usable for later stages of other Risk MAP processes.* The FOA should be presented in a format that is easy to access and distribute, so it can be used in other areas of Risk MAP, either "as-is" or enhanced. FOA outputs may be developed into a variety of products but they will appear primarily in a standardized File Geodatabase in FIRM Database Technical Reference format, HEC-RAS hydraulic models and summary metadata (e.g., listing data sources). A standardized schema and metadata for the FOA data will be necessary; the simplest possible versions are preferred (refer to the Data Capture Technical Reference and FIRM Database Technical Reference). Vector- and raster-based products will be useful internal and external stakeholders.
- *Able to provide meaningful and credible data.* The data must be informative regarding prediction of changes that may occur resulting from a new study. Specifically, the FOA outputs must be reliable enough to allow FEMA to make informed decisions about whether or not to restudy an area. To do this, all limitations of the analysis should be

clearly documented (in the metadata) and understood. It is also likely and desirable, that comparisons of the FOA data to known high-quality effective data will be available. Such comparisons can serve as good measures of the limitations of the data.

- *Capable of offering more detailed information than is available from CNMS and AAL combined.* As discussed in Section 2.2, the analysis should be based on HEC-RAS or other approved models that are readily available and repeatable.
- *Developed using data commonly available.* The FOA should be performed using only the data available before the project's data creation stage. For example, new LiDAR should NOT be acquired for the sole purpose of conducting an FOA.
- *Completed on a watershed scale.* The FOA should be run at the watershed level to be consistent with current FEMA standards.
- *Capable of providing Base Flood Elevation (BFE) data for areas currently mapped as Zone A without model-backing.* FOA analysis should be usable as advisory data through the FEMA GeoPlatform and/or the MSC inside the NFHL.
- *Available in all areas with effective studies.* FOA should be performed for flooding sources draining more than 1 square mile.
- *Able to deliver data for specific return periods.* Return periods should include the 10%, 4%, 2%, 1%-, 1%+ ("plus"), 1%- ("minus") and 0.2%-annual-chance floods.
- *Cost effective.* Cost of producing an FOA should be significantly less than standard flood production costs.

4.4.2 Coordinated Needs Management Strategy Assessments

For CMNS assessments of Zone A studies, FOA data should be able to identify significant and meaningful changes in the following elements:

- Topography
- Hydrology
- Land development in watersheds
- The extent of floodplain boundaries

For specific details on using FOA outputs for the assessment of Zone A studies, refer to Section 3.0.

4.4.3 Regulatory and Non-regulatory Products

For regulatory products, FOA data should:

- Tie into other regulatory data
- Meet standards and be easily adapted to meet technical references for mapping and database development (such as the [Data Capture](#) and [FIRM Database Technical References](#))
- Use topographic data meeting the applicable requirements of SID 43

- Be technically credible
- Be scalable (e.g., easy to upgrade when better data are available).

For non-regulatory products, FOA data should:

- Be defensible
- Tie in to regulatory data, as applicable
- Meet standards and be easily adapted to meet technical references (such as the Flood Risk Database Technical Reference)

4.4.4 Outreach and Risk Communication

All FOA requirements should result in data that is technically credible—the FOA should be defensible and easily explained to local officials and stakeholders involved in the Risk MAP Discovery process.

4.4.5 MT-1 Processing

An FOA should be able to be performed using the data commonly available with MT-1 processing. FOA outputs should provide BFE data for areas currently mapped as Zone A with no modeling and they should be available in all areas that have effective Zone A studies.

4.4.6 Use of FOA Data for BFEs on Elevation Certificates

Traditionally, BFEs used on Elevation Certificates have been required to meet the standards of FEMA 265: Managing Floodplain Development in Approximate Zone A Areas (April 1995). FOAs prepared in accordance with this guidance document will meet the FEMA 265 requirements for Elevation Certificate BFE development. FOA provides a good understanding of the best available topography, hydrology and hydraulics for a watershed and provides data on backwater effects that the single cross section methods of FEMA 265 cannot provide. As with any other BFE development process, the more accurate the input topography, hydrology and hydraulics is for FOA, the more accurate the resulting BFE. Where the FOA is created with the intent to provide long-term BFE data for a community to use on Elevation Certificates, it is recommended to utilize topography meeting current FEMA standards as defined in SID 43. However, where FOA has been created for other purposes and BFEs are required with less frequency for use on Elevation Certificates, it is acceptable to use FOA based on the best available digital topographic data for the area that may not strictly meet SID 43.

FOA data created under any FEMA program meets the requirements from the National Flood Insurance Program, Flood Insurance Manual¹ (June 2014), which state: “Where sources other than those [United States Geological Survey, United States Army Corps of Engineers, Department of Transportation or Division of Water Resources] are used, the local community official must agree in writing with the established BFE.” However, data created by other partners outside FEMA programs may also be useful. In this case, the entity that wishes to use

¹ National Flood Insurance Program, Flood Insurance Manual is located at: <https://www.fema.gov/flood-insurance-manual>

the FOA data for BFE purposes should request a Best Available Data Letter (BADL) from FEMA.

4.5 Scalability Constraints

The discussions below summarize concerns, possible limitations and constraints for the scalability of FOAs.

4.5.1 Matching at Political Boundaries

FOA data does not naturally match political boundaries. In the vicinity of these boundary areas, there may be a need to blend different sources of topographic data and different hydrology regression equations. Furthermore, there may be gaps or inconsistencies in input data to the model at international boundaries. A good example of this would be drainage areas presented in metric units or as a percentage of wetlands and lakes, which may not be tabulated in the neighboring country but may be key to regression equations in the U.S. These factors should be discovered and considered properly when scoping FOAs.

4.5.2 Matching at Confluences

FOA data also may not naturally match at confluences, depending on the method chosen for mapping and modeling. Typically, tributary models will start at normal depth and floodplain mapping from the main stem will overwhelm the lower elevations of the tributary. Unless the FOA cross sections are long enough, however, that backwater effect may not extend far enough upstream on the tributary. Special consideration should be given to ensure that the effects of backwater are captured as accurately as possible when performing a FOA.

4.5.3 Overflows to Adjacent Watersheds

Conversely, if the FOA cross sections are too long, flows may inappropriately escape a watershed and cause excessive flooding areas. Care needs to be taken to properly observe watershed boundaries.

4.5.4 Two-Dimensional Modeling Scenarios

In many parts of the country, two-dimensional modeling scenarios are common and a one-dimensional FOA is not applicable. For these circumstances, other large-scale floodplain identification methods may be more accurate. It may also be possible to artificially force one-dimensional flow analysis in some cases.

4.5.5 Intersections with Coastal Data

As with more detailed modeling, the intersection of riverine data with coastal data is complex. In general, it is recommended that FOA data produced for riverine areas be modeled to the limits of low tide, that coastal flood data (even very approximate data) be superimposed and that the FOA be trimmed to the coastal data so that only truly riverine data is shown.

4.5.6 Lakes

FOA processing can proceed through lakes in most cases but the water surfaces and floodplains may not be accurate in the lakes. If peak flood elevation data are available for lakes, it is better to delineate each lake individually and then superimpose the data on the FOA.