Guidance for Flood Risk Analysis and Mapping

Hydraulics: One-Dimensional Analysis

November 2016

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.

Table of Revisions

Affected Section or Subsection	Date	Description
First Publication	November 2016	Initial version of new transformed guidance. The content was derived from the Guidelines and Specifications for Flood Hazard Mapping Partners, Procedure Memoranda, and/or Operating Guidance documents. It has been reorganized and is being published separately from the standards.

Table of Contents

1.0 Introduction

This document describes the standards and methods to be applied by Mapping Partners in the performance, analysis, and presentation of results for one-dimensional riverine flooding analyses. The overall objectives of a hydraulic study are to:

- Identify areas subject to flooding from riverine sources and accurately define the flood-frequency relation at locations within those flood prone areas.
- Depict the data and analyses results with maps, graphs, tables, and explanatory narratives in order to support flood insurance decisions and sound floodplain management.
- Document data and analyses in a digital format to the extent possible to enable the results to be readily checked, reproduced, and updated.
- Maintain (or establish) consistency and continuity within the national inventory of Flood Insurance Rate Maps (FIRMs) and Flood Insurance Study (FIS) reports.

Riverine analyses consist of hydrologic analyses to determine discharge-frequency relations along the flooding source and hydraulic analyses to determine the extent of floodwaters (floodplain) and the elevations associated with the water-surface of each frequency studied. The base (1-percent-annual-chance) flood is delineated on the FIRM as the Special Flood Hazard Area (SFHA). When determined, the 0.2-percent-annual-chance floodplain and/or floodway are also depicted on the maps. The analyses must be based on existing ground conditions in the watershed and floodplain. A community that conducts its own future-conditions analysis may request through their FEMA Regional office to reflect these results on the FIRM.

2.0 One-Dimensional Hydraulic Analysis Procedures

The choice of hydraulic procedures for the analyses and presentation of flood hazard information is determined during the scope definition portion of Discovery. The level of effort and the amount of data collected determines whether flood elevations, or only floodplain boundaries, can be shown on the FIRM.

The approach used for the hydraulic analyses can generally be categorized as one of three types: one-dimensional steady flow, one-dimensional unsteady flow, and two-dimensional steady and unsteady flow analyses. The approaches require different level of effort. For more information about selecting the appropriate modeling analysis see the General Hydraulic Considerations Guidance. For more information about two-dimensional analysis see the Hydraulics: Two-Dimensional Analysis Guidance.

2.1 Hydrology

The choice of hydrologic procedures is associated with the size and characteristics of the watershed, the study type, the effective FIS methods, the availability of data, the requirements from the hydraulic study, and the allocated funds. For more information about hydrologic analysis see the General Hydrologic Guidance.

2.2 One-Dimensional Steady Flow Procedures

One-dimensional steady flow models are applicable to streams with well-defined open channels with gradually varied flows. Steady flow models are best used where flow peaks are not dominated by significant storage changes, where the channel storage-discharge relationship can be reasonably represented by a single-valued rating curve instead of a looped rating curve, and water surface profiles are not affected by reversed flow conditions.

Hydraulic analysis is most commonly performed using a one-dimensional, steady flow, step-backwater model for subcritical flow. The governing assumption applied in a one-dimensional model is that the flow properties can be based on cross sections placed perpendicular to the direction of flow. The basic approach is to compute the energy of water passing through a cross section as equal to the energy of the water passing through the cross section immediately downstream plus the energy lost to friction and turbulence in the reach between the cross sections. One-dimensional steady flow step backwater models are most applicable to channels with mild to moderate slopes and gradually varied flow that is not dominated by storage; they should not be used in channels with reversed flow conditions during flooding.

Specifications for performing subcritical flow modeling are discussed below; modeling of supercritical flow will be discussed in a later section.

There are essentially four types of input data required:

- Cross-section geometry (including hydraulic structures).
- Loss coefficients.
- Water-surface elevation at the most downstream cross section (starting water-surface elevation.
- Peak flow discharge.

2.2.1 Profile Baseline

The profile baseline is the horizontal distance along the Flood Profile as represented on the FIRM and shown in the Floodway Data Table. The profile baseline can be the distance between cross sections or nodes in a one-dimensional model. The profile baseline may be the same as the stream centerline, which is the channel configuration shown on the base map.

Flow distances in one-dimensional models must be referenced to the profile baseline. For more information about profile baseline see the Profile Baseline Guidance.

2.2.2 Cross Sections

Cross sections must be placed perpendicular to flood flow and extend beyond the most extreme event modeled. Often the 0.2-percent-annual-chance or 1-percent + floodplain boundaries on either side of the stream. Cross sections must be spaced so that the geometry and hydraulic roughness of the reach between adjacent cross sections varies gradually and that variation can be estimated as linear. The general slope of the flow path between adjacent cross sections should be approximately constant. Cross sections should be located at all major breaks in the streambed profile, at points of minimum and maximum cross-sectional areas, and at points where channel roughness and channel shape changes abruptly (USGS, 1984). Cross sections may be spaced further apart for types of studies that require only the SFHA parameter to be computed.

Underwater portions of cross sections should be surveyed in the field by conventional surveying techniques or can be obtained from interpretation of aerial photographs or topographic mapping. Some hydraulic models may need approximated "typical" cross sections to reflect the conveyance of flow. Cross-section data above water are obtained through conventional survey techniques, by interpretation of aerial photographs, from remotely sensed topographic data, either digital or in the form of contour maps, or approximated as a "typical" cross section. Additional details on surveying cross sections see the Data Capture Technical Reference.

For each reach studied, the sources of cross-section data and methods of measurement must be fully documented. Where more than one technique is used to acquire cross-section data, the documentation must include an explanation of how the data were merged. Where cross-section geometry is approximated as "typical," the documentation must include an explanation of how each typical cross section was developed; the sources of data used in the approximation and means of measuring those data; and how typical cross sections are aligned vertically with topographic information used for mapping.

2.2.3 Hydraulics Structures

Flow in the vicinity of hydraulic control structures may exhibit a combination of free surface flow, pressure flow, and weir flow. The hydraulic analysis in the vicinity of control structures generally uses a combination of simple steady flow hydraulic theory and discharge coefficients.

The dimensions of hydraulic structures crossing the stream should be surveyed in the field for studies where a BFE will be published. In some cases it may be appropriate to estimate appropriate dimensions of hydraulic structures by either direct measurement in the field or taken from as-built plans. Verification of datum and orientation may be necessary for dimensions obtained from alternative sources. The effects of the structure can be ignored if the study type requires only the SFHA boundary to be computed. The phrase "measured in the field" means measuring the relative dimensions of the structure without relating the structure's elevations to a known vertical datum, as is implied by "surveyed in the field." Additional details on surveying hydraulic structures are provided in the Data Capture Technical Reference**.**

The sources of data and means of measurement must be fully documented. Unless surveyed in the field, the documentation must include an explanation of how the data were tied to a vertical datum and how the alignment of the structure relative to the stream and floodplain was determined. Where stream crossing dimensions are approximated, the Mapping Partner must document the reasoning leading to the approximation and the sources and means of measuring any data used in the approximation.

Bridges are the most common hydraulic structure crossing a stream and may significantly affect water-surface profiles. The Federal Highway Administration (FHWA) has published a series of hydraulic engineering guidelines, which addressed bridge hydraulic calculations and provided detailed technical guidance. For example, FHWA Hydraulic Design Series No. 1 (HDS1, 1978) addressed a broad range of hydraulic issues of bridged waterways including water-surface profile of skewed bridges, and FHWA Hydraulic Engineer Circular No.18 (HEC-18, 2001) addressed scour at bridges. It is important to note that bridge scouring may result in significant changes in cross sections from the original design conditions; use of outdated as-built plans as the source for bridge cross sections should be avoided.

Hydraulic structures that are designated to divert flood flow from its natural path, such as flood gates and diversion channels, must be clearly labeled on all mapping and fully documented. The documentation must include identification of the owners and operators of the structure; the date it became operational; operation, inspection, and maintenance plans; and as-built plans describing the dimensions and identifying any moving parts. The structures can also be measured in the field.

As a general rule, hydraulic structures are assumed free of blockage, and debris loading is not modeled in hydraulic analysis for NFIP studies. At locations where there is evidence that a structure is likely to be blocked by siltation, structure blockage may be modeled as requested by the community and approved by the RPO. FHWA HEC-9 (2005) provides general guidelines for analyzing debris accumulations on a bridge structure and determining the impacts the debris would have on the water-surface profile.

Hydraulic structures that are a part of a levee system are addressed in the Levee Guidance**.**

2.2.4 Ineffective Flow Areas

Conveyance areas are those portions of cross sections through which floodwaters flow. An area adjacent to a floodplain where floodwater collects as a pond of standing water is not a conveyance area. Inundated areas adjacent to flowing floodwaters, but through which floodwaters are not conveyed, are referred to as ineffective flow areas (also as non-conveyance areas). In addition, ineffective flow areas can be used to reflect the non-conveyance flow areas created upstream and downstream of high grounds within the floodplain and those caused by the flow constriction and expansion due to topography of the floodplain. USACE report TR-151 (April 1996), RD-42 (Sept 1995), the HEC-RAS User Manual, or the HEC-RAS Hydraulic Reference Manual discuss the appropriate placement of ineffective flow stations due to contraction and expansion due to structures and topography. Portions of cross sections are, in general, modeled as ineffective areas in one of two ways:

- Removing the ineffective area and wetted perimeter computations through artificial data (e.g., vertical walls) incorporated in cross-section geometry or through ineffective flow, blocked obstruction, or encroachment options entered into the model.
- Assigning artificially high roughness coefficients to the area, thereby reducing the computed flow through the area to a negligible value (if the hydraulic model does not have other capabilities to reflect ineffective flow).

The modeling technique should be chosen to reflect the natural conditions (topography and roughness) as closely as practical. The Mapping Partner must fully document the location and the technique used to model non-conveyance areas. The documentation must include a clear explanation of the natural conditions where artificial data have been used.

2.2.5 Energy Loss Coefficients

Friction losses are usually computed using the Manning's equation, and, therefore, channel and floodplain roughness are usually expressed as Manning's "n" values. Values of "n" are estimated by observing irregularities, ground cover, and vegetation in stream channels and overbank areas and comparing those observations with channel and overbank areas that have known values. Guidance on selecting "n" values is given in almost any treatment of open channel hydraulics. The HEC-RAS Hydraulic Reference Manual (USACE 2001 and 2008) and the FHWA report FHWA-TS-84-202 (1984) are the most commonly used documents. Water-Supply Papers 1849 and 2339, published by the USGS (1967, 1989), are also applicable and dedicated specifically to guidance on selecting "n" values in natural channels and floodplains.

When estimating roughness coefficients, the Mapping Partner should consider the size and makeup of streambed and bank material, the slope of the channel, the type and density of vegetation in the floodplain, the degree of meandering, and the expected depth of flooding. The Mapping Partner should consider variation of roughness coefficient values with flood stage, depending upon factors such as the width-to-depth ratio of streams, vegetation in the channel and overbanks, and materials of the river bed. The Mapping Partner should carefully select roughness coefficients in overbank areas to represent the effective flow in those areas. There is a general tendency to overestimate the amount of flow occurring in overbank areas, particularly in broad, flat floodplains. The Mapping Partner must document clearly the use of roughness coefficients to define ineffective-flow areas in the documentation submitted for inclusion in the FIS report.

The most detailed observations are made in the field, and the most reliable estimates are those calibrated to historic events. An on-site visit is recommended to estimate roughness values for studies where results are used to define additional frequency flood profiles. Manning's roughness values may be assigned by consulting aerial and/or oblique photographs for studies that require the computation of the SFHA boundary or only one flood profile for the base flood.

The Mapping Partner must fully document how roughness coefficients were selected and computed. Documentation of on-site observations must include photographs as well as the computations used to estimate roughness coefficients. If "n" values were adjusted based on calibration, the documentation must include a summary of the values before and after the adjustments. Calibrating hydraulic models in general is discussed in Section 4.5 of the General Hydraulics Considerations Guidance.

Most models include a calculation of eddy losses to be added to friction losses and the downstream energy. Those losses are computed as a fraction of the difference in velocity head. The fractions are typically referred to as the contraction coefficient if velocity increases in the downstream direction and as the expansion coefficient if velocity decreases in the downstream direction. Values are typically 0.1 and 0.3 for gradual contraction and expansion, and 0.3 and 0.5 at bridge structures (USACE, 2008). If warranted and approved by the RPO, the Mapping Partner may use other values for these coefficients instead of taking those standard values. The Mapping Partner must document this deviation, including justification for the different value (e.g., abrupt expansion) and the location or extent of where that reasoning applies.

Energy losses through bridges are typically calculated by subroutines in the hydraulic model or by consulting graphs and nomographs for various bridge types and openings published by the FHWA (1978, 1985). Additional information and guidance on selection of loss coefficients and other coefficients is provided in user's manuals of the hydraulic models, such as the HEC-RAS program developed by USACE (2008).

For each stream crossing modeled, the Mapping Partner must document the dimensions of the crossing, values of loss coefficients, and the reasoning behind those values. The documentation must clearly state whether those values and corresponding reasoning are based on observation, measurement, or assumption.

2.2.6 Starting Water Surface Elevations

The downstream boundary condition in a one-dimensional, steady flow, step-backwater model should, whenever possible, be taken from a previously established water-surface elevation (accounting for any required vertical datum correction), such as a contiguous effective FIS immediately downstream. The Mapping Partner may need to extend the model downstream of the proposed downstream limit of study to tie into an established elevation. Except where a clearly identified change in flood characteristics or an error in the existing data can be shown, the proposed BFEs must agree with those of other contiguous studies of the same flooding source within 0.5 foot. In rare cases, if an agreement within 0.5 foot cannot be achieved, this mismatch should be identified as an unmet need, and reasons for the mismatch must be documented.

If no downstream elevation has been established, the Mapping Partner should identify any "control" cross sections in the immediate downstream vicinity of the downstream limit of study. A control cross section is a cross section at which the computed water-surface elevation is unaffected by (reasonably expected) changes in the downstream flood elevation, and the reach upstream can be treated as hydraulically independent. A control cross section can be man-made, such as a drop structure, culvert, or a bridge; or a naturally occurring constriction and/or change in grade where the flow regime passes through critical depth.

Absent established downstream elevations or a control cross section, the Mapping Partner should compute starting water-surface elevations using normal depth calculations (or slope area) at a cross section sufficiently distant downstream from the downstream limit of study so as to render the effects of uncertainties in the starting water-surface elevation negligible. For normal depth calculations, the friction slope (energy slope as defined in HEC-RAS) should be the slope of the water surface measured along the flood path (EM 1110-2-1416, USACE, 1993).

For starting conditions on tributaries, the Mapping Partner should use normal depth unless a coincident peak situation is assumed, or the tributary flow depths are higher than the corresponding mainstream events.

The assumption of coincident peaks may be appropriate if all the following are true:

- The ratio of the drainage areas lies between 0.6 and 1.4.
- The arrival times of flood peaks are similar for the two combining watersheds.

- The likelihood of both watersheds being covered by the storm being modeled is high.

If gage records are available for the basins, the Mapping Partner performing the hydraulic analysis should obtain guidance from the RPO on coincidence of peak flows using streamflow records.

When the downstream boundary of a modeled stream is within a coastal tidal reach, the tidal boundary of the model is taken as equal to the Mean Higher High Water (MHHW) level of the nearby tide station. Location of tide station(s) must be verified to represent true downstream conditions. The tide level can be transferable to other locations along open coast; however, tide level at an estuary station is not transferable to locations beyond the estuary. For more information about the interaction of riverine and coastal flooding see the Combined Coastal and Riverine Floodplain Guidance**.**

2.2.7 Split Flow, Diverted Flow

When two (or a finite) major flow directions are identified, split flow or diverted flow conditions exist. Split flow, generally, rejoins the main stream, while diverted flow is lost to the floodplain being modeled.

Split flow is the situation where floodwaters following a single well-defined flow path split and follow two or more paths separated by areas of dry land or relatively shallow flooding. In this Appendix, split flow refers to floodwaters that are separated from the main channel or primary flow path for some distance and then merge with the floodwaters from the main channel. Procedures for analyzing split flows associated with uncertain flow paths on alluvial fans are described in the Alluvial Fan Guidance**.**

The Mapping Partner should examine the topography to establish that major flow directions exist and the momentum transfer between these flow paths occurs within a clearly defined area where the split flow path deviates from the main channel and joins downstream. If flow leaving the main channel spills into an unconfined floodplain where a single flow direction is not evident a 2-D model may be appropriate. See the Hydraulics: Two-Dimensional Analysis Guidance for more information. The discharge transfer between the main stream and the split flow path is computed using an appropriate hydraulic method. Spill over flows with a nappe that contain a critical flow section can be estimated reliably using lateral weir flow equations. The discharges estimated for the diverted flow should be checked to ensure that the flow direction is from the mainstream to the floodplain; this can be achieved by selecting an appropriate weir coefficient. Selection of the appropriate location of the lateral weir profile is crucial in obtaining realistic results.

When a weir flow situation is not evident, the Mapping Partner should analyze the split flow as an additional study reach. That analysis should meet the level of effort requirements of the originating reach (main channel). Unless the split flow re-enters the main channel through a control cross section, the downstream limit of analysis should be the first cross section in the main channel downstream of the point where the paths merge.

When the split flow re-enters without a control section, the starting water-surface elevation for the split flow analysis should be the corresponding (same frequency) elevation at that cross section. This type of split flow is referred to as divided flow in the HEC-RAS manual (USACE, 2016) where an island or other obstruction separates flow into two or more channels over a substantial length. In this analysis, the quantity of water passing on each side of the island or obstruction should be determined because the total energy loss should be the same for both flow paths.

The Mapping Partner should verify that the flow value in the main channel and split flow path is constant. If the flow values are not constant, the Mapping Partner should verify that the results indicate shallow flooding between the main channel and overflow paths and adjacent cross sections sufficient to allow the transfer of sufficient floodwaters between the paths to account for the difference in flows.

Floodwaters overtopping low-lying basin divides, leaving the floodplain of the studied reach and flowing into an adjacent stream or body of water, are referred to herein as “diverted flow”; the Mapping Partner should consider possible increases in flood discharges on the adjacent stream or water body due to diverted flow, if coincident peaking conditions between the diverting and receiving streams are evident. Discharges in the diverted flow reaches are determined by applying methods applicable for split flows. Diverted flows should be analyzed as tributaries to the adjacent stream or water body. Those analyses should meet the level of effort requirements of the originating reach.

Split flow and diverted flow analyses must be fully documented. The documentation must include a description of how the amount of flow analyzed was determined, the location along the main channel of the split or diversion, and the location of the downstream limit of analysis. The paths (profile baselines) of each split or diverted flow must be shown on the FIRM and labeled with a name that clearly associates it with the main channel.

2.2.8 Supercritical Flow

The standard step-backwater approach is an iterative process. For subcritical flow, when a steep reach is encountered where the flow would be supercritical, subsequent iterations do not converge to an answer. In such cases, calculations typically reach a limit of iterations and, then, default to the minimum energy (critical depth) and move on to the next upstream cross section. Elevations associated with supercritical flow for natural streams are not plotted on flood profiles or reflected on FIRMs. With the approval of the RPO, supercritical flood profiles may be shown for concrete lined chutes, specifically designed and constructed to carry supercritical flow.

Where supercritical flow exists in natural channels, elevations associated with critical depth should be used if subcritical flow analysis indicates critical or supercritical flow to exist for long reaches of the channel. The Mapping Partner must verify that, when calculations default to minimum energy, the maximum number of allowable iterations was not exceeded for some reason other than flow regime.

Concrete-lined channels should be analyzed by supercritical flow regime; man-made or improved channels where supercritical flow is likely should be analyzed for both subcritical and supercritical flow regimes. The hydraulic analysis should extend both upstream and downstream of the project area to have a smooth transition between subcritical and supercritical profiles. The water-surface elevations from the subcritical run are drawn downstream of the project horizontally until they cross the supercritical profiles to eliminate drawdowns. The Mapping Partner should check the effects of supercritical flow velocity on the flood carrying capacity and stability of improved channels, including erosion and super elevation of floodwaters at bends in the channel. The findings resulting from those considerations must be fully documented. The Mapping Partner must report to the RPO any findings that the stability or flood carrying capacity of improved channels may be jeopardized during a flood.

2.3 One-Dimensional Unsteady Flow Procedures

One-dimensional unsteady flow models are most applicable to urban systems with both open channels and closed conduits; and stream systems with significant storage changes, reversed flow, or subject to rapidly varied flow and wave changes. For such streams, storage-discharge curves are usually looped.

In unsteady flow models, depth of flow and/or velocity of flow vary with time. FEMA-approved unsteady state models include (1) unsteady state channel routing models, which utilize inflow hydrographs produced by separate hydrologic analysis, and (2) hydrodynamic models, which include a rainfall-runoff modeling component to simulate both watershed hydrographs and channel routing.

Some one-dimensional unsteady state models describe the drainage system as a nodal network, consisting of nodes (junctions) and links (conduits); others use channel network features by cross sections, similar to 1-D steady state models. If nodes and links are used ensure that geometry of the features are complete so that available storage and conveyance is accounted for. The hydraulic analysis in the vicinity of control structures is computed using steady flow analysis methods for the range of discharges the structure is likely to experience. Nodal system models are most applicable to urban drainage systems including open channels, storm sewers, and other structures, or natural streams with significant on- and off-channel storage such as swamps and wetlands where flow may change direction during a flood event. Typical channel network models are mostly applicable for larger rivers where open channel flow is the predominant source of flooding. These models are suitable for simulating flood waves in large rivers, tidal flows, and waves generated by operation of control structures, as well as rapid flow changes such as would result by failure of a dam. For each reach studied, the sources of node or link data and methods of measurement must be fully documented. Where more than one technique is used to acquire node or link data, the documentation must include an explanation of how the data were merged. Where node and link geometry is approximated as "typical," the documentation must include an explanation of how each typical node or link was developed; the sources of data used in the approximation and means of measuring those data; and how typical node or link are aligned vertically with topographic information used for mapping

Unlike steady state models, which assume flow peak is constant within a stream reach and consider only conveyance, unsteady state models also compute storage along with conveyance within the floodplain. Changes in storage in an upstream reach directly affect flow and water-surface elevations in the downstream direction.

Input requirements to one-dimensional unsteady state channel routing models include inflow hydrograph(s), geometry data for channel cross sections or other conduits, junctions and/or other storage areas, energy loss coefficients, and downstream boundary conditions. In addition to direct measurement, geometry data for urban watersheds are often available from databases managed by public utility agencies, such as the community's Department of Public Works. The Mapping Partner must document such data sources used to develop the hydraulic model, including name of database, format, accessibility, and contact information.

2.3.1 Boundary Conditions for Unsteady Flow Computations

The downstream boundary condition is usually a flood stage hydrograph or, less commonly, a flood flow hydrograph. The Mapping Partner must fully document the downstream boundary conditions including the sources of data and the reasoning used to assign frequencies to the hydrographs.

In addition, for all the frequencies studied for the FIS, the one-dimensional unsteady flow models require inflow hydrographs as upstream boundary conditions, as well as corresponding inflow hydrographs from significant tributaries, and lateral inflow hydrographs representing local direct inflow to the channel. The Mapping Partner must clearly document the source of these inflow hydrographs. The derivations and supporting documentation of input hydrographs should meet the requirements discussed in the General Hydrologic Considerations Guidance, Rainfall-runoff Models, including synchronization of all input hydrographs. Observed historical hydrographs provide valuable reference for synchronization and can be used in model calibration; however, they should not be assigned any frequency unless frequency of the historical event has been established through separate studies. In such a case, the Mapping Partner must provide documentation of the study.

2.3.2 Non-conveyance Areas for Unsteady Flow Computations

Non-conveyance portions of cross sections for unsteady flow computations can be designated as ineffective areas in modeling; these cross-section areas can still be considered in the storage computations.

Many one-dimensional unsteady flow models have the capability to explicitly model off-channel storage areas connected to the channel. These storage areas are usually defined by elevation-volume or elevation-surface area relations or modeled by user-defined flow allocation ratios. Such areas should be clearly labeled with a unique identifier corresponding to the storage area used in the model. The Mapping Partner must fully document any elevation-storage relationships used in the analysis, including the methods, sources, and measurements of data used to define the relationships.

2.4 Floodway Analysis

A floodway is a tool to assist communities in balancing development within the floodplain against the resulting increase in flood hazard. The Mapping Partner must coordinate with the community when developing floodways.

A regulatory floodway is defined as the channel of a river or other watercourse and the adjacent land area that is reserved from encroachment in order to discharge the base flood without cumulatively increasing the water-surface elevation by more than a designated height. NFIP minimum regulations designate a maximum height of 1.0 foot although some communities may have higher standards and those should be considered in this determination. The portions of the floodplain beyond the floodway are called the floodway fringe. The community is responsible for maintaining the floodway to mitigate flood hazards; the community must not allow any activities causing a rise in the BFE in the regulatory floodway. For more information about conducting a one-dimensional floodway analysis see the Floodway Analysis and Mapping Guidance.

3.0 Calibration of Hydraulic Models

Calibration of hydraulic model parameters is performed through modeling major historic floods on stream reaches where flood flow and elevation data are available. By comparing the measured water-surface elevation from a flood to the modeled water-surface elevation, the modeler can judge the reliability of the model and adjust input parameters accordingly. The parameters adjusted are usually energy loss coefficients. The user's manuals for most models provide guidance and, in many cases, optimization options for calibrating friction loss (roughness) coefficients. For more information about the Calibration of hydraulic models see the General Hydraulic Guidance.

4.0 Deliverable Products

The Mapping Partner must submit the hydraulic and floodway data in digital format as described in Technical Reference: Data Capture (Nov 2014). The Mapping Partner must submit files via the MIP; other media may be acceptable if coordinated with FEMA. For more information about the Calibration of hydraulic models see the General Hydraulic Guidance.

5.0 Hydraulic Review Requirements

The reviewing Mapping Partner will be responsible for performing hydraulic reviews as described in section 9 of the General Hydraulics Guidance. The reviewing Mapping Partner is responsible for determining whether the proposed analyses are reasonable. Section 9 provides requirements and criteria that should be used to determine if the hydraulic analyses are reasonable.

Related Templates associated with this Guidance

Note:

The following templates will be a tool to help practitioners comply with the guidance contained in this document and will help with overall program consistency. Once they have been reviewed and comments have been addressed, the templates will be stored individually on the fema.gov G&S web page under the "Templates and Other Resources" link (http://www.fema.gov/media-library/assets/documents/32786?id=7577). They are merely provided here to aid in the consolidation of review comments to one document.