7.0 Level of Study and Level of Risk

As explained in prior sections, different types of studies have different costs associated with them. In general, more complex studies take more time and effort, and therefore cost more than more simple studies. This section discusses the varying types of data collection and analysis techniques used to develop flood hazard data to relate the level of study and level of risk for each county.

7.1 Map Modernization Quality

Recognizing this variability, the GAO recommended that FEMA "develop and implement standards that will enable FEMA, its contractors, and its state and local partners to identify and use consistent data collection and analysis methods for communities with similar risk."

FEMA is committed to delivering high-quality mapping products to its stakeholders using proven and reliable technologies.

FEMA is committed to delivering high-quality mapping products to its stakeholders using proven and reliable technologies. The products will be tailored to meet local needs while also supporting the objective of reducing the Nation's vulnerability to floods.

One of the goals of Map Modernization is to provide a reliable Web-based national flood layer in digital GIS format. While the quality of the final digital products will be superior to that of the current maps, stakeholders have clearly expressed concerns that simply digitizing the existing maps will not result in reliable products ensuring a high level of quality for all studies is critical for Map Modernization.

Engineering modeling software and GIS have advanced dramatically in the past 5 to 10 years. These advances have revolutionized hydrologic and hydraulic modeling and floodplain mapping. Figure 7-1 provides an example of such mapping. GIS advances have helped to reduce many of the more tedious and labor-intensive tasks associated with modeling and mapping.

Significant advances also have been made in terrain processing and development. These technologies use remote sensing methods to provide input data to models that generate Base Flood Elevations (BFEs) and additional digital information to support floodplain boundary mapping. Digital terrain information supports determination of BFEs in Flood Insurance Studies (FISs) and delineation of floodplain boundaries more efficiently than conventional, field-collected methods.

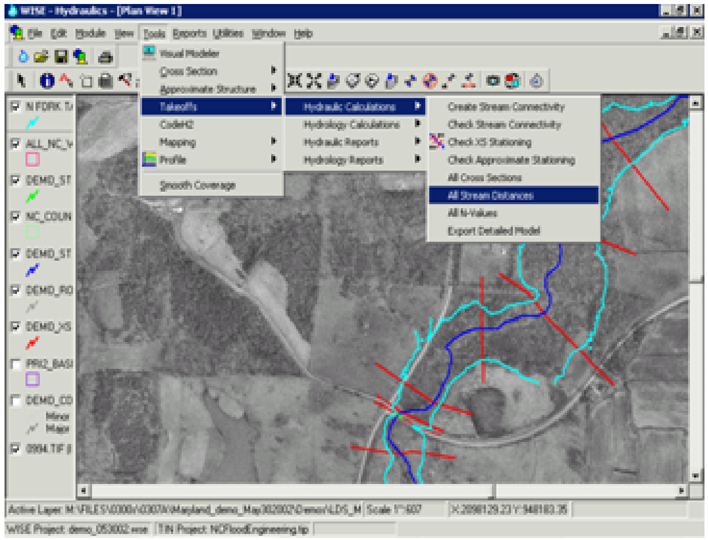


Figure 7-1. Example of GIS-Based Automated Modeling Software

These advances have enabled FEMA's mapping partners to study considerably more flooding sources more efficiently and cost-effectively, than in the past. These technologies make possible images using Light Detection and Ranging (LIDAR) such as that in Figure 7-2.

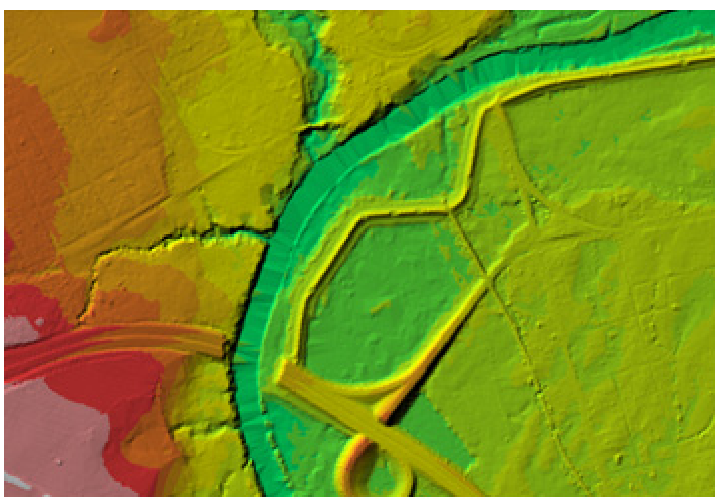


Figure 7-2. Example of Bare Earth LIDAR Data

7.2 Aligning Resources with Risk

The primary mission of the NFIP is to mitigate future property damage and loss of life, as well as to enable individuals to purchase Federally backed flood insurance. The greatest benefit would be realized by using high-end, state-of-the-art data collection and flood hazard identification techniques for every flooding source across the Nation. However, because this is not practical, FEMA plans to focus resources commensurate with flood risk. Technological advances enable FEMA to do this without sacrificing product reliability for lower-risk areas.

7.2.1 Study Costs

Study and mapping costs vary by mapping partner and study complexity. Costs for different study types typically are expressed in dollars per linear mile of stream (riverine) or shoreline (coastal). Factors that affect unit costs include:

- Contributions from mapping partner(s)
- Economies of scale
- Regional factors
- Technical complexities (unsteady flow, levees, alluvial fan, etc.)
- Density of hydraulic structures

Ranges of cost per stream mile depend on the level of study:

- Approximate study: $200 to $2,500
- Detailed: $2,500 to $7,500
- Detailed with floodway: $7,500 to $10,000
- Detailed by watershed (in lieu of stream mile unit cost): $20,000 to $60,000

Guidance exists for associating levels of study and levels of risk by flooding source, so that individual flooding sources are studied at the proper level, depending on the risk of flooding for that location. In addition, the level of study also must be associated with the comparative level of risk nationwide.

Currently, the expenditure of Federal funds is planned and budgeted for studies at a county level, based on relative flood risk and state and Region plans (see section 3). However, during the scoping process, as FEMA meets with local and state representatives, they may combine funds from multiple counties for a single study of a larger area in order to perform a study for a complete watershed, or along larger reaches of stream or shoreline that extend beyond a single county.

FEMA is encouraging the participation of communities through the CTP program, which promotes cost sharing and leveraging of existing data, thereby producing a more detailed product than would be possible if FEMA was the only partner contributing to the study. Therefore, the level of a study ultimately can be significantly higher than that which is considered suitable for the corresponding risk classification given the collective contribution of FEMA and its mapping partners.

7.2.2 Determination of Study Funding Based on Flood Risk

In FY03, FEMA did not have a multi-year planning process in place. FEMA used flood risk to determine which studies would be performed using funding for that year. Many stakeholders expressed a need for a multi-year planning tool that addresses not just flood risk, but also flood mapping project cost and schedule information as well as factors such as project need and partner contributions.

In response, FEMA openly shared its decision-making process in FY04 and invited local and state partners to develop business plans describing their vision to support Map Modernization and any supporting efforts they have undertaken or planned. These plans, along with information used to quantify flood risk nationally, were used to develop the cost and schedule information shown in appendix A. FEMA took into account project need and partner contributions when developing the MHIP and may consider those factors even more strongly in subsequent plans as Map Modernization moves forward.

7.3 Risk Classes and FEMA Products

Without a long and well-documented record of flooding in each study area, the precision of flood hazard information is difficult to determine. The final results of the flood boundaries and BFEs on the FIRMs would have to be compared with a statistical analysis of flooding events and historic high-water elevations, and adjusted to account for changes that have impacted or will impact the runoff characteristics of the watershed. Because weather predictions and land use are difficult to predict, the absolute correctness of the FIRMs cannot be determined with meaningful certainty. Instead, the FIRMs must be evaluated based on a relative correctness or general reliability of the product.

General reliability is determined by evaluating the final floodplain boundary delineation with topographic maps, calibrating and validating the predictive models against historic high-water marks (where available), and evaluating the measurements and model parameters against established engineering practices and industry standards. Some of the factors that impact reliability of the study are the topographic data used, the selected model parameters, validation routines, and the final mapping.

In the past, zone designations generally were correlated with the reliability of the flood hazard information produced. However, advances in technology have improved the reliability of flood hazard information across all zone designations, weakening this correlation. For a more meaningful correlation between risk and reliability, FIRMs can be grouped into five classes of characteristics that correspond to various levels of risk, or risk classes, shown in table 7-1.

Table 7-1. Risk Classes of Flood Insurance Rate Maps

Risk Class	Characteristics	Typically Achieved By	Delineation Reliability of the Flood Boundary[1]
A	High population and densities within the floodplain, high anticipated growth	Zones AE, VE, AO, AH	± 0.5 foot / 95%
B	Medium population and densities within the floodplain, modest anticipated growth	Zones A and AE	± 1.0 foot / 95%
C	Low population and densities within the floodplain, small or no anticipated growth	Zones A and AE	± ½ contour / 90%
D	Undetermined risk; likely subject to flooding	Zone D	N/A
E	Minimal risk of flooding; area not studied	(area not mapped)	N/A

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

The significance of risk classes is discussed further in Subsection 7.4.2.

7.4 Level of Study/Mapping

7.4.1 Nomenclature—Study/Mapping Techniques

The main components of any study used to develop flood hazard data are:

- Topographic data
- Survey methodology
- Flood hazard identification techniques (modeling and mapping)

Topographic data generally can be collected using airborne remote sensors such as LIDAR and Interferometric Synthetic Aperture Radar (IFSAR), photogrammetric techniques, or conventional land surveying techniques. Unit costs per land area generally increase from LIDAR to photogrammetry to surveying. The applicability of each technique tends to vary with terrain type, and most topographic data collection projects use a combination of techniques to fully define floodplain geometry and other characteristics. The combined approach has provided necessary details at a cost similar to or less than those used historically. Further, terrain data that is captured in the form of a digital elevation model further reduces the overall flood study cost by automating tasks that otherwise would be performed manually.

When not available from existing sources, survey data for hydraulic structures (dams, bridges, culverts, and levees) generally is obtained by three different methods. The first method uses topographic data. This data can be used to determine the top-of-structure elevations but cannot obtain the opening data. The second method is field measurement. This technique focuses on obtaining a reasonable representation of the opening area for hydraulic structures crossing streams and rivers (bridges and culverts). The third method uses field survey or as-built plans. This method is the most specific and precise and traditionally has been used for study areas with high flood risk.

Digital terrain modeling that allows the use of automated techniques is rapidly revolutionizing flood hazard modeling. With digital terrain models, the engineering modelers can use automated and semi-automated techniques to delineate watershed boundaries, determine floodplain geometries, and map the floodplain boundaries. Although automated techniques can speed the production and enhance the precision of a flood study while reducing unit costs, automated techniques in many cases require significant effort by senior engineering modelers to ensure that they are producing reliable information.

Various combinations of techniques can be used to generate five types of studies. The technique used is based on data availability and level of risk for each flooding source. Table 7-2 lists the study types and mapping products using various combinations of techniques.

Table 7-2. Product Descriptions

	Floodplain Boundaries	Base Flood Elevations	Flood Profile	Data Table	Floodway
Not Studied or Zone D[1]					
Zone A [2]	X				
Zone A ("Enhanced")	X	X[3]	X[3]	X[3]	
Zones AE, VE, AO, AH (Detailed)	X	X	X	X[3]	
Zone AE w/ Floodway (Detailed with Floodway)	X	X	X	X	X

[1] For areas where no flood hazard has been determined
[2] For areas that can be digitized from reliable existing data
[3] Products are available for floodplain management uses but are not formally published

Historically, the level of effort that went into a flood study generally was commensurate with the study's overall "accuracy" or precision as compared to known flood elevations. However, given the advances in technology and the availability of very high-quality data, the level of Federal effort for any given study is no longer necessarily commensurate with the overall product quality or value for floodplain management purposes. Any given study for a particular flooding reach can be developed with any combination of terrain, modeling, and mapping techniques described above. The defining factor between "approximate" and "detailed" is whether or not the BFEs have been characterized sufficiently to be published on the DFIRM.

For example, an approximate or enhanced study will be one in which flood elevations, a flood profile, and a data table are available to local officials but are not formally published. This gives local floodplain administrators additional floodplain information to assist in doing their jobs.

A detailed study will be one in which flood elevations and a flood profile are published. This will require local floodplain administrators to adopt those elevations in their local floodplain management ordinances, thereby restricting them to the use of those elevations only.

A detailed study with a floodway is similar to a detailed study, with the exception that a floodway will be published, which leads to further floodplain management requirements; however, it will have no impact on insurance rates or purchase requirements.

7.4.2 Method of Analyses and Suitability for Each Risk Class

FEMA's decision to publish BFEs (the difference between an approximate study and a detailed study) depends on the reliability of predicted and mapped BFEs. Many factors affect BFE reliability; the major factor is the quality of the input data used in the hydraulic or coastal models. Based on the risk class determined for each flooding source (see table 7-1), varying methods of analyses can be employed. The methods chosen for each component of the study should be mutually compatible to achieve overall reliability. Investment in detailed methods for some components of a study should not unduly shortchange the effort applied to other components. Several factors affecting BFE reliability are described in this subsection.

Discharges: Proper application of the hydrologic methodologies can have a significant impact on BFEs . Discharge variation can affect BFEs by as much as 3 to 5 feet. However, it is common to have very similar discharges in a detailed or approximate study for the same study area.

Depending on the risk class for the flooding source and input data availability, there are several levels of detail in the methods used for determining the flood discharges. These methods range from empirical methods (stream gage records and regression analysis) to computer models of the watershed's response to rainfall (rainfall-runoff models). The major difference among the methods is the level of input data and validation for the predicted flood flows. Table 7-3 lists the general suitability of various levels of hydrologic analysis.

Table 7-3. Suitability of Various Hydrologic Analyses Methods

Hydrology Analysis Method	Risk Class Suitability
Rainfall Runoff Modeling	Acceptable for all risk classes (A-C) when properly validated
Detailed Gage Analysis	Acceptable for all applicable risk classes (A-C) when sufficient record exists
Regional Regression Equations	Limited acceptability for risk class A, generally acceptable for risk classes B and C.
Regional Regression Equations, Gage Transpositions	Acceptable for risk class C

Validation of Predicted BFEs: Validation of predicted BFEs involves the comparison of predicted BFEs to surveyed or measured high-water marks from certified sources (U.S. Army Corps of Engineers, U.S. Geological Survey) or from anecdotal sources (residents living along the flooding sources). Regardless of the study type, validation (when possible) to historical water surface elevations can significantly increase product reliability and every attempt should be made to compile and use trustworthy historical flood data.

Table 7-4 lists the general suitability of various methods of validation.

Table 7-4. Suitability of Various Methods of Validation

Validation Methods	Risk Class Suitability
Known high-water marks along the flooding source	Acceptable for all applicable risk classes (A-C)
Basin approach to validation. Collection of several high-water marks inside the same river basin but not on every studied stream.	Acceptable for risk class A [1] Acceptable for risk classes B-C
No high-water mark validation	Acceptable for risk classes B-C

[1] Where high-water mark information is not available along the flooding source, other model inputs for Risk Class A should be as detailed as possible.

Manning's N-values: Manning's n value is the roughness coefficient indicative of the resistance to flow in stream channels. The n value is a function of vegetation in the channel and in the floodplain, obstructions that might be in the channel or floodplain, the type of material in the channel and variations in shape and size of the channel, including the meandering (sinuosity) of the stream. The Corps of Engineers' December 1986 report titled *Accuracy of Computed Water Surface Profiles* states that "the reliability of the estimation of Manning's coefficient has a major impact on the accuracy of the computed water surface profile," so the appropriate Manning's coefficient should be determined carefully. Table 7-5 lists the general suitability of various methods of n-value determination.

Table 7-5. Suitability of Manning's N-value Methodology

Manning's N-Value Methodology	Risk Class Suitability
Determination by field investigation	Acceptable for all applicable risk classes (A-C)
Determined using available aerial photography with support from field photos	Limited use for risk class A Acceptable for risk classes B and C
Determined using automated routines and remote sensed data or generally accepted values	Limited use for risk class B Acceptable for risk class C

Topographic Data Quality: In general, the value of any hydraulic model is highly dependent on the quality of the topographic and other data used to generate the model. Conventional detailed studies contain a combination of data taken from topographic maps along with detailed field survey data for the cross-sections and hydraulic structures. Topographic field surveys are among the more costly components of a detailed study, and the development of accurate topographic maps also can be costly. However, ground elevation information has a multitude of other uses and often is already available. CTPs and communities are encouraged to provide topographic data to enhance the spatial delineation of the flood boundaries.

The best available topographic information will be used for both approximate and detailed study modeling. This topographic data can include any of the following:

- Conventional topographic data (spot elevations and breaklines)
- Contours
- LIDAR
- IFSAR (in areas of sparse vegetation)
- USGS 30-meter DEMs (primarily for hydrology)
- USGS 7.5 minute hypsography – quad contours
- Field survey data

In some cases, countywide, statewide, or regionwide topographic data will be available. Research is currently underway to identify these topographic data sources for use in planning and project scoping/sequencing.

Table 7-6 lists the general suitability of topographic data for flood hazard identification purposes.

Table 7-6. Suitability of Topographic Data Sources

Topographic Data Source	Suitability		
	Hydrology Suitability	Hydraulics Suitability	Mapping Suitability
Field Survey	Generally not applicable for hydrology	Acceptable for all risk classes (A-C)	Acceptable for mapping at surveyed sections, but mapping will be interpolated between sections based on available topographic data between survey sections
Detailed Terrain	Acceptable for all applicable risk classes (A-C)		
USGS Quadrangle Maps (tagged vector contour information)	Acceptable for all risk classes (A-C)	Limited acceptability for risk classes A and B; Acceptable for risk class C	Limited acceptability for floodplain mapping for risk classes A and B; acceptable for risk class C
30-meter USGS DEMs	Generally accepted for hydrologic modeling if hydro-enforced	30-meter DEMs may not be acceptable for hydraulic modeling; 10-meter DEMs, if available, may be acceptable [1]	30-meter DEMs, generally not acceptable for floodplain mapping; 10-meter DEMs acceptable for risk class C

[1] 10-meter DEM data currently exists for approximately 50 percent of the United States

Inclusion of Hydraulic Structures: The choice to include specific hydraulic structures (bridges, culverts, and dams) in the model routine can be important for certain flooding sources. Structures designed to pass discharges higher than the base flood (1 percent annual chance) and those that are significantly overtopped generally do not have a significant impact on flood elevations or flow patterns. However, structures designed at or near the base flood level probably do have some impact on elevations or flow patterns; thus, their omission could lead to unreliable results.

Table 7-7 lists the general suitability of the inclusion of hydraulic structures.

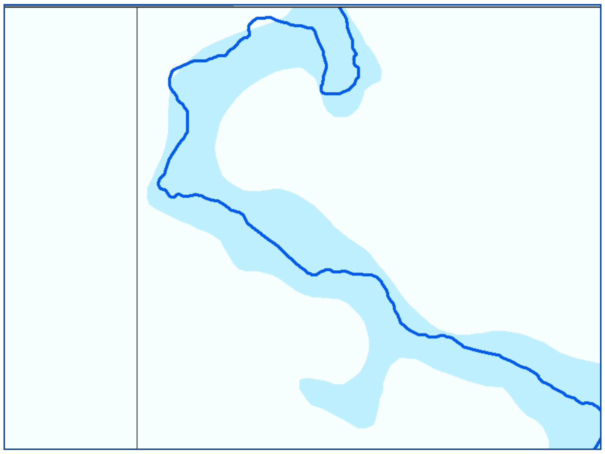
Table 7-7. Suitability of the Inclusion of Hydraulic Structures

Method of Inclusion of Hydraulic Structures	Suitability
Field Survey of Hydraulic Structures and associated cross-sections, obtaining structure information from as-built plans	Acceptable for all applicable risk classes (A-C)
Field Measurement of hydraulic structures	Limited acceptability for risk class A Acceptable for risk classes B and C (note: It may be determined that structures for risk class B flooding sources may not require survey or field measurement based on engineering judgment.)
Structures omitted or reflected as obstructions (based on FEMA regional decisions)	Acceptable for risk class C

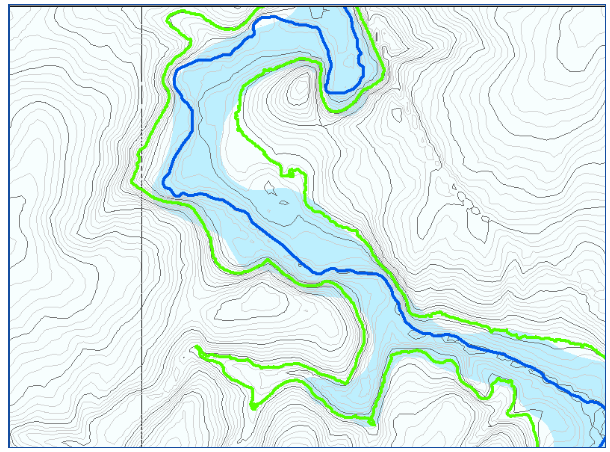
These levels of hydrologic, hydraulic, and topographic analyses and/or data collection recognized as suitable for various risk classes also apply to flood hazard modeling and mapping in coastal areas. However, these standards apply only to the delineation of the inundation limit boundary due to storm surge in coastal areas and not to the delineated flood hazard zone boundary between zones V/VE and A/AE or the location of the mapped BFE gutters within the coastal floodplain.

7.4.3 Utilization of Effective Flood Insurance Study Information

If, during study scoping, the level of study for the existing models and data is determined to be suitable for the level of risk for the area, then the new Flood Insurance Study (FIS) should use the existing effective study information. The effort will involve remapping the effective flood hazard information in a digital form. Note that the manual cartographic and topographic information that was available at the time may not have accurately reflected ground elevations. Remapping typically also includes converting the vertical datum for the profiles and BFEs from NGVD 29 to the NAVD 88 and checking against available topographic data. In cases where new or updated topographic data exists, the flood elevation data would be remapped to the new topographic data source to improve the spatial quality of the mapped boundaries, as illustrated in figure 7-6. If, based on consultation with the community, the previous study for a flooding source is found to be inaccurate (for example, post-flood high-water marks reveal that the current FIS under- or over-predicts the flood hazards), the flooding source will be restudied, as budget is available.



Original FEMA Floodplain Boundary Data (Zone AE)



Updated FEMA Floodplain Boundary Data based on Updated Contours (with Redelineated Flood Boundaries outlined in green)

Figure 7-6. Original Flood Map (Left), Updated Flood Map (Right)

There are three types of redelineation: revised topographic redelineation, work map-based, and FIRM-based. Detailed explanations are provided below. For each type, the deliverable will be digital flood boundaries that match best available topographic data, recreated flood profiles, and floodway data tables meeting FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners.* For most cases, the elevation data will be referenced to NAVD 88 vertical datum. If another vertical datum is used, coordination with the FEMA National Office will be necessary to make certain that the vertical datum recommended is or can be supported by FEMA. These delineation types include:

Case 1: Revised Topographic Redelineation: This case involves situations for which new topographic data exists for a study reach or entire county. The new topographic data is more recent and of higher quality than the topographic data originally used in the effective study. When the original hydraulic model is not available digitally but the model is correct, the effective FEMA profile forms the basis of the redelineation. The appropriate vertical datum conversion is applied, and the revised flood boundaries are mapped on the new topographic source. In this case, the BFEs should be republished on the DFIRM.

Case 2: Work Map-Based: This case involves the redelineation of a flooding source for which revised topographic information is not available. The original work maps from the effective study are obtained from the FEMA library. These maps are used to digitize the flood boundaries and cross-sections because the work maps typically contain horizontal coordinate reference grid lines that assist in proper digitization of the paper data. Using the original work maps will not perpetuate any spatial error that may have occurred when the effective paper FIRMs were created. The wholefoot BFEs will not be digitized because the vertical datum offsets for most streams will not be an even-foot multiple. BFEs will be placed using the converted profile. Redelineations of this type will be used where, after consultation with the community, the models have been examined and deemed adequate. This type of new study may have published or unpublished BFEs.

Case 3: FIRM-Based: This case describes the redelineation of a flooding source for which revised topographic information and the original study contractor work maps are not available. For this case, the best quality paper FIRM and/or floodway maps are digitized. The FIRM is registered to a base map that has horizontal coordinates by using road intersections and other landmarks visible on both the FIRM panel and the base map. This process (sometimes called “rubber sheeting”) introduces some error. In addition, because this process perpetuates any spatial error that may have occurred when the effective paper FIRMs were created, significant modifications to the digitized floodplain boundary will be necessary to meet the performance standards related to matching the source topographic data. This is the least-preferred method for redelineation.