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PREFACE

This edition of the Flood Insurance Study Guidelines and Specifications for Study Contractors reflects the changes in mapping policy and technical procedures that have been adopted by the Federal Emergency Management Agency since the Guidelines were last issued in March 1993. In summary, the major changes are as follows:

- An expanded discussion on the requirements for the preparation of draft Flood Insurance Studies (FISs) in a digital format.
- An expanded discussion of when a draft FIS should be performed using the North American Vertical Datum of 1988.
- Inclusion of the requirement for the Study Contractor to complete the certification forms entitled, Certification Forms and Instructions for Study Contractors.
- An expanded discussion on the use of Global Positioning System (GPS).
- Inclusion of current photogrammetric technologies.
- Inclusion of criteria for when to perform confidence limits test.
- Inclusion of requirement for floodway surcharge values be between zero and the maximum allowable value.
- Inclusion of guidance on floodway delineation where storage was taken into account in flood routing.
- Inclusion of requirement for Study Contractor to coordinate the paneling scheme and scale for data capture and work maps with the Regional PO and FEMA's TEC.

Study Contractors and State or Federal agencies planning to perform Flood Insurance Study work for FEMA should become thoroughly familiar with these Guidelines. In addition, the following Glossary of Acronyms is provided to assist the users of these Guidelines.

CHAPTER 1. FLOOD INSURANCE STUDY GENERAL BACKGROUND AND REQUIREMENTS

A. Introduction

The National Flood Insurance Program (NFIP) was established by the National Flood Insurance Act of 1968 and further defined by the Flood Disaster Protection Act of 1973. The 1968 Act provided for the availability of flood insurance within communities that were willing to adopt floodplain management programs to mitigate future flood losses. The act also required the identification of all floodplain areas within the United States and the establishment of flood-risk zones within those areas.

A vital step toward meeting these goals is the conduct of Flood Insurance Studies (FISs), restudies, and Limited Map Maintenance Program (LMMP) FIS projects for flood-prone communities. An FIS provides a community with sufficient technical information to enable it to adopt and amend the floodplain management measures required for participation in the NFIP. An FIS also develops the flood risk information necessary to establish and maintain accurate actuarial flood insurance premiums.

The Federal Emergency Management Agency (FEMA) has compiled the Flood Insurance Study Guidelines and Specifications for Study Contractors (referred to herein as the Guidelines) to define technical policy and procedures to be followed in the preparation of FISs, restudies, and LMMP projects.

General guidance is provided for work involving standard professional practice for flood hazard evaluation and revision, whereas specific instructions are provided for work unique to FISs and subsequent updates. The results of these studies are set forth in a final FIS report, which contains a written section, flood profiles, figures, and tables. In addition, an essential product of the study is the Flood Insurance Rate Map (FIRM), which is distributed to the private insurance industry, the community, Federal and State agencies, and others. This map provides 100-year flood elevations and divides the area studied into flood hazard zones that are used to establish actuarial insurance rates. The FIRM may also depict areas determined to be within the FEMA-designated floodway and 500-year floodplain. In addition, certain landmark features in the community may be shown on the FIRM to assist in locating individual properties.

These Guidelines have been structured to reflect the Map Initiatives format. This format allows for all floodplain/flood hazard information previously shown on the Flood Boundary and Floodway Map (FBFM) to be shown on the FIRM. In addition, Zones A1-30, V1-30, and B have been superseded by Zones AE, VE, and X, respectively. The SC should determine all appropriate zones as outlined in Chapter 8 of these Guidelines.

These Guidelines include requirements for digital data submissions. Appendix 7 specifies the digital product requirements in detail, and Appendix 4 provides specifications for aerial mapping and surveying performed using digital techniques.

These Guidelines apply to all flood-related hazards covered by the 1968 Act. Specific guidance is provided herein for the evaluation of riverine and alluvial fan flood hazards, coastal flooding and flood-related erosion, and flood hazards along the Great Lakes. Guidelines for determining wave elevations and V-zone mapping are currently being prepared and will be published as a separate document. Guidelines for evaluating other flood-related hazards may also be provided as a supplement to this document as they are developed.

The Flood Disaster Protection Act of 1973 requires consultation with local officials and others during the course of developing or updating an FIS as well as full consideration of all relevant facts and technical data available locally. To make certain this is accomplished, the legislation establishes procedures for consultation, coordination, and appeal with respect to the FIS. These procedures are described in the NFIP regulations at Title 44, Chapter 1, Code of Federal Regulations (44 CFR) Parts 65, 66, 67, 70, and 72.

Accordingly, the appropriate officials of the community are kept fully informed on all aspects of the FIS as it progresses. These officials are extended every opportunity to present relevant facts and technical data that might have some bearing on the conduct or conclusions of the FIS. All information thus provided is given complete and careful consideration by the contractor conducting the FIS. Pertinent details of these consultation and coordination activities are then set forth in the FIS report.

In the following chapters of these Guidelines, the terms "study" and "restudy" are used extensively. For clarification, study refers to a hydrologic and hydraulic analysis of a flooding source (or sources) that is being done for the first time. This hydrologic and hydraulic analysis would be used to establish base (100-year) flood elevations (BFEs). A restudy represents a revised or updated hydrologic and hydraulic analysis of a flooding source or sources. Restudies are performed for communities that are participating in the Regular phase of the NFIP or have an existing FIRM.

B. General Performance Requirements

Adherence to these Guidelines are required in the Contract Statement of Work. Performance in accordance with these Guidelines is required of any contractor preparing a FIS, restudy, or revision unless otherwise specified in the contract.

Study Contractors (SCs) must provide to FEMA all data and other materials necessary to produce the reports and maps that meet the requirements of these Guidelines. Specific performance requirements, especially with respect to deliverable items, are detailed in the Contract Statement of Work and in Chapter 11 of these Guidelines. For coastal flood hazard studies and for alluvial fan studies, specific performance requirements, documentation and intermediate data submission requirements are outlined in Appendices 1, 1A, and 1B, and in Appendix 5, respectively. The digital product delivery requirements are outlined in Chapters 3 and 9, and Appendix 7. The requirements for aerial mapping and surveying performed using digital techniques are outlined in Appendix 4. In addition, prior to performing any work for preparation of an FIS, the SC should carefully review the contents of Chapter 10, "Review for Quality Assurance" of these Guidelines. Also, the SC is required to complete, as a deliverable item, the Certification Forms and Instructions for Study Contractors, which is an addendum to these Guidelines.

A Regional Project Officer (PO) is assigned by FEMA to each contract. The Regional PO has the responsibility to ensure, through liaison with the SC, that the technical requirements of the contract are achieved. This includes the responsibility for providing technical direction, monitoring the progress of the SC, and evaluating the SC's performance. The Regional PO may issue written or oral instructions to fill in the details of the Statement of Work or these Guidelines. The Regional PO will also make recommendations to the Contracting Officer whenever the Statement of Work, period of performance, or other technical provisions of the contract need to be amended to accomplish the objectives of the FIS. The Regional PO cannot direct the SC to undertake any activity that will affect the price, period of performance, scope, or administrative provisions of the contract. If such changes are required, these can only be authorized by the Contracting Officer on the recommendation of the Regional PO. The SC must obtain such authorization prior to conducting any work outside the scope of contract.

The SC must remain alert for unique or unusual circumstances that may be encountered during the course of the FIS and are not addressed in these Guidelines. As soon as such problems are identified, the SC should notify the Regional PO and obtain approval of any proposed plan for handling them. An Exceptional Procedure Notice form must be completed by the SC and must be included with the draft FIS submittal for such problems.

CHAPTER 2. DETERMINING SCOPE OF STUDY

This chapter discusses the necessary investigation and coordination to be performed by the SC. Only after noting the total extent and severity of flood hazard information deficiencies within a community can funds be appropriately allocated to address them. While funds may not be available to address each noted deficiency, a full understanding of existing deficiencies will allow each to be ranked by priority so that the most severe problems are addressed.

A. General Considerations

Regarding the level of study detail, FEMA has classified study approaches into two broad categories: approximate and detailed. Approximate study methods are those that result in the delineation of 100-year floodplain boundaries, but do not include the determination of base (100-year) flood elevations or depths. Detailed study methods are those that, at a minimum, result in the determination of base flood elevations or depths that will be displayed on the FIRM. However, within the detailed study classification, there is opportunity to vary both the study procedures and the FIS products to maximize study efficiency. Further detail on conducting approximate and detailed flood hazard studies are provided in Chapters 4, 5, and 6.

In general, the decision to utilize one study method over another is based on existing and projected floodplain development pressures; flood hazard determinations for flooding sources that affect developing areas[1] should be based on detailed studies when possible; determinations for other flooding sources should be carried out using approximate study methods. Although detailed and approximate studies shall normally be terminated where the 100-year floodplain permanently narrows to a width of 200 feet or less, or where the drainage area of the flooding source is less than 1 square mile, decisions to terminate studies at these points shall be guided by consideration of actual flood hazards and development projections; if situations arise that preclude the above-stated criteria, the Regional PO should be consulted.

Flood hazard determinations, to the extent possible, should be based on conditions that are planned to exist in the community within <u>12 months</u> following completion of the draft FIS report. Examples of future conditions to be considered are public works projects in progress such as channel modifications, hydraulic control structures, storm-drainage systems, and various other flood protection projects. It is important that consideration to proposed structures or structures under construction should be given only after the approval of the Regional PO has been obtained. If proposed structures are taken into account, when the preliminary map is issued, the SC must confirm that the structures were built or will be completed before the map becomes effective.

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[1]Developing areas are defined herein as areas where industrial, commercial, or residential growth is beginning, and/or where subdivision is underway <u>and</u> where these trends are likely to continue. They include areas that are likely to be developed within 5 years following completion of the study.

For flooding sources where federally designed, funded, and constructed flood protection measures will not be completed within 12 months, but where adequate progress has been made, the SC may be asked to provide two separate analyses; one for the existing condition and one for the future condition. In this case, separate flood profiles, floodway computations, and maps should be prepared for each condition. Adequate progress, as defined by law and interpreted by 44 CFR 61.12(b), has been made when the project costs have been 100 percent authorized, at least 60 percent appropriated, and at least 50 percent expended, and where the project itself is under construction and is at least 50 percent completed for all of its critical features.

B. Initial Coordination and Information Search

In the interest of identifying all existing flood hazard data and flood problems to better establish the scope of study, it is recommended that the SC contact all possible sources of information to become cognizant of available data, including digital data files, and identified flood problems. In conducting restudies, the SC should focus on the area being restudied. Such sources shall include the community (city engineer, planning, permitting, and zoning officials); contractors studying adjacent areas for the NFIP; State water resources agencies; flood information repositories; State Coordinating Agency for the NFIP; and Federal agencies (Federal Emergency Management Agency, U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Bureau of Reclamation, U.S. Soil Conservation Service, and Tennessee Valley Authority). At a minimum, the SC shall contact the appropriate FEMA Regional office, FEMA's Technical Evaluation Contractor (TEC) servicing the geographic area in which the community is located, and local community officials to discuss existing flood hazard data and identified flooding problems prior to attending the initial community Consultation and Coordination Officer's (CCO) meeting. The CCO is an employee of FEMA that is responsible for carrying out the consultation and coordination responsibilities set forth in Section 66.5 of the NFIP regulations.

C. Initial Field Reconnaissance

Prior to attending the initial CCO meeting, it is strongly recommended that the SC perform an informal "windshield survey" field reconnaissance to become familiar with the following:

- Extent and condition of floodplains within the community;
- Existence and apparent maintenance of any flood control structures, including channels, culverts, dams, and levees; and
- Apparent development pressures in floodplain areas.

The initial field reconnaissance for restudies should focus on the area(s) being restudied.

D. Initial CCO Meeting

The SC shall attend an initial CCO meeting with representatives from FEMA and the community. The purpose of this meeting is to identify and rank the deficiencies in flood hazard data with respect to existing and expected conditions within the community. The actual scope of study will be finalized later based on an assessment of identified deficiencies and available funding. It is the role of the SC to propose the scope of the study and the Regional PO to define it.

To facilitate discussion, FEMA representatives shall bring a copy of the effective FIS, FIRM, and/or FBFM; FEMA representatives shall also bring copies of the effective FIRMs for contiguous communities. Community officials are requested to bring any available maps showing current and planned development, current corporate limits, urban growth boundaries, extraterritorial jurisdiction boundaries, topographic information, and any local and regional floodplain studies not reflected on the FIRM or FBFM, or in previous LOMRs.

The following questions shall be considered:

- For detailed study streams, has development in the watershed, or the construction of flood-control structures, since the effective FIS, rendered existing flood discharge values significantly out-of-date?
- Have physical changes occurred in the floodplain, such as channelization projects or the construction of bridges, that are not reflected in the effective FIS?
- Have actual flooding events suggested that the results of the effective FIS analyses are no longer appropriate?
- Are flood control structures credited on the FIRM that should not be? Examples include levees that do not meet the criteria of 44 CFR 65.10, or poorly maintained channelization projects. Conversely, are flood control structures not credited on the FIRM that should be? It is the responsibility of the community to supply all information necessary to determine whether a flood control structure can be credited on the FIRM with providing 100-year flood protection.
- Are Zone A delineations appropriate? Are they generally consistent with the best available topographic information? How do Zone A floodplain delineations compare to those of detailed studied streams with similar basin characteristics?
- Is flood hazard information shown on the effective FIRM consistent with that shown on contiguous communities' FIRMs? Effective FIRMs brought to the initial CCO meeting by FEMA representatives shall be reviewed for consistency.
- Are areas within the community's jurisdiction experiencing or expected to experience rapid development?
- Is sufficient flood hazard information available for areas within both the community's corporate limits and its extraterritorial jurisdiction boundaries? Any recently annexed areas should be carefully considered.
- Has land subsidence rendered existing flood hazard information out-of-date?
- What, if any, GIS capabilities does the community have, what digital data sets are available for use in preparing a new FIS, and what use will the community make of digital FIS files?

After the initial CCO meeting, the scope of study will be defined by reconciling identified needs with the priorities for study of other communities and available funding.

CHAPTER 3. DATA COLLECTION AND COORDINATION

The SC shall, at the beginning of the contract period, research all existing pertinent data to avoid duplication of effort. This research effort shall include a literature search; an information search, including contact with local, State, and Federal agencies, as well as contractors that may be conducting studies of adjacent areas; contact with local, State, or Federal agencies that may be able to provide pertinent digital data files, including base mapping or floodplain boundary files; and field reconnaissance of the study area. This information may consist of revisions to a community's FIS, FIRM, and/or FBFM, such as Letters of Map Revision (LOMRs), that are not widely published. The Regional PO shall be consulted to ensure that all such revisions have been obtained. The SC shall also prepare an announcement for a local newspaper soliciting relevant historical flood or existing flood hazard information in either hard copy or digital format. Specific subtasks are outlined below.

A. Literature Search

A detailed literature search shall be made to obtain published reports and other available data dealing with flooding problems in the study area, in adjoining communities, and in the surrounding region.

B. Information Search and Retrieval

All possible information sources shall be requested in writing to submit pertinent data, including digital data files. Such sources shall include the community; contractors studying adjacent areas for the NFIP; State water resources agencies; flood information repositories; State Coordinating Agency for the NFIP; and Federal agencies (FEMA, U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Bureau of Reclamation, U.S. Soil Conservation Service, and Tennessee Valley Authority). The SC shall document all contacts and shall provide, in the draft FIS report data, a list of the agencies contacted and the information obtained.

An assessment of the useability and technical accuracy shall be made of all available information, including historical hydrologic data, high-water marks, flooding problems within the community, flood-control measures, hydraulic structures that affect flooding, available community maps <u>showing and naming all roads in the floodplains</u>, topographic maps, digital data files, and elevation control data (including consideration of land subsidence where applicable). Photographs of past major floods, if available, shall be obtained for inclusion in the FIS report.

Digital files obtained from any source must be accompanied by the "Digital Data Submission Checklist," shown as Figure A7-1 in Appendix 7. This form provides the SC and any subsequent users of the data with information they may need on the data sources, projections, datums, file formats, etc. These forms must be submitted to FEMA along with the digital data files.

For areas being restudied, basic data <u>must</u> be obtained from the hydrologic and hydraulic models used to prepare the effective FIS, including any subsequent revisions (such as LOMRs) to this data. This information is available through the FEMA Regional office from FEMA's TEC servicing the geographic area in which the community is located, and may include hydrologic and hydraulic models, engineering and construction plans, floodplain maps, and flood profiles. In addition, any information should be obtained that may provide data for evaluating changes to the effective hydrologic or hydraulic models. The SC should obtain this information from the FEMA Regional office and adjacent communities.

C. Detailed Field Reconnaissance

To supplement the suggested initial field reconnaissance conducted prior to the initial CCO meeting, the SC shall conduct a detailed field reconnaissance of the specific study area to determine conditions along the floodplains, types and number of hydraulic structures involved, apparent maintenance or lack thereof of existing hydraulic structures, locations of cross sections to be surveyed, and other parameters needed for the hydrologic and hydraulic analyses.

D. Surveys

For each flooding source to be studied in detail where an existing hydraulic analysis is either unavailable, outdated, or must be supplemented, the SC shall identify or establish necessary Elevation Reference Marks (ERMs), obtain channel and floodplain cross sections, and obtain the physical dimensions of hydraulic structures. The SC must exercise particular care in areas subject to land subsidence to ensure that ground elevation data obtained or developed in the course of the study are based on the most recent bench mark data as published by the National Geodetic Survey or other authoritative source. It is recommended that existing ERM values be verified. When it has been determined that a study area is affected by land subsidence, the SC shall consult with the Regional PO to determine the most appropriate procedure to evaluate the subsidence. For further guidance on surveys, refer to Appendix 4.

1. Identify/Establish Bench Marks

Third-order leveling[2] shall be used to tie temporary bench marks and ERMs to the National Geodetic Vertical Datum of 1929 (NGVD) or, when available, the successor North American Vertical Datum of 1988 (NAVD); to determine the elevation of high-water marks; and, where needed, to establish vertical control for aerial photography. Whenever possible, available vertical control shall be used in lieu of field surveys.

ERMs shall be established and recorded in and near the floodplains of all streams studied in detail. These shall include existing elevation references and those ERMs that can be established in the course of setting temporary bench marks for cross sections or vertical control for photogrammetry. Acceptable ERMs would consist of any solid object set in a stable structure or ground. Surveys shall <u>not</u> be undertaken for the sole purpose of establishing ERMs without the approval of the Regional PO. As a general rule, and not withstanding the limitations on surveys, ERM density should be approximately two per mile of stream length or four per square mile of floodplain, as appropriate.

2. Obtain Cross Sections

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[2] Closures within 0.05 foot X square root of distance in miles.

Where 4-foot contour mapping (or the equivalent) is unavailable, above-water valley and channel cross sections shall normally be taken photogrammetrically, using methods described in Appendix 4. Otherwise, field surveys may be used to establish cross sections. Field surveys should normally be accomplished by differential leveling or differential Global Positioning System (GPS) methods, with vertical error tolerances of ✂<0.5 foot across the 100-year floodplain. Cross-section elevations and stations should be determined at those points that represent significant breaks in ground slope and at changes in the hydraulic characteristics of the floodplain.

Each cross section shall, at a minimum, cross the entire 100-year floodplain and, if possible, extend at least one foot above the estimated 100-year elevation. For areas between the 100- and 500-year floodplain boundaries, floodplain geometry, where needed, shall be estimated using available ground elevation data, without conducting field surveys. The number of cross sections needed for a study reach will vary depending on the particular hydraulic methodology selected for application and the hydraulic characteristics of the reach. As a general rule, cross sections should be selected to be representative of average conditions in reaches that are as long as possible, without permitting excessive conveyance change between cross sections.

In general, the use of interpolated cross sections is not permitted, unless approved by the Regional PO. Where Regional PO approval has been obtained, floodway delineations should be based on actual cross sections.

3. <u>Obtain Physical Dimensions of Hydraulic Structures</u>

Necessary dimensions and elevations of all hydraulic structures and underwater sections along the streams shall be obtained from available sources or by field survey where necessary. Dimensions and elevations of hydraulic structures may <u>not</u> be established by aerial photogrammetric methods.

4. <u>Global Positioning System (GPS) Surveys</u>

The use of GPS equipment is encouraged, provided differential GPS (DGPS) techniques are used (as described in Appendix 4). DGPS testing should yield centimeter-level horizontal and vertical accuracies for the roving GPS receiver(s), relative to the GPS base station, positioned on control points or bench marks, which simultaneously receive signals from the same four (or more) GPS satellites as are received by the roving GPS receiver(s). This enables known errors at the base station to be applied as corrections to positions of the roving receiver(s).

E. <u>Coordination</u>

In order to keep abreast of changes in the community that may affect the draft FIS, the SC shall coordinate periodically with the community, particularly for large studies or when the study effort spans a significant time between the initial CCO meeting and delivery of the draft FIS to FEMA. These changes could include newly annexed or de-annexed areas, new floodplain projects, or the availability of new data. Under no circumstance shall the SC allow more than 6 months to elapse without establishing contact with the appropriate community official.

The SC shall also coordinate with the Regional PO, notifying FEMA of any changes brought to the SC's attention by community officials. The SC shall also provide the Regional PO with periodic progress reports to document coordination with community officials.

The SC is encouraged to submit a sample digital data file to FEMA at approximately the 10-percent completion milestone. This will enable FEMA to review the sample files for ease of use, compatibility between computer mapping systems, and develop an understanding of the file contents. Any modifications to the data capture techniques or file format used by the SC can be implemented at an early enough production phase to avoid excessive rework.

CHAPTER 4. DETAILED HYDROLOGIC ANALYSES

This chapter addresses hydrologic methods and assumptions to be utilized in conducting FISs for riverine applications. For coastal applications, please refer to Appendix 1A.

A. General Guidance

As part of the initial scope of work defined by the Regional PO, the exceedence frequency of flood events to be studied should be determined. At a minimum, the contractor must analyze the 100-year event; however, often the contractor will also be requested to determine flood discharges for the 10-, 50-, and 500-year flood events. Where appropriate, the SC shall use all available flood flow frequency information and shall not duplicate previous work by Federal, State, or local agencies, or that in published FISs. Where such data are not available, where conditions have changed invalidating the published information, or where the methodologies or data used in the previous FISs are not appropriate, the SC shall conduct a hydrologic analysis. The SC should consider gaged versus ungaged streams and the appropriateness of developing a rainfall-runoff model. Each of these approaches are briefly discussed later in this section. When an expected probabililty adjustment has been included in published discharge determinations, the SC shall contact the Regional PO for approval before proceeding.

Prior to conducting a hydrologic analysis, the SC should work with the Regional PO to identify which, if any, of the hydraulic structures should be included in the analysis and to identify appropriate methodologies. If using existing flood discharge data from an effective FIS, the SC shall verify that the data are current before proceeding.

Where large amounts of floodplain storage exist and are capable of significantly attenuating flood hydrographs within the community, this attenuation shall be evaluated by the use of standard flood routing techniques. The use of these procedures shall be cleared with the Regional PO.

Storage capability, below the Normal Pool Elevation of dams operated primarily for purposes other than flood control normally should not be considered in a FIS because the availability of such storage is uncertain. The exception is when all of the following conditions have been met:

- Operation of the project in accordance with its documented water control plan could affect the 100-year flood elevations in a community by 1 foot or more.

- The storage capability to be considered must be totally dedicated to flood control. Where different amounts of storage can be totally dedicated during different parts of the year, the flood discharges to be used should be obtained from the joint probability combination of frequency curves established for each part of the year when the different storage levels are dedicated. Joint use storage based on forecasted inflow is not acceptable in the NFIP.

- ✐ A project water control plan providing explicit details of operation during flooding conditions must be in effect and must be reviewed and approved by FEMA or another Federal agency responsible for Federal flood-control activities. The Regional PO should be contacted to discuss the review and approval process.

- ✐ A commitment to dedication of the flood-storage capacity and to the approved water control plan must be assured through a mandatory condition of Federal or State licensing or through a direct agreement between the project operator and FEMA for non-Federal projects.

<u>Gaged Streams</u>: Flood flow frequency analyses shall be made in accordance with the latest methodology presented in Bulletin No. 17B (Reference 1) and subsequent modifications. The basic flood flow frequency curve for gaged sites on unregulated streams shall be obtained from the local district office of the U.S. Geological Survey (USGS), Water Resources Division. These data shall be used and modified if necessary to provide reliable discharge estimates for the site under consideration. The methodologies outlined in the U.S. Army Corps of Engineers "Hydrologic Frequency Analysis" EM 1110-2-1415 (Reference 2), can be used to address needs for modification of USGS results.

Generally, peak discharges for ungaged sites on a gaged stream shall consider both the gaged site information and information from an appropriate regional estimate, where available. An appropriate transfer technique for establishing discharges at the ungaged location shall be selected by the SC. The transfer technique should consider the difference in drainage area from that at the gaged site. The procedures prescribed in most regional flood flow frequency reports published by the USGS are recommended for this purpose. An example of an acceptable transfer technique is provided in "Regionalization of Peak Discharges for Streams in Kentucky" (Reference 3). In cases where a more specialized local study of a watershed may be more appropriate than one prepared by the USGS, the Regional PO should be consulted.

For gaged streams with regulated flows, peak discharges shall be obtained from the agency responsible for the regulation. If the effects of regulation on flood flow frequency have not been established, the SC shall determine the most appropriate analysis technique and obtain approval from the Regional PO before proceeding (see Reference 2).

<u>Ungaged Streams</u>: The SC shall make use of any valid existing flood flow frequency analysis conducted by a Federal, State, or local agency that authoritatively establishes the discharges for an ungaged stream under consideration or the discharges in published Flood Insurance Studies. In the absence of such an analysis, the SC shall use, where appropriate, the most recent regional flood flow frequency report published by the USGS that is applicable to the area under study. Such reports are generally available on a statewide basis. The SC should exercise caution in that these reports are to be used only for conditions and locations for which they are recommended. Where these reports do not contain procedures to account for presently urbanized conditions, and where the basin under study is more than 10 percent urbanized, the discharges determined for the rural condition shall be adjusted using techniques described in <u>Flood Characteristics of Urban Watersheds in the United States</u> (Reference 4). The USGS microcomputer program, "National Flood Frequency" (Reference 5), can be used to determine different flood frequency discharges for the continental United States, Alaska, Hawaii, and Puerto Rico for both rural and urbanized conditions.

When a Regression Equation other than one published by the USGS is proposed to be used, the SC shall obtain approval of the PO and shall justify why this equation is more proper to use.

<u>Rainfall-Runoff Modeling</u>: Where USGS regional flood flow frequency reports have not been developed or are not applicable due to flow regulation, storage, rapid watershed

development or other unique basin characteristics the SC with Regional PO approval may select to develop a rainfall-runoff model such as HEC-1 or TR-20 (References 6 and 7). In developing a rainfall-runoff model, the following factors should be considered:

- The unit hydrograph method is preferred when developing hydrographs. However, subbasin drainage areas should be provided to limit the area included in the unit hydrograph and to better identify watershed response to changing conditions.

- Loss rates should be varied when computing different frequency floods. Urbanization effects must be reflected in the loss rates. The Soil Conservation Service (SCS) curve number method is one of the methods that can be used.

- Time of concentration or lag computations must reflect the effects of increases in velocities due to channel modifications and urbanization.

- Rainfall duration must be large enough to capture all excess rainfall as well as provide reasonable runoff and sediment volumes when performing storage analyses.

- Stream flow routing methods should be able to analyze the attenuation and translation of hydrographs.

Parameters in the models should be calibrated with known storms in the study area, when available data permits, before determining different discharge frequencies. Computed peak discharges from the hydrologic model should be compared with the discharges from published regional studies such as USGS regression equations. If the discharge values are not comparable, a Special Problem Report must be submitted to the Regional PO to resolve the differences before beginning the hydraulic analysis.

B. Initial Flood Insurance Study Methodology

Before proceeding with the hydraulic analyses, the SC shall compare his calculated discharges proposed for use in the FIS with all available flood flow frequency data that exist for the study area to ensure compatibility with existing data. A cursory check of discharge/drainage area relationships can sometimes identify a problem. The SC must also inform the Regional PO, as well as Federal, State, and local agencies involved in water resources programs in the area, of the proposed discharges. Any discrepancies between available information and the discharges proposed for the FIS must be resolved by the SC. Such discrepancies shall be brought immediately to the attention of the Regional PO in a Special Problem Report as discharge discrepancies shall not be cause for delay in the study. In addition, the Regional PO should be kept informed of progress made in resolving such discrepancies.

Proposed flood discharge values must be compatible with those used in previously completed studies on the same watercourse. Discharge values from a later flood flow frequency analysis that disagree with previously used discharges should be considered only when the later discharges can be shown to be significantly different statistically from the previous discharges. The test for significance shall be based on the confidence limits of the latest analysis: the latest discharges shall be adopted if the previously established discharges do not fall within the 95 and 5 percent confidence limits (90 percent confidence interval) of the most recent estimates; the previously established discharges shall be adopted if they fall within the 75 and 25 percent confidence limits (50 percent confidence interval) of the most recent estimates. Bulletin No. 17B (Reference 1) should be consulted for procedures on computing confidence limits. Where the previously established discharges fall between the 50 and 90 percent confidence intervals of the most recent estimates, the situation shall be presented to the Regional PO in a Special Problem Report for resolution. For gages with record lengths less than 50 years, the results of confidence limits test should be discussed with the Regional PO before proceeding.

Where significantly different discharges are proposed for use, the Regional PO shall be contacted immediately for approval. Where confidence limit tests are not applicable, unresolved discrepancies shall be brought to the attention of the Regional PO. The determining factor then becomes the impact on the BFE.

C. Considerations for Flood Insurance Restudies

In general, a restudy of hydrologic analyses could be initiated for any of four reasons: (1) Longer periods of record or revisions in data; (2) Changed physical conditions; (3) Improved hydrologic methods; or (4) Correcting an error in the original FIS. Examples of changed physical conditions could be the construction of hydraulic structures that have impacted the effective FIS analyses, or development within a watershed subsequent to the effective FIS analyses. Regardless of the reason for the restudy, the contractor must provide detailed documentation of the changes that have been addressed in the restudy and why discharges developed for the restudy are superior to the effective FIS. If the reason for the restudy is an improved method, the contractor must provide documentation as to why the alternative method is superior to the original FIS and must obtain Regional PO approval concerning the use of the improved method.

It is important to note that a restudy of a community's FIS and FIRM may include a flooding source(s) that does not have any established BFEs. In these cases, Section B of this chapter entitled "Initial Flood Insurance Study Methodology" should be consulted for necessary guidance on establishing flood discharges.

Rapidly developing watersheds with increasing flood hazards will be chosen for restudies as a first priority. Communities should be requested to provide available master plans on land use for these watersheds prior to the initiation of a restudy. The hydrologic analysis for rapidly developing watersheds will be performed in two phases: preliminary and detailed analyses.

Preliminary Hydrologic Analysis

The preliminary hydrologic analysis should use USGS regression equations, considering urbanization effects, to determine the existing condition 100-year flood discharges at several locations along the stream(s) to be restudied. Effects of urbanization can be determined by the methods described in the USGS publication Flood Characteristics of Urban Watersheds in the United States (Reference 4). Alternatively, the USGS microcomputer program, "National Flood Frequency" (Reference 5), can be used to determine different flood frequency discharges for the continental United States, Alaska, Hawaii, and Puerto Rico for both rural and urbanized conditions.

For watersheds with an existing hydrologic model, the existing model can be used in lieu of the USGS regression equations provided the model was calibrated. Such models should, however, be updated to account for developments that occurred in the watershed since the existing model was created.

To determine whether or not new flood discharges should be used, the effective FIS step-backwater computer printouts can be utilized to evaluate the effect of the new discharges on effective 100-year flood elevations. If the new discharges yield 100-year flood elevations that differ from the effective FIS elevations (effective 100-year flood elevations must be obtained from the water-surface profile and not the FIRM) by more than 0.5 foot, a detailed hydrologic analysis would then be conducted. Otherwise, the selected stream should not be restudied at this time, unless other substantial changes in hydraulic conditions exist, such as channelization and construction of flood control structures; or unless there are errors in measurements in the effective study. Results of the preliminary analysis shall be documented in a report to the Regional PO for instructions on the need for detailed hydrologic analyses.

Detailed Hydrologic Analysis

If a revised hydrologic analysis is required, the SC should coordinate with the Regional PO to determine the appropriate detailed methodology. Caution should be used when selecting a methodology for watersheds that are undergoing or are projected to undergo development. In such cases, developing a rainfall-runoff model should be considered in lieu of a gaged analysis with nonhomogeneous data. The factors outlined in Section A of this chapter should be considered in the model.

Parameters in the models should be calibrated with known storms in the study area before determining different discharge frequencies. Computed peak discharges from the hydrologic model should be comparable with the discharges from published USGS regression equations or other appropriate statistical analyses of recorded data. If the discharge values are not comparable, a Special Problem Report must be submitted to the Regional PO to resolve the differences before beginning the hydraulic analysis.

When modeling mixed populations of hydrologic events, the SC should refer to EM 1110-2-1415.

To avoid internal discontinuities in the restudy data, discharge analyses must extend far enough to ensure a logical transition between the restudy and effective FIS data. Should significant discontinuities exist between the updated discharges and the existing FIS discharges, the Regional PO should be consulted and a Special Problem Report completed.

CHAPTER 5. DETAILED HYDRAULIC ANALYSES

A. General Requirements

The SC shall use, to the maximum extent possible, all valid existing flood elevation, survey, and other pertinent information for the study area. Whenever existing 100-year flood elevations are available for the study area, the SC shall assess their validity without undertaking extensive computations or a reanalysis. Except where significant changes in discharges, floodplain geometry, or flooding characteristics have occurred, or errors in the original computations have been found, such elevations shall be considered valid for use in the FIS. If an existing study that contains a valid 100-year flood profile does not provide other profiles or a floodway that may be required for the FIS, the SC shall attempt to obtain the original hydraulic model and use it to generate this information. Whenever the original model is unavailable or unusable, the Regional PO, through the Contracting Officer, may delete the requirement for these additional elevations and floodway data or request that they be determined by a simplified analysis. In any case, the SC shall obtain approval from the Regional PO before conducting hydraulic analyses for flooding sources that have previously established 100-year flood elevations.

The SC should not study areas having a drainage area less than one square mile unless Regional PO approval has been obtained.

Roughness coefficients for use in backwater computations should be carefully estimated by experienced engineers. The estimates should include the consideration that roughness may vary with flood stages, depending on such factors as the width-to-depth ratio of streams, vegetation in the channel and overbanks, and materials of the channel bed. Wherever possible, hydraulic models should be calibrated using measured profiles, estimated profiles, or reliable high-water marks of past floods. Models should match known high water marks within 0.5 foot. The SC should not calibrate to data that results in roughness coefficients out of the realm of observed conditions. If such data are lacking, or are out of date, the roughness coefficients should be determined by field inspection of the channel and floodplain. It is extremely important that roughness coefficients in overbank areas be selected to carefully 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 use of roughness coefficients to define ineffective flow areas must be clearly documented in the FIS.

For guidance concerning areas of shallow flooding and alluvial fans, refer to Appendices 2 and 5, respectively. In addition, for guidance regarding appropriate starting water-surface elevations and supercritical flow areas, refer to Section D of this chapter.

Before proceeding to the preparation of work maps, the 100-year flood profile proposed for the FIS must be reconciled with all published or unpublished information. Any discrepancies must be identified and resolved by the SC in consultation with the Regional PO. Except where a clearly identified change in flooding characteristics or an error in the existing data can be shown, the proposed 100-year flood elevations must agree with those of other contiguous studies of the same flooding source. It is only necessary that elevations be computed to match within ✂0.5 foot of an existing valid elevation; however, the final 100-year flood elevation or profile submitted with the draft FIS report data must be shown to match the contiguous study exactly. Where elevations cannot be reconciled to within ✂0.5 foot because of changed flooding conditions or an error in the previous analysis, a full explanation and justification for the difference shall be provided to the Regional PO in a Special Problem Report. The SC must obtain approval for the discrepancy in 100-year flood elevations from the Regional PO before proceeding.

B. Initial Flood Insurance Study Methodology

1. Flood Elevation Determination

Flood elevations shall normally be determined for the 10-, 50-, 100-, and 500-year floods, unless otherwise instructed by the Regional PO, and referenced to NGVD or NAVD. Flood elevations for riverine areas are normally determined by step-backwater computer models. The U.S. Army Corps of Engineers, Hydrologic Engineering Center's HEC-2 Generalized Computer Program (Reference 8), the U.S. Geological Survey/Federal Highway Administration WSPRO computer model (References 9 and 10), and the Soil Conservation Service's WSP-2 Computer Model (Reference 14) are acceptable for this purpose. Regardless of the hydraulic model utilized, the SC should follow modeling techniques specified in the most recent version of the appropriate user's manual. In addition, the SC should utilize a HEC-2 model from a vendor approved by the Hydrologic Engineering Center. The use of alternative computer programs must be approved by the Regional PO and satisfy the criteria outlined below:

✎ It must have been reviewed and accepted by a government agency responsible for the implementation of programs for flood control and/or the regulation of floodplain lands. For computer programs adopted by non-Federal agencies, certification that the program has been reviewed, tested, and accepted by that agency for purposes of design of flood control structures or of floodplain land use regulation must be provided by a responsible agency official.

✎ It must be well-documented including source codes and user's manuals.

✐ It must be available to FEMA and all present and future parties impacted by flood insurance/floodplain mapping developed or amended through the use of the program. For programs not generally available from a Federal agency, the source code and user's manuals must be sent to FEMA free of charge, with fully-documented permission from the owner that FEMA may release the source code and user's manuals to impacted parties.

The Regional PO should be contacted for a list of currently accepted models.

2. Floodway Determination

A floodway is defined as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water-surface elevation by more than a designated height. Floodways are developed by the SC as unobstructed waterways to convey floodwaters. The floodway, developed by the SC, is coordinated with the community, Regional PO, and, if applicable, with the State Coordinating Agency. The community is responsible for maintaining the conveyance of flooding sources to mitigate flood hazards.

Normally, the floodway will include the stream channel and that portion of the adjacent land areas required to pass the 100-year flood discharge without cumulatively increasing the water-surface elevation at any point more than 1.0 foot above that of the pre-floodway condition. If the state in which the study is being performed has established more stringent regulations for the maximum rise in water-surface elevations, through legally enforceable statutes, then these regulations shall apply. In the case of interstate streams, where opposite sides of the floodplain are under the jurisdiction of different states, the 1.0-foot maximum allowable rise criterion will be used unless the states have previously agreed on a lesser rise criterion. The SC must obtain the written approval of the Regional PO, through the Contracting Officer, before computing or mapping a second floodway based on a criterion established by the community.

When flow is in the supercritical regime, or where velocity conditions are such that normal encroachment analyses are not possible or are inappropriate, the allowable rise shall be applied to the energy grade line instead of the water-surface elevation.

The surcharge values should be between zero and the maximum allowable value. Negative surcharge values may be caused by excessive encroachment, errors in the bridge modeling, or insufficient encroachment at the downstream section. If attempts to eliminate negative surcharges are unsuccessful, the SC shall contact the Regional PO for guidance. Normally, the floodway shall be determined using equal reduction of conveyance on opposite sides of the stream. If equal reduction of conveyance is not technically appropriate, or where unusual flow patterns are encountered (e.g., interbasin flow, divided flow, etc.), the SC shall coordinate with the Regional PO in selecting the most appropriate engineering methods. Where the stream forms the border between contiguous communities, and the floodway designation affects both of them, equal reduction of conveyance <u>must</u> be used.

The computation of a floodway on a tributary stream should be based on the 100-year flood discharge and elevation of that stream only and normally should not include consideration of any backwater flooding from the main stream. Therefore, the floodway elevations in the lower reach of a tributary subject to backwater flooding may be lower than those used to plot the flood profiles.

The SC must consider the maximum allowable surcharge (e.g., 1.0 foot) established at the upstream-most cross section in the downstream community when conducting the floodway analysis for upstream communities. This is necessary to avoid excessive increases that would occur if the floodway in the downstream community was not considered. In addition, the starting water-surface elevation for a floodway analysis at the first cross section should be 1.0 foot above the natural 100-year flood elevation unless a lesser rise criterion is imposed by the State.

If storage areas behind structures are accounted for in the discharge computations by routing the 100-year flood hydrograph, and no encroachment is to be allowed, the floodway encroachment stations should be equal to the 100-year floodplain boundary of the storage area. In this case, the same discharge should be used for the unencroached and encroached profiles in the step-backwater analysis to determine the surcharge values. However, if the storage area is to be encroached, then the discharges for the encroached profile downstream of the structure must be determined by routing the 100-year flood hydrograph through the reduced storage area. In this case, the discharge for the encroached profile can be greater than the discharge for the unencroached profile in the step-backwater analysis.

Floodways are not normally delineated in coastal high-hazard areas (Zones V1-30, VE, and V). The computation of floodways on rivers in coastal floodplains should be based on the 100-year flood discharge and elevations of the rivers only and should terminate at the boundary of the V1-30, VE, or V zone or where the mean high tide exceeds the 100-year flood elevation from a riverine-only flood, whichever occurs further upstream.

The SC shall begin to coordinate all floodway determinations with State and community officials and the Regional Office as early as possible. Where the floodplain is entirely contained within one community, the location of the floodway should be coordinated with the State Coordinating Agency, the community, and the CCO through the Regional PO. This coordination shall not be a reason for delay of the FIS. If the SC is unable to arrive at a final floodway determination prior to the final community coordination meeting, the floodway shall be determined as described above.

C. Considerations for Flood Insurance Restudies

1. Flood Elevation Determination

Except for the cases where errors in measurements or modeling have been found, or where substantial changes in topographic conditions are not reflected in the effective FIS, the cross-sectional and structural information for the hydraulic model must be obtained from step-backwater computer models of the effective FIS and subsequent revisions. In the case of topographic changes, only the affected cross sections should be revised; the remaining data should come directly from the existing models. The SC should review the existing data for accuracy. If errors in the existing data are detected, the Regional PO should be contacted.

It is important to note that a restudy of a community's FIS, FIRM, and/or FBFM may include a flooding source(s) that does not have any established BFEs. In these cases, Section B of this chapter entitled, "Initial Flood Insurance Study Methodology" should be consulted for necessary guidance.

The existing conditions 10-, 50-, 100-, and 500-year flood discharges as determined by one of the hydrologic methods described previously, will be used in the standard step-backwater computer program that was used in the effective FIS to compute the water-surface profiles. The most recent version of the effective FIS computer models should be used to reduce the cost in setting up the hydraulic model. The use of alternative computer programs must be approved by the Regional PO and satisfy the criteria outlined in Section B of this chapter.

Roughness coefficients in the model should reflect existing conditions and should be verified by field reconnaissance and backwater studies of observed floods.

Regional PO approval should be obtained in choosing the standard step-backwater computer program.

2. Floodway Determination

The existing floodway configuration should be retained wherever possible. If it is not possible to retain the existing configuration, then the Regional PO should be contacted for guidance. If a revised floodway analysis is deemed necessary, the information pertaining to floodways as outlined in the previous Section B of this chapter entitled "Initial Flood Insurance Study Methodology" should be consulted.

Because the community has implemented floodplain management decisions based on the effective floodway, the intent of this guideline is to determine initially if the effective floodway can be retained given the changes that have occurred along the restudied flooding source. However, floodway revisions are justifiable and necessary if restudy data indicate an increase in surcharge above the maximum limit, or if, as a result of improved data, the width or configuration of the floodway necessitates a change from that shown on the effective map. When revisions are made to the floodway that will change the effective map, the SC shall notify the Regional PO immediately so that the Regional PO can coordinate with the community as soon as possible in the restudy process.

D. General Modeling Methodologies and Guidance

INTRODUCTION

In the preparation of an FIS, the SC may encounter unique hydraulic situations that require specialized modeling techniques to accurately determine the flood hazard potential. This section provides guidance in handling these situations:

1. Two-Dimensional Water-Surface Computer Models

Two-dimensional (2-D) computer models may be used to determine the water-surface elevations in two directions in the horizontal plane, where one-dimensional computer models may have difficulty analyzing these situations.

2-D computer models may be used for shallow flooding areas, split flow situations, and at complex bridge sites. Although it is not recommended because of the complexities involved and the costs that would be incurred, 2-D models can be used in areas subject to alluvial fan flooding.

These models will only be requested where 1-D models, current accepted techniques, and engineering judgment will not provide satisfactory information for floodplain management and flood insurance purposes. All 2-D models must meet the criteria as specified in 44 CFR 65.6 (a)(6).

Floodways must be developed through an interactive trial-and-error procedure and must be based on equal conveyance reduction.

2. One-Dimensional Unsteady Flow Models

One-dimensional unsteady flow models may be used for floodplains with substantial overbank storage areas, streams where there may be a reversal of flow, and complex pipes, channels, ponds, and reservoir systems.

Any one-dimensional unsteady flow model used must be accepted by FEMA and meet the criteria specified in 44 CFR 65.6(a)(6). The use of any one-dimensional unsteady flow model must first be coordinated with, and approved by, the Regional PO.

Floodways must be developed through an interactive trial-and-error procedure and must be based on equal conveyance reduction.

3. Starting Water-Surface Elevations

In general, the starting water-surface elevations chosen for profile computations should be based on normal depth (or slope-area), unless known water-surface elevations are available from other sources. When using normal depth on the main stream, the model should be started several cross sections downstream of the corporate limits. For starting conditions on tributaries, normal depth should be used unless a coincident peak situation is assumed, or the tributary flow depths are higher than the corresponding main stream events. The assumption of coincident peaks may be appropriate if a) the ratio of the drainage areas lies between 0.6 and 1.4, b) the times of peak flows are similar for the two combining watersheds, and c) the likelihood of both watersheds being covered by the storm being modeled are high. If gage records are available for the basins, guidance for coincidence of peak flows should be taken from them.

4. Modeling Techniques for Streams with Supercritical Flow Regimes

Step-backwater analyses are normally performed from downstream to upstream as subcritical profile runs. Critical depth messages will appear in the backwater runs at several consecutive cross sections, if supercritical flow occurs. For natural streams, critical depth should be used at all times, including the plotting of water-surface profiles. For channel modification projects, a supercritical run should be performed for the project area. For modified channels, the composite roughness coefficient should account for the sediment that accumulates on the channel bottom and for the lined surface of the sides of the channel. The analysis must 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 downstream of the project should be drawn horizontally until they cross the supercritical profiles to eliminate drawdowns. Velocities at the bends should be checked to determine potential erosion. Any deviations from the aforementioned procedures should be approved by the Regional PO.

5. Split-Flow Analyses

Split-flow analyses should be considered when flows overflow the banks of the main stream and take a different flow path. The analyses should address the reduction of flow in the downstream reach with respect to the multiple-flood profile and floodway. Because overbank discharges may flow into another stream, possible increase in discharges on the other stream should be considered. Overflow segment on the main stream should remain open by analyzing a separate floodway for the overflow path, or by a note on the FIRM (or FBFM) stating that the overflow area should remain unencroached until a detailed hydraulic analysis is performed to establish a floodway. The Regional PO should be informed if overbank flow paths lead into another jurisdiction where a floodway is not determined thus necessitating that the overflow area remain unencroached.

The Regional PO may approve, as an alternate, that the SC analyze the floodway on the main stream downstream of the overflow area by computing the floodway with the total flow (including the flow lost as overflow). The SC should compare the water-surface elevations from the total flow computation to the water-surface elevations of the 100-year flood (which has been reduced because of flow lost as overflow) to determine surcharges. If the calculated surcharge is less than or equal to the allowable surcharge, then the floodway is shown on the main stream only. Otherwise, the SC should compute a separate floodway for the overflow path.

CHAPTER 6. APPROXIMATE FLOODPLAIN BOUNDARY DELINEATIONS AND SIMPLIFIED METHODS

Approximate study streams being restudied, or unstudied streams to be analyzed by approximate methods, will fit in one of the following four categories:

1. Flooding sources that will have previously determined 100-year floodplain boundaries adjusted in accordance with updated topographic information.

2. Flooding sources that have new technical information available that can be used in updating approximate 100-year floodplain boundaries.
3. Flooding sources previously unstudied or whose previous 100-year floodplain boundaries are unreasonable from an engineering standpoint; simplified hydrologic and/or hydraulic analyses will be performed to delineate the approximate 100-year floodplain.

4. Flooding sources with previously established Base (100-year) Flood Elevations (BFEs) that are being changed to approximate A zones because of the uncertainty regarding previously computed BFEs. It is important to note that this category is selected by Regional PO.

Where new floodplain boundaries are developed, the SC shall submit a work map with the 100-year floodplain delineated and designated as Zone A. The work map shall also include any hydraulic information generated on water-surface elevations or water depths. All back-up data/calculations used to obtain the 100-year floodplain delineation should be submitted. Unchanged approximate floodplains shall <u>not</u> be redelineated without approval of the Regional PO.

For those areas that will have hydrologic and hydraulic analyses performed, the SC shall select appropriate methods to be used. Common methods are discussed below; the factors of cost, watershed development potential, and existing development should be weighed together when determining the methods to be used. Regional PO approval of the methodology must be obtained prior to initiation of the analyses. In addition, the SC may recommend or the Regional PO may specify that the flood elevations be established using the methods discussed below.

Acceptable methods for hydrologic and hydraulic analyses of approximate floodplain areas and approved 100-year flood elevation areas are listed below. Please note that this is not a complete listing; however, it does contain the methods more frequently used.

✐ Hydrologic Methods for determining the 100-year flood discharge

  - The Index-Flood Method of utilizing statistical analyses of data at meteorologically and hydrologically similar gages to develop a flood frequency curve at an ungaged site.

- Transfer Methods in which peak flows are interpolated from peak flow values upstream and downstream of the point of interest or extrapolated from other sites where frequency curves have been developed.

- Regional regression equations; i.e., U.S. Geological Survey Regional Equations.

- Rational Formula (primarily for drainage areas less than one square mile but not to be used for an area larger than two square miles).

- Soil Conservation Service (SCS) TR-55 urban hydrology procedures (Reference 11).

✎ Hydraulic Methods for determining the approximate 100-year flood elevation

- Normal-depth calculations using Manning's Equation.

- Highway culvert nomographs from "Hydraulic Design of Highway Culverts" (Reference 12).

All cross sections should be obtained from existing topographic maps. Also, the number of cross sections for each flooding source should be minimal; i.e., one or two sections that are representative of the entire stream should be used. Any Manning's "n" values used shall be estimated from field inspection; this effort should also be minimized by choosing a value that is representative of the entire stream.

CHAPTER 7. EVALUATION OF LEVEE FLOOD CONTROL SYSTEMS

The following paragraphs describe procedures for evaluating earthen riverine levees. Procedures for evaluating concrete dikes, floodwalls, seawalls, and other structures shall be coordinated with and approved by the Regional PO. The Regional PO should also be contacted to obtain the appropriate criteria in analyzing agricultural levees. Specific guidance addressing coastal structures are contained in Appendix 1A.

In evaluating the ability of levee systems to provide protection against the 100-year flood, the criteria outlined in Section 65.10 of 44 CFR and the step-by-step procedures as summarized on the proceeding pages should be used. The SC should always initiate its analyses by evaluating the levee's freeboard and maintenance plan and should only proceed with further analyses if these requirements are met.

1. Freeboard. A minimum levee freeboard of 3 feet shall be necessary, with an additional 1 foot of freeboard within 100 feet of either side of structures within the levee or wherever the flow is constricted, such as at bridges. An additional 0.5 foot above this minimum is also required at the upstream end, tapering to the minimum at the downstream end of the levee. The criteria concerning freeboard is detailed in 44 CFR 65.10(b)(1).

2. Structural Design Analyses. The SC must review the structural analyses which address closures, embankment protection, embankment and foundation stability, and settlement. The structural analyses must meet the criteria detailed in 44 CFR 65.10(b)(2),(3),(4) and (5).

3. Interior Drainage. Where credit will be given to levees providing 100-year flood protection, the adequacy of interior drainage systems will be evaluated. Interior drainage systems associated with levee systems usually include storage areas, gravity outlets, pumping stations, or a combination thereof. These drainage systems will be recognized by FEMA only if the criteria outlined in 44 CFR 65.10 (b)(6) and (c)(2) are met.

4. Operations. In general, levee evaluation shall not consider human intervention (e.g., capping of levees by sandbagging, earthfill, or flashboards) for the purpose of increasing a levee's design level of protection during an imminent flood. Only in exceptional cases where no practicable alternative exists and technical justification is provided, will FEMA permit sandbagging to satisfy freeboard requirements. The Regional PO must coordinate all such cases with FEMA. Human intervention will normally only be accepted for the operation of closure structures (e.g., gates or stoplogs) and manual back-up for pumping stations in a levee system designed to provide at least 100-year flood protection, including adequate freeboard as described earlier. Where levee closures and/or pumping stations are involved, an officially adopted operations plan must be submitted that meets all the criteria set forth in 44 CFR 65.10(c)(1) and (2).
5. Maintenance. For a levee system to be recognized as providing protection from the base (100-year) flood, the system must be maintained in accordance with an officially adopted maintenance plan, and a copy of this plan must be provided to FEMA by the owner of the levee system. The specific requirements of the maintenance plan are detailed in 44 CFR 65.10(d). Note that a governmental agency must assume ultimate responsibility for maintenance plans.

6. Certification Requirements. All levee systems must be certified in accordance with 44 CFR 65.10(e).

7. Exception Procedures. FEMA will accept certification from another Federal agency that an existing levee system is designed and constructed to provide protection against the 100-year flood in lieu of the requirements outlined in 44 CFR 65.10(b)(1) through (7). Under certain circumstances, FEMA may also grant exceptions to the above requirements or approve alternate analysis techniques.

The SC shall follow the steps listed below in determining a levee system's ability to provide protection against the 100-year flood. The final decision concerning the creditability of the levee system must be coordinated with the Regional PO before the SC proceeds with further hydraulic analyses.

1. Identify the levee system to be studied, including all "levee elements" (e.g., main levee, tieback levee, railroad or highway embankment), interior drainage elements and any other elements required to form a stand-alone flood-control structure.

2. Determine the ownership of each system element via telephone contact with community officials and/or appropriate State and Federal agencies.

3. Determine the status of all system elements, as presently reflected on the effective FIRM (i.e., credited or uncredited, detailed or approximate study).

4. Obtain from the system element owner, operator (i.e., local, State, or Federal agency; or private individual or corporation), and/or the appropriate FEMA data repository, all available supporting documentation, including but not limited to "as-built" plans; survey data; geotechnical reports; structural analyses; interior drainage analyses; inspection reports; and operation and maintenance plans.
5. Obtain written confirmation of any previous certification by the agency responsible for design and construction that the levee system or elements thereof are Federal projects that provide protection from the 100-year flood, when appropriate.

6. Make an individual inventory of data received for the levee system.

7. Perform hydraulic analyses of the 10-, 50-, 100-, and 500-year floods, assuming the levee system to be in place if these water-surface profiles are not available. Otherwise, assess the available computations for present-day application and modify, if necessary.
8. Use available "as-built" levee profiles or topographic data and the 100-year water-surface profile obtained from the hydraulic analysis conducted with the levee in place to make a determination of the available freeboard of each system element.

9. Contact the Regional PO immediately if any element of a levee system is found to provide less than the required freeboard and notify him or her of the level of freeboard deficiency identified. Based on this discussion and the availability of other design data, the Regional PO may request more detailed surveys of the levee profile or that a risk analysis be performed on uncertainties related to elements of levee design.

10. Review the available operation and maintenance plans to determine whether the plans conform with the requirements of Section 65.10 (c) and (d) and document in writing to the Regional PO any noted deficiencies. The Regional PO will provide guidance on any supplemental investigations necessary to ascertain the adequacy of operation and maintenance plans.

11. Summarize the results and conclusions of the above-mentioned levee investigation in a final letter report to the Regional PO and include as attachments and/or references all correspondence and reports of telephone conversations among the SC, the Regional PO, local, State, and Federal entities, and levee owners; inventories of available data; and field inspection reports and photographs.

12. Summarize the actions taken in the investigation, the ownership of each system element, and the outcome of the investigation in the draft FIS report, under the section headed "Local Flood Protection Measures."

    If the levee satisfies the appropriate aforementioned requirements, as verified by the Regional PO, the protected area (landward side of the levee) will be designated as Zone X or the appropriate zone determined by the interior drainage analysis such as Zone AH. If an interior drainage analysis does not exist or has been determined to be insufficient in the levee investigation, the SC shall coordinate internal zone designations with the Regional PO.

    If the subject levee does not meet the requirements stated in 44 CFR 65.10, as verified by the Regional PO, the 100-year flood elevations will be recomputed as if the levee did not exist. None of the subject levee should be recognized as providing 100-year flood protection unless there are portions of the levee system that can meet requirements of 44 CFR 65.10 independent of the remaining levee system. The 100-year flood levels on the unprotected side of the levee will be equal to the 100-year water-surface elevations computed with the levees in place.

    If the 100-year flood level, with the levee in place, is higher than the top of the levee, the computed 100-year flood levels should be used on the river side of the levee. The 100-year flood levels will then be recomputed for the landward side of the unrecognized levee as if the levee did not exist.

    If water-surface elevations of the other floods (10-, 50-, and 500-year) are higher than the top of the levee elevations, they will also be considered equal to the top of the levee on the unprotected side. If these elevations are lower than the top of the levee, they will be shown as computed on the profile. Further analyses for the conditions without the levees should not be made for frequency floods less than the 100-year.

For the levees that do not satisfy the minimum requirements, a maximum of five flood profiles might be drawn on the profile sheet representing the 10-year, 50-year, 100-year flood with levee, and the 100-year and 500-year flood without levee elevations.

If the "with levee" BFEs are higher than the "without levee" BFEs, the FIRM should show a line, running along the levee centerline, separating the areas of different BFEs. Otherwise, only "without levee" BFEs will be shown.

The floodway widths will be computed for the "without levee" condition if the levees do not meet the requirements of 44 CFR 65.10. The equal conveyance reduction method should be considered, if it is technically appropriate. The "Regulatory" column in the Floodway Data table will show two BFEs, representing "river side" and "land side" conditions, if the former elevation is higher than the latter elevation. Otherwise, "without levee" BFEs will be shown. At a tributary's confluence with the main stream, BFEs from the main stream will be shown as the regulatory elevations if they are higher than the "river side" or "land side" BFEs of the tributary.

The above procedures for the determination of profiles and floodways can also be applied to the conditions where levees exist on both sides of the stream. If levees exist on both sides of a stream, the evaluation of levee systems must consider the possibility of simultaneous levee failure, failure of only the left side, and failure of only the right side. Simultaneous levee failure should be considered for profile and floodway computations.

Floodways will be delineated at the landside toe of mainline and tributary levees that are recognized as providing 100-year flood protection on a FIRM. Thus, the community's floodplain management ordinance will prohibit encroachment upon the levee, which could jeopardize the levee's integrity or effectiveness. It may also be appropriate to place floodways at levees providing a lower level of protection if encroachment on the river side of the levee is of concern to the community. The SC should consult with community officials and the Regional PO in resolving this situation.

For levee systems where an area of land may be totally or partially surrounded by levees or where two or more flooding sources join that have levees on both sides of the stream, the SC should contact the Regional PO before proceeding with any analyses for levee failures. For these complex situations, the flood hazard in the area that would have been protected by the non-failed levee(s) should be based on selection of failure scenarios that yield the highest BFE or flood hazard.

CHAPTER 8. FLOOD INSURANCE RATE ZONES

To assist the insurance agent in determining actuarial flood insurance rates for specific properties, each floodplain or special flood hazard area is divided into flood insurance rate zones that are based on the floodplain boundaries determined in an FIS. Appropriate flood insurance rate zones are delineated by the SC on the work map. Areas within the 100-year floodplain boundary are termed Special Flood Hazard Areas; areas between the 100- and 500-year floodplain boundaries are termed Areas of Moderate Flood Hazard; and remaining areas above the 500-year floodplain are termed Areas of Minimal Flood Hazard.

The areas are subdivided into flood insurance rate zones according to the following criteria:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding with a constant water-surface elevation (usually areas of ponding) where average depths are between 1 and 3 feet. The BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. A description of technical methods used to identify these areas is provided in Appendix 2.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. The depth should be averaged along the cross section and then along the direction of flow to determine the extent of the zone. Average depths derived from the detailed hydraulic analyses are shown within this zone. A description of technical methods used to identify these areas is provided in Appendix 2. In addition, alluvial fan flood hazards are shown as Zone AO on the FIRM. For a comprehensive description of alluvial fan studies, refer to Appendix 5.

Zone A99

Zone A99 is the flood insurance rate zone that corresponds to areas of the 100-year floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No BFEs or depths are shown within this zone.

Zone AR

Zone AR is the Flood Insurance Rate Zone that corresponds to areas of special flood hazard that results from the decertifications of a previously accredited flood protection system that is determined to be in the process of being restored to provide a 100-year or greater level of flood protection.

Zone V

Zone V is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no BFEs are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 100-year floodplain, and areas of 100-year sheet flow flooding where average depths are less than 1 foot, areas of 100-year stream flooding where the contributing drainage area is less than 1 square mile, or areas protected from the 100-year flood by levees. No BFEs or depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible. Zone D designation may not be used in Flood Insurance Studies unless otherwise approved by the Regional PO.

It should be noted that the SC is not required to perform a flood hazard factor analysis and subsequent Zone A1-A30 determination even though this information may currently be reflected on a community's FIRM published in the non-map initiative format.

CHAPTER 9. FLOOD INSURANCE STUDY PREPARATION

A. Map Preparation

To achieve uniformity and efficiency in the production of final FIS products, the review, cartographic preparation, and FIS Report text preparation are centralized. This system permits FEMA to efficiently incorporate minor changes in data or format resulting from review, appeals resolution, or specification changes without delays caused by returning materials to the SC. The SC is required to submit two maps, a community base map, and a draft work map. To minimize SC costs in this area, FIS products are submitted in draft format that comply with the specifications indicated below.

1. Community Base Map

The SC is responsible for obtaining the best available community base map for use by FEMA in preparing and updating the base map for the FIRM. The SC should not undertake any drafting effort or photographic work to provide FEMA with this base map; hand-drawn annotations noting corrections and providing required information may be performed to supplement the base map.

a. Hardcopy Base Maps

The community map provided shall be within the range of scales specified in this chapter. The community map must indicate the current up-to-date corporate boundaries for the community under study and any areas of extraterritorial jurisdiction as of the study submission date. It should be of a good quality material, and not subject to distortion, so that accurate base maps can be prepared or revised by FEMA. It shall show the scale and all current, pertinent cultural features, streets with correct names, railroads, airfields, levees, dikes, seawalls, dams, etc. All streets and roads within or near the 100-year floodplain shall be shown and named. Physical features, such as streams, rivers, canals, flood-control structures, and coastlines, shall be shown and named. It is desirable that the community maps not contain contour lines, lot numbers, or lot lines. However, they need not be removed if shown on available maps. The community base map may be of varied sizes and of multiple or single sheets.

In addition, if no extra cost is involved, the communities may identify selected landmark buildings or other prominent features within or near the floodplains. Examples of landmarks include: courthouse, town hall, church, school, post office, and parks. The landmarks may be displayed and identified on the community base map so that building orientation and the exterior dimensions are reasonably approximated.

b. Digital Base Maps

Digital base mapping files must also include the current up-to-date corporate boundaries for the community under study and any extraterritorial jurisdictional areas. The files shall, at a minimum, meet National Map Accuracy Standards for maps published at a scale of 1:24,000. See Appendix 4 for a detailed discussion of digital map accuracy requirements for new mapping generated using photogrammetric mapping and surveying techniques.

The files must show all current pertinent cultural features, streets with correct names, railroads, airfields, levees, dikes, seawalls, dams, etc. All streets and roads within or near the floodplain shall be shown and named. Physical features such as streams, rivers, canals, flood control structures, and coastlines shall be shown and named.

All of the various features in the base mapping files must be separated by layer/level and color or attribute code. It is desirable that the files not contain vegetation outlines, building footprints, utility lines, lot lines, etc. However, if these features are provided, they must be able to be separated from the other features in the files by either layer/level and color or attribute code.

It is desirable that all feature names, especially road names, be placed in the files at a size and location suitable for plotting at the final FIRM publication scale. (1"=500', 1"=1,000', or 1"=2,000'). A detailed discussion of map scale selection follows this section.

It is also desirable that the digital base mapping files be in vector format, and cover the entire county within which the studied FIS falls. Digital FIRMS (DFIRMs) are generally produced in the countywide mapping format, and obtaining suitable base mapping files that cover an entire county from one source greatly facilitates this process.

Appendix 7 outlines FEMA's criteria for digital files provided to them by other agencies. FEMA will not distribute proprietary digital files to data requestors without written permission from the providing agency. In addition, if required to do so, FEMA may agree to enter into a licensing agreement with a data provider. The SC shall contact the Regional PO if these issues need to be resolved to enable the release of digital mapping files for FEMA's use.

2. **Work Maps**

The work map will be used by FEMA to develop the FIRM in final format for publication. The SC shall provide, in draft format, a neatly compiled work map that contains the flooding and insurance data necessary for the FIRM. The proper symbology to be used on the work map is illustrated in Figure B. This map must be submitted in digital form. As indicated in this chapter and Appendix 7, the compiled work map (original copy) and/or plots of the digital files are to be submitted with the transmittal of the draft FIS data.

GENERAL GUIDELINES - The work map must cover all areas studied by the SC by any method. However, the detailed work mapping described below is required only for areas where the SC has established flood elevations. For areas studied by approximate methods, floodplain delineations may be made as specified below or on copies of the existing FIRM or FHBM for the community. Where information on the existing FIRM or FHBM will remain unchanged, a copy of that map indicating the unchanged areas may be submitted in lieu of a work map. Work maps should be submitted for all study areas determined at the initial CCO meeting.

Where more than one work map panel is needed to show all the data for the flooding source studied, the SC shall include a "JOINS PANEL" label at the edge of each work map.

In detailed study areas, the work map base shall be the best available topographic map, either complete or strip maps, covering the floodplain areas.

MAP SCALE SELECTION - The scale to be used for the work map should be coordinated with the Regional PO prior to preparation of the maps. The following are suggested work map scales for use in preparing draft work maps:

1"=400'
*1"=500'
1"=800'
*1"=1,000'

*preferred scales for digital work map submittals

For panels within unincorporated areas containing flood hazard data determined by approximate methods, a scale of 1"=2,000' may be satisfactory.

When selecting the work map scale, the following factors should be considered:

- Compatibility with Existing FIRM

Existing FIRM scales should be reviewed, and where appropriate, either the same map scales or a compatible map scale should be used for the SC draft work maps. Existing small scale FIRM panels are often remapped at larger scales to
accommodate detailed floodplain mapping with narrow floodplains and/or floodways. To accomplish this at a reasonable cost, FEMA will photo-enlarge the existing base map artwork to be used as-is for the revised FIRM. For example, one panel of an existing FIRM at a scale of 1"=1,000' may need to be photo enlarged by the TEC 100 percent to create four 1"=500' scale panels due to the narrowness of the new floodplain delineations. Thus, it is important that compatible map scales be considered when preparing the work maps (see Table I). Guidance on appropriate work map scales with respect to narrow floodplains is provided in Table II.

If the existing FIRM is at the scale of 1"=1,000', the SC should prepare the work maps at 1"=1,000' (or 1"=500' if the floodplains are narrow). If a work map scale of 1"=400' was used by the SC, FEMA would be required to either photo-reduce the SC work maps to match the existing FIRM base materials or to redraft the entire FIRM to match the SC's work map scale. Both of these procedures significantly increase FIS costs. Compatible map scales are indicated in Table I.

Table I
Compatible Map Scales

Existing FIRM	Work Map
1"=400'	1"=400'
1"=500'	1"=500'
1"=800'	1"=400' or 1"=800'
1"=1,000'	1"=500' or 1"=1,000'
1"=2,000'	1"=500' or 1"=1,000', or 1"=2,000'

- Floodplain Width

When the floodplain/floodway width of the new or revised floodplain mapping is narrow (less than 1/2 inch), selecting a scale for the work map is crucial to the usability of the final FIRM. Table II provides some guidelines to be followed when choosing appropriate scales for maps with narrow floodplains.

Table II
Work Map Scales for Narrow Floodplains

Existing FIRM	Work Map
1"=400'	1"=400'
1"=500'	1"=500'
1"=800'	1"=400'
1"=1,000'	1"=500'
1"=2,000'	1"=500' (if floodplain width is 1/4" or less; 1"=1,000' if floodplain width is greater than 1/4")

- Multiple Work Map Scales

  Sometimes it is best to use more than one map scale when preparing the SC work maps; however, these scales should be compatible (see Table I and the previous discussion of work map scales).

- Data Compilation and Data Capture Scale

  Existing digital data may affect the scale of data compilation chosen. If community base mapping and contours are available at a scale greater than 1"=400' (e.g., 1"=200'), the SC, with the approval of the Regional PO, may choose to compile and digitize the FIS data at that scale. Checkplots may be delivered at a scale other than the manuscript or compilation scale.

- Compatibility with Contiguous Communities

  When preparing an FIS that impacts several jurisdictions such as a countywide FIS, it is important to consider map scales that are compatible with the existing FIRMs for both the surrounding unincorporated areas and incorporated communities. It is much more common to change the scale of an incorporated community than redraft an entire county map. Therefore, in general, if it is anticipated that the study/restudy/LMMP would result in a countywide mapping effort, selecting a scale that is compatible with the county's FIRM is exceedingly important. Compatible map scales are indicated in Table I.

- Special Requests

  A community may request that their FIRM be prepared at an unusual scale to meet their specific needs. Prior to preparing work maps at a specific scale requested by the community, such requests should be approved by the Regional PO.

- Urbanization

  Urbanization within the community's floodplain should also be considered when selecting an SC work map scale. When proposed or current development impacts the community's floodplain, a scale of 1"=400' or 1"=500' is preferred.

- Paneling Scheme

The SC shall coordinate the paneling scheme and scale of mapping used for data capture and work maps with the Regional PO and FEMA's TEC before beginning the work maps. If DFIRMs are produced for a county from the information produced by the SC, the existing FIRM paneling scheme will be revised. The DFIRM paneling scheme follows that used by USGS for their 7.5-minute quadrangle series, or subdivisions thereof. The paneling scheme chosen by the SC shall be approved by the Regional PO before the work maps are generated.

Work Map Content - The following minimum information should be shown in and near the floodplains on the work map:

- Cultural features, such as railroads, airfields, streets, roads, highways, levees, dikes, seawalls, dams and other flood-control structures, and other prominent man-made features and landmarks
- Hydrographic features, such as rivers, streams, lakes and ponds, coastlines, tidal flats, canals, and channels (including both banks of a stream when graphically possible)
- Corporate limits, extraterritorial jurisdiction limits, and boundaries of excluded areas
- Grid lines (State Plane or UTM) with appropriate values annotated.

The work map may contain, but is not required to show, building outlines, spot elevations, property lines, section lines, and details of areas outside the corporate boundaries. Areas shown on the work map that are excluded from the community under study should be delineated by a solid line border and labeled "AREA NOT INCLUDED." The name of any excluded areas should also be provided within the appropriate map area.

- Area Not Included

  An "Area Not Included" is defined as an area excluded from the mapping of the subject community because (1) it is under the jurisdiction of another community and is mapped on the FIRM for that community, or (2) access to the area is limited due to security reasons (e.g., military installations, Indian Reservations). The SC should submit any available flood information within these areas. The decision for depicting the information on the FIRM is the responsibility of the Regional PO.

  Please note: areas subject to Federal or State jurisdiction such as Parks, National Forests, Game Reserves, and certain military bases should normally not be excluded from the FIRM. When the SC encounters an area such as these, the Regional PO should be consulted for guidance. The SC may be requested to assess and delineate Special Flood Hazard Areas (SFHAs) in these areas using available source maps, such as USGS flood-prone quads. Where existing SFHA delineations on an effective FIRM are terminated at the boundary of an improperly excluded area, the Regional PO may request that the SC use detailed topographic mapping to extrapolate floodplain boundaries through the subject area.

  All data should be clearly drawn on the work maps. Other symbols identifying the various floodplain boundaries and/or other necessary information must be clearly defined. The SC is to place a scale and a legend of any nonstandard FEMA symbols used directly on the map; lettering is to be neat, easily read, and of a size appropriate to the map scale.

The work map must be submitted on stable translucent matte drafting film (polyester, minimum 0.004 inch), and show 100-and 500-year floodplain boundaries, base flood elevations (BFEs), flood insurance rate zones, floodway boundaries, cross-section lines and their labels, and any other pertinent planimetric features located in, or directly adjacent to, the flood hazard areas; the names of these items should be provided on the map. Whenever corporate limits and extraterritorial boundaries coincide with the floodplain boundaries, only the corporate limits should be depicted. The SC must maintain legibility and accuracy when preparing the work map. Refer to Appendix 7 for specifications for digitally generated work maps.

- <u>Flood Boundaries and Floodways</u>

  For streams studied in detail, the 100-year floodplain boundary is to be shown on the work map as a continuous solid line. The 500-year floodplain boundary is to be shown as a line with intermittent dashing. Approximate 100-year floodplain boundaries are to be shown by lightweight, short dashed lines. The boundaries shown on the work maps must be consistent with the flood elevation determinations. In cases where the 100- and 500-year floodplain boundaries cannot be shown separately due to the map scale, only the 100-year floodplain boundary should be shown. Care should be taken to ensure that the floodplain delineation is in agreement with the local topography.

  Zone X areas that are within the limits of the 500-year floodplain (formerly Zone B) should be outlined and labeled. Zone X areas that are outside the limits of the 500-year floodplain (formerly Zone C) should be labeled Zone X (unshaded).

  The floodway boundary is to be shown by long, dashed lines. The floodway widths shown on the work map must be consistent with the widths given in the Floodway Data table, and must be plotted to within a maximum tolerance of 5 percent of the map scale. In cases where the floodway and the 100-year floodplain boundaries cannot be shown separately due to the map scale, only the floodway boundary should be shown. When a floodway boundary follows an existing feature, such as a levee or road, it should be clearly indicated.

- <u>Unnumbered Zone A Areas</u>

  If the SC plans to utilize automated floodplain boundary generation techniques, with HEC-2 data and a Digital Elevation Model or Digital Terrain Model as inputs to the program, and areas of unnumbered Zone A fall within the study area, the SC should consider including the remapping of these areas in the scope of work proposed to the Regional PO.

- <u>Cross Sections</u>

  The locations of all cross sections listed in the Floodway Data table should be shown. The lines drawn should correspond to the actual sections studied and should cross the entire 500-year floodplain. They should be identified by the same letters on both the Floodway Data table and the flood profiles. Locations of cross section lines on the work map must correspond to the cross section locations on the flood profiles. Lettered cross sections should be chosen such that they will roughly duplicate the 100-year profile. If, due to map scale, the map is crowded, cross sections may be deleted.

Numberic labels for cross sections on navigable rivers with established mile markers may be used if the Regional PO approves.

Distances between cross sections, as measured along the stream channel or hydraulic base line, <u>must agree</u> with corresponding distances shown on the flood profiles to within a maximum tolerance of 5 percent of the map scale. This tolerance applies to deliverable materials, not to information maintained in supporting files.

- <u>Base Flood Elevations (BFEs)</u>

  BFEs represent 100-year flood elevations and are shown by wavy line contours drawn <u>normal to the direction of the flow of floodwater</u>; they should extend completely across the 100-year floodplain. Each contour should indicate its elevation above NGVD or NAVD or appropriate datum, measured to the nearest whole foot. For streams studied in detail, BFEs are to be shown on the work map where necessary to reconstruct the 100-year flood elevations shown on the flood profile to an accuracy of ±0.5 foot. If BFEs are plotted correctly, the FIRM should be able to be used to recreate the flood profile to within an accuracy of ±0.5 foot. The following guidelines should be followed when plotting BFEs on the work map:

  - BFEs should be plotted at significant profile inflection points or as close to them as possible. Significant profile inflection points are those points along the 100-year flood profile that exhibit a well-defined change in slope. These points are critical to the accuracy of the map because the profile could not be reproduced accurately without them.

  - Intermediate BFEs should be plotted between inflection points. Intermediate BFEs should be placed at their whole-foot locations whenever possible. To determine the proper interval at which to plot intermediate BFEs, the main factor to be considered is the profile slope (gradient). The following guidelines shall be used, keeping in mind that the profile slope should be relatively constant between inflection points:

    1. If BFEs rise less than 1 foot per 1 inch of map distance, plot the BFEs at every whole foot of elevation rise. Intermediate duplicate BFEs may be added on very gentle slopes as needed for clarity.

    2. If BFEs rise more than 1 foot, but less than 5 feet per 1 inch of map distance, plot the BFEs at approximately 1-inch intervals.

    3. If BFEs rise 5 feet or more per 1 inch of map distance, plot the BFEs at 0.5-inch intervals of map distance or at 5-foot intervals, whichever is greater (i.e., whichever results in a wider BFE spacing).

- Plot BFEs perpendicular to the floodplain, not necessarily perpendicular to the stream. The exception to this rule is the need to skew a BFE to account for the backwater effects of hydraulic structures such as bridges.

- BFE lines are to be drawn at, or within approximately 0.5 inch of, both sides of all hydraulic structures, confluences of detailed study streams, the upstream and downstream limit of each detailed study area, and at the corporate limits.

- BFEs should not be placed on top of roads or other structures, or other features such as corporate limits. Allow for 1/10th inch between BFEs and other features. BFEs may be placed on cross sections if necessary, but it is advisable to move the BFE slightly (1/20th inch) to avoid an overprint.

- Backwater areas must contain BFEs as needed to ensure ease of elevation determination. As a general guide, backwater areas need BFEs if they are twice as long as they are wide.

- Where the BFE is uniform within a ponded, tidal, or lacustrine area, it shall be notated "(EL XXX)," and placed immediately below the zone label.

- Elevation Reference Marks (ERMs)

  All ERMs located or obtained in the course of the FIS must be in their exact locations on the work map. The tabulation of the ERM descriptions shall be included in the FIS report data.

- Map Index

  For every community that is of a geographical size requiring more than one map panel, an index to map panels must be prepared. The index should show the entire jurisdictional area of the community and the panel number for each map panel. The index sheet should be on an existing map base, and it need not be reproducible. The SC is not required to create a final FIRM Index for direct use by FEMA.

- Restudied Areas

  When conducting a restudy or LMMP, the SC at the Regional PO's direction, may contact FEMA to obtain a positive translucent matte drafting film of the FIRM base map information for use in preparing work maps. The SC may then register strip topographic maps to the matte and plot hydrologic features and floodplain boundary information previously described. This process may result in a significant cost saving during the study process since the SC is delineating new or revised floodplain boundaries on the existing FIRM base.

3. Digital Work Map Specifications

A digital FIS submittal will be comprised of the following items:

- Digital base map file(s)
- Digital Flood Insurance Study files (work map files)
- Digital Elevation Model (DEM) or Digital Terrain Model (DTM) if used
- Hard copy plots
- Map index
- Data quality report
- Computer generated profiles
- Digital data submission checklist

The SC is responsible for obtaining and providing these materials and assuring that the accuracy of the data in the submitted files meets or exceeds National Map Accuracy Standards for maps at a publication scale of 1:24,000, and that the data meet FEMA's criteria for release of digital data.

As specified in Appendix 4, when new photogrammetric mapping and surveying are included in the scope of work, the SC is also responsible for utilizing surveying and mapping procedures, within floodplains and adjacent buffer zones, that are appropriate for 1"=500' (1:6,000-scale) maps, with a 4-foot contour interval, which satisfy the American Society for Photogrammetry and Remote Sensing (ASPRS) 1990, Class I standards.

Coordination with FEMA is recommended before beginning a digital FIS submission, to clarify data format requirements and scope of work.
Appendix 7, Digital Product Delivery Specifications, outlines all requirements for digital data submission.

B. <u>Flood Profiles</u>

Profiles should be neatly drawn and lettered on standard 11"x17", 10x10 to the inch grid, mylar profile sheets. At the SC's request, the Regional PO may provide assistance in obtaining blank standard mylar profile sheets. Use of non-standard profile sheets (i.e., continuous computer-generated profile sheets or paper copy vs. mylar) must be coordinated and approved by the Regional PO. If the use of a continuous profile sheet is approved, the SC must assure that the selected vertical scale would not be a cause for the TEC's replotting of the profiles; i.e., the TEC should be able to trace-draft the submitted continuous profile sheet onto standard 11"x17" mylar profiles (see "Scale" below). The symbology and format to be used is shown in Figures A and B.

The datum should be NGVD or NAVD unless another datum is authorized by the Regional PO. Profiles should be continuous for the entire stream length studied in detail. The water-surface profile of the 10-, 50-, 100-, and 500-year floods and the channel bottom (stream bed) or hydraulic base line should be drawn. Breaks in the profile shall not occur for stream segments passing through areas not included or where the stream and floodplains leave and return to the community. Profiles are also required for those watercourse segments that may not lie within the community, but do contribute to the flood inundation within the community. Profile limits should include areas where the stream has left the community, but flood inundation continues. These limits which are located outside the community should be labeled "Limit of Flooding Affecting Community." On the profiles of tributary streams, 100-year flood backwater from the main watercourse or water body should be labeled "Backwater from (main stream name)."

Sudden drawdowns should be eliminated at structures. Drawdowns not located at structures should also normally be eliminated from the profiles. Computer-drawn profiles may be submitted in lieu of hand-drafted profiles; however, the profiles must conform to the criteria stated in these Guidelines.

Any well-documented high-water marks of past major floods that are discovered during the reconnaissance should be shown and referenced on the flood profiles.

- Scale - An elevation scale (vertical) of 1 inch equals 1, 2, 5, 10, or 20 feet should be used. Use of non whole-foot scales (e.g., 1 inch = 2.5 feet) must be approved by the Regional PO. Elevations should be shown on the left side of the grid at 1-inch intervals within the profile elevation range. Elevations need not be shown on the right side of the grid. The profile plottings shall agree to at least 1/20 inch of the 100-year regulatory flood elevations provided in the Floodway Data table.

  The stream distance scale that is used should be chosen so that the profile measures at least 3 inches in length and the average slope across the profile page does not exceed 35 degrees. When determining scales, consideration should also be given to the total number of profiles that will be created. A horizontal scale of 1 inch equals 100, 200, 400, 500, 1,000, or 2,000 feet is preferred. The horizontal scale should be labeled at 1-inch intervals along the bottom edge of the grid and legend box. The use of miles, and fractions thereof, should be avoided except for major streams where a reference system in miles has already been established; however, the units for any one stream must be consistent. Stationing notation (i.e., 100 + 00) should be converted into conventional feet measurement. Stationing should be referenced from a physical location such as a confluence, structure, etc. Corporate limits should only be used as a last resort for profile stationing. Downstream elevations should begin on the left edge of the grid. Stream distance is measured along the stream channel centerline or some other hydraulic base line as defined and delineated on the maps by the SC. Distance and elevations units used on a profile must be consistent with the units provided in the computer printout and should agree with the units used on the Floodway Data table.

- Cross Sections - Profile cross sections must be plotted at distances that are consistent with tabularized data and work map locations. All cross sections are to be labeled in alphabetical sequence, labeling each new stream or tributary with A and continuing to Z, AA, AB, AC . . . AZ, BA, BB, BC, as required.

- Physical Features - All hydraulic structures, points of confluence, corporate limits, and other pertinent information must be indicated on the profiles. Points of confluence for entering tributaries shall be labeled, "Confluence of ____________________________."

  For bridges, top of road (TOR) and low steel (LS) should be represented by the conventional symbol, "I," where TOR is represented by the upper horizontal bar, LS by the lower bar, and the center of the structure by the vertical bar. For high level bridges where the symbol cannot be shown on the profile TOR and LS elevations should be indicated.

For culverts, the symbol should represent the overburden; the culvert pipe is assumed to be the open area between the stream bed and the bottom of the overburden.

- Restudied Streams - In the preparation of flood profiles for restudied streams, the existing FIS format must be maintained. For example, the existing horizontal and vertical scales utilized in the effective FIS should be used. Stationing notation and datum reference must be consistent with effective profiles in order for FEMA to perform any modifications in a cost-effective manner.

  All profiles for restudied streams must reflect all required recurrence interval flood elevations as specified in the contract and must reflect the stream bed or hydraulic base line. All structures reflected on the effective FIS profile as well as any new structures must be depicted on the revised profile. All cross sections shown on the revised FIRM (or FBFM) and Floodway Data table must be clearly reflected on the submitted profiles. Any deviations from the effective FIS profile format must be authorized by the Regional PO.

  The backwater area on profiles for tributaries that flow into a revised stream must be adjusted to reflect the revised elevations.

Please note that FEMA has developed a computer program, FISPLOT, that enables study contractors to generate computer plotted flood profiles that meet the requirements described above. The FISPLOT program allows users to create drawing interchange format (*.DXF) files from HEC-2 input and output files. FISPLOT may later be enhanced so that it can generate flood profiles from other backwater computer models, such as WSPRO and WSP2. Briefly, FISPLOT is set up so that most FEMA-required profile entities are obtained from three files the program creates. These three files are:

1. Project Data File

   This file lists the complete community name, the flooding source, the limits of detailed study, the number of flood frequencies analyzed, the starting profile number, and the starting lettered cross section.

2. Water-Surface Elevation Data File

   This file presents, in tabular form, the following information obtained from the HEC-2 formatted output Summary Table 150; section number, channel invert, and the 10-, 50-, 100-, and 500-year flood elevations. In this file, a user can designate which cross sections will be labeled as lettered cross sections.

3. Landmark Data File

   This file reads HEC-2 input files and generates, in tabular form, the following structure information: section number, structure-specific geometric information. This table also indicates whether the structure is a bridge, a culvert, or a dam.

The FISPLOT-generated *.DXF files can then be imported into AutoCAD® and all the appropriate FEMA symbols, such as bridge deck information, are displayed in an AutoCAD® drawing (*.DWG) file.

If the SC would like to obtain a copy of FISPLOT to generate computer plotted flood profiles, the Regional PO should be contacted.

C. Preparation of the Flood Insurance Study Report Data

Preface

The presentation of the facts, figures, and results of an FIS in a concise, standardized format is required. Not only does the FIS report stand as the basis for actuarial flood insurance premium rates, but as a key reference for the community in establishing sound floodplain management measures.

The SC is expected to submit all appropriate data as outlined on the FIS report data checklist (Figure C). This checklist requires that the SC provide only the necessary data that apply to any particular study; FEMA will supply standard paragraphs during processing of the FIS. The SC should not undertake any effort to create a complete draft FIS or to redraft original FIS report materials. Any effort beyond that of completing all appropriate portions of the checklist unless approved by the Regional PO is beyond the SC's scope of work.

The SC should utilize the community's effective FIS and FIRM, and FBFM, if applicable. If not available or produced, please contact the Regional PO to obtain a copy of a sample FIS report.

CHAPTER 10. REVIEW FOR QUALITY ASSURANCE

PREFACE

This chapter presents guidelines that are to be used by the SC in assuring the quality of FIS report data submittals. The SC should review this chapter prior to submitting the draft FIS Report data. The suggestions contained in this chapter are intended to facilitate the SC's internal review and are not to be construed as additional contractual obligations.

The guidelines in this chapter are presented in the format of typical problems encountered in the process of reviewing FIS report data submittals. Where the solution to a particular problem may not be obvious, a suggested solution is presented. The SC should also be cognizant that certain data developed in the course of performing a study might be useful in resolving questions that could arise during the review and processing of FIS report data. Some of these additional data submissions are incorporated as suggested solutions to specific problems.

A. Typical Problems

There are typical problems encountered in the review of FIS report data submittals. These problems may generally be categorized as follows: a) internal data consistency problems, b) external data problems, c) data submittal problems, d) methodology application problems, and e) digital data problems. This section identifies the most significant of these problems and offers a solution where none is obvious.

1. Internal Data Consistency

The basic problem of internal data consistency is the lack of agreement among the various data sources included in a submittal. Many of these problems arise from non-compliance with tolerances given in various sections of these Guidelines. Typical problems in this category which must be resolved by the SC are as follows:

- Locations and names of physical features on the work maps do not agree with those on the flood profiles.

- Physical features and structures modeled and shown on the flood profiles are not shown on work maps.

- Physical features and structures shown on work maps, but not modeled, have not been documented as such.

- Cross-section locations on the work maps do not agree with flood profiles.

- Cross-section locations on the flood profiles do not agree with tabulations in the Floodway Data table.

- Distances between cross sections on the work maps do not agree with distances on flood profiles.

- Distances between cross sections and features on the flood profiles do not agree with distances indicated in the computer printout.

- 100-year flood elevations on profiles do not agree with the regulatory column of the Floodway Data table.

- BFEs (rounded) on work maps do not agree with 100-year flood elevations on the flood profiles.

- Floodway widths on work maps do not agree with widths tabulated in the Floodway Data table or those indicated in the computer printout.

- Floodway and floodplain boundary delineations do not agree with data determined at cross sections.

- Locations of ERMs on work maps do not agree with the tabulation of ERM descriptions; road names on work maps do not agree with those given in the ERM descriptions.

2. External Data

External data problems concern the lack of agreement with contiguous FISs or with other reports published by authoritative sources. The Regional PO should be contacted to resolve these types of problems. Typical problems in this category are as follows:

- Discharges do not match those used in contiguous FISs or other authoritative reports.

- BFEs do not match those in contiguous FISs.

- Flood hazard zones do not match those in contiguous FISs.

- Floodplain boundaries do not match those delineated in contiguous FISs.

- Floodway widths do not match those in contiguous FISs.

- Survey data do not match those used in contiguous FISs.

- Corporate limits do not match those delineated in contiguous FISs.

- Extent and magnitude of coastal flooding not consistent with authoritative reports is not adequately explained.

- The datum used for modeling storm surge is not consistent with the datum used in the wave height analysis.

3. Data Submission

These are problems that arise from incomplete submittals of required data. The SC should be cognizant that the submittal of certain other data items is not required, but that the inclusion of these data items in a data submittal might provide enough information to clarify certain unusual or difficult situations. Typical problems in this category are as follows:

- Community base map and/or work map does not contain required data.

  Refer to Chapter 9 of these Guidelines for community base and work map data requirements.

- Required data absent from the draft FIS report data submittal.

  Refer to Figure D of Chapter 9 of these Guidelines for FIS data submittal requirements.

- Unusual conditions, necessitating departure from conventional methodologies, exist in the study area.

  Identify the area and document all procedures necessitated by unusual conditions, citing references and presenting calculations. Use handwritten or coded comments in computer printouts to clarify unusual modeling situations. Include detailed printouts, channel cross-section plots, and photographs as aids in explaining unusual situations or decisions that require departure from normal procedures. Reference all communications with appropriate officials authorizing unusual procedures.

- Data tables, work maps, and flood profiles do not reflect data contained in computer printouts.

  Assure that the latest runs have been submitted, and that all data presented in data tables and on work maps and flood profiles reflect these latest runs. Assure that all data on the work maps, flood profiles, and data tables have been correctly identified in annotated printouts.

✐ Lack of specific and detailed information regarding flood protection structures that comply with FEMA levee policy.

Ensure that all applicable data and information regarding flood protection structures complying with FEMA levee policy have been submitted.

4. Methodology Application

There are problems involved in the application of various methodologies used to conduct an FIS. Chapters 4 and 5 and the Appendices of these Guidelines provide general information on, and references to, specific methodologies that have been developed for and adopted as standards for conducting an FIS. Methodology application is also an area where the submittal of additional data items, developed in the course of conducting an FIS, but not specifically required, often proves to be useful in documenting assumptions and procedures required in certain instances.

One such instance occurs when unusual situations exist in the study area requiring departure from, or modification to, the application of standard FIS methodologies. Complete documentation of all assumptions, methodologies, and deviation from standards is required by sound engineering practice. Typical methodology application problems are:

✐ Application of methodologies deviates from standards.

Include documentation of all assumptions made. Cite references and include data and calculations. Reference all sources used. Include detailed computer printouts, detailed cross-section plots, and photographs of areas affected. Include records of communications with appropriate officials authorizing departure from standard methodologies.

✐ Bridges or culverts not coded correctly, specifically in the use of normal bridge and special bridge routines for HEC-2 modeling.

Include documentation of assumptions made in choosing bridge routine. Include detailed cross-section plots, bridge or culvert plans, and photographs of the structures.

✐ Manning's "n" values appear to be unrealistic.

Include documentation of assumptions. Include photographs of overbank areas, structures, and channels, where available.

✐ Expansion and contraction coefficients deviate significantly from suggested values.

Include documentation of assumptions. Include photographs and engineering or construction plans of structures or channel areas.

✐ Floodway boundaries are irregular; transition between cross sections is not smooth.

Assure that floodway run has been optimized. Assure that all ineffective flow areas have been properly considered and removed, where appropriate.

5. Digital Data

Problems may arise from incomplete or poorly documented submissions, specifications not being followed for layer/level and color or attribute, file transfer problems, etc. These problems may arise in files prepared by the SC or their subcontractors, or may be inherent in files provided by local or State agencies. Some of these items could cause considerable rework, either on the part of the SC or FEMA, and should be checked for at the initial stages of the mapping process. The 10-percent submittal is designed to identify problems of this nature.

Automated checking routines are employed by FEMA to review the files submitted by the SCs, and in some cases, depending on the software platform used by the SC, this software may be made available to the SC. Software may also be available for use in data capture and data coding, and its use by the SC would reduce potential problems that would need to be resolved later. Typical problems in the category of digital data include:

- Incomplete file documentation, including not enough information on data sources, projection, datum, x or y shift used, layer/level list not provided, etc.

  Include a completed "Digital Data Submission Checklist" for all files submitted.

- Layer/level list does not match the actual data file structure.

- FIS features are digitized on wrong layers/levels, or contain incorrect attribute codes.

- Coincident features are not separated from non-coincident segments.

- FIS files contain gaps or overshoots in the linework.

  Check the data files for "clean" data capture. Most GIS, and some digital mapping software packages, have a built-in capability to check for this and assist the user in cleaning the data.

- Digital floodplain boundaries cross each other. (For instance, the 500-year floodplain boundary crosses the 100-year floodplain boundary and falls within it for a reach.)

- Digital files contain splines, arcs, or curves.

- Text size is not appropriate for the final DFIRM publication scale.

  Coordinate the scale of data capture and work map generation with the Regional PO before beginning the study.

- Base map files are not separate from FIS files.

- Base map features are not separated by layer/level and color or attribute code.

  Specify FEMA's needs for data separation to the providers of base mapping data files.

- Digital data capture is not smooth.

Ensure that the scale chosen for data capture is compatible with the final DFIRM publication scale.

✐ File format is not compatible with FEMA's.

Provide a sample data file at the 10-percent milestone.

NOTE: SCs are encouraged to utilize the Global Positioning System (GPS) to perform QC on mapping within floodplains and to determine if the maps meet ASPRS 90 standards for Class 1 maps. The ASPRS standards (developed for digital mapping) would require a minimum of 20 horizontal and 20 vertical test points to be measured utilizing GPS to determine the magnitude of errors as mapped by Photogrammetric Subcontractors.

CHAPTER 11. DELIVERABLE ITEMS

All items discussed in this section are deliverables as specified by the Regional PO. These items are to be organized into the Technical Support Data Notebook (TSDN) to be created by the SC for each community under study. The TSDN is to be organized and submitted according to the format and instructions provided in this chapter of these Guidelines and in the Guide for Preparing Technical Support Data Notebook which is a supplemental document to these Guidelines.

Items to be submitted in the TSDN will include the original FIS products, such as the draft FIS Report data which may include the following FIS tables as required: Summary of Discharges table; Summary of Stillwater Elevations table; Floodway Data table; Transect Descriptions table; Transect Data table; tabulation of ERM descriptions and locations; and Coastal Storm Parameter Data table. Also included with the FIS Report would be photographs of historic floods or possible future flood levels, flood profiles, transect location map (coastal), work maps, and associated technical support data (such as hydrologic and hydraulic computations and analyses, survey data, general correspondence, and documentation). The completed TSDN will be submitted to a TEC as specified by the Regional PO. The TSDN should be bound, preferably using three-ring binders. The TSDN shall be organized as indicated below.

1. General Documentation

    i) Special Problem Reports
    ii) Contact (Telephone Conversation) Reports
    iii) Meeting Minutes/Reports
    iv) General Correspondence
    v) Certification Forms and Instructions for Study Contractors (these forms may be obtained from the Regional PO)

2. Engineering Analyses

    Input and summary output printouts (final runs) of computerized hydraulic and hydrologic computations shall be submitted for coastal areas to include coastal study documentation as outlined in Appendices 1, 1A, and 1B.

    i) Hydrologic Analyses (in printout form and computer diskette if applicable)
    ii) Hydraulic Analyses (in printout form and computer diskette)
    iii) Supporting hand calculations, sketches, and figures used to compute hydrologic and hydraulic analyses.
    iv) Key to Cross-Section Labeling
    v) Key to Transect Labeling

3. Draft FIS Report Data

    The draft FIS Report data will include profiles and tables.

FIS Report data shall be prepared as shown in the FIS Report Data Checklist discussed in Chapter 9 and included as Figure D of these Guidelines. In submitting this material, the SC shall not prepare camera-ready copy of any report materials, and should not undertake any final typing or drafting. The SC shall submit the materials below upon completion of the work. Two copies of these materials (do not send originals) shall be sent to the appropriate FEMA Regional office.

4. Mapping information, including base maps and work maps or plots (the original copy) on stable translucent matte drafting film (polyester, minimum 0.004 inch).

5. Miscellaneous reference materials.

6. Certification

The following certification, signed by a senior representative of the firm who is registered as a Professional Engineer (private SCs) or the responsible official (government agencies), shall be submitted:

This is to certify that all work accomplished in the conduct of this FIS was done in accordance with the Statement of Work and General Provisions of Contract ____________ (or, in the case of Federal agencies, IAA ____________), and all amendments thereto, together with all such modifications, either written or oral, as the Regional PO and/or the Contracting Officer or their representatives have directed, as such modifications affect this contract, and that all such work has been accomplished in accordance with sound and accepted engineering practice within the contract provisions for respective phases of the work. This statement is included in the Certification Forms and Instructions for Study Contractors, which are an addendum to these Guidelines.

A. Technical Support Data Notebook - Engineering Study Data Package

These Guidelines establish revised procedures pertaining to the organization, identification, and submission of the draft FIS Report data and associated technical support data developed by SCs during FIS preparation.
These procedures will facilitate FEMA's practice of developing an Engineering Study Data Package (ESDP) containing all relevant technical support data for each FIS. To reduce storage requirements, most of the technical support data is transferred to microfilm. Some materials, such as the SC work maps, are maintained within the ESDP storage facility in hard-copy. The data retained as part of the ESDP is often utilized by FEMA contractors, private firms and individuals, and other Federal, State, and local governmental agencies for future risk assessment purposes. Therefore, it is essential that the submittal of the FIS Report data and the associated technical support data for each FIS be well prepared and organized to assure that the materials will microfilm well and that they are carefully documented for ease of future use.

The revised procedures require the SC to incorporate all essential FIS data, including the draft FIS components (FIS report data, tables, profiles, work maps, and engineering analyses) and the technical support data generated during the FIS process, into one comprehensive data package to be known as the Technical Support Data Notebook (TSDN). Upon completion of the study, the TSDN will be submitted to the appropriate TEC. In order to respond to technical issues raised during review and processing of the FIS, the SC is to retain copies of support data relating to the hydrologic and hydraulic analyses.

Under the refined procedures, FEMA will now incorporate the essential data it develops during the technical review and processing phases with those data submitted by the SC in the TSDN. This combined TSDN package will be forwarded to FEMA's ESDP facility to be microfilmed and prepared for future access by FEMA, its contractors, private engineering firms, and individuals.

Specific instructions concerning the organization, identification, and submission of the FIS report data and associated technical support data by the SC are contained in the following section of these Guidelines and in the Guide for Preparing Technical Support Data Notebook, which is a supplemental document to these Guidelines.

B. Preparation of the Technical Support Data Notebook

The SC shall create and submit a TSDN containing the original study products (e.g., FIS report data, flood profiles, data tables, and work maps), associated technical support data (e.g., hydrologic and hydraulic analyses, survey data, general correspondence, documentation, and mapping information), and the appropriate completed Certification Forms.

The SC shall be responsible for preparing the TSDN in accordance with the format and instructions provided in these Guidelines and the Guide for Preparing Technical Support Data Notebook.

A separate TSDN shall be submitted for each community studied. In those cases where the data developed pertain to more than one community's FIS, the SC shall either provide duplicate copies of those data for each community's TSDN or provide detailed cross-referencing of those data in each TSDN.

The TSDN is comprised of five major sections:

- General Documentation
- Engineering Analyses
- FIS Report Data (Draft FIS Report Text)
- Mapping Information
- Miscellaneous Reference Materials

The specific requirements for the data to be included in each of these categories are discussed as follows:

1. <u>Data Organization</u>

Within the TSDN, the SC shall organize the FIS data into the following five categories:

(a) General Documentation - This category includes written documentation that pertains to the general processing of an FIS. Items such as Special Problems Reports; contact (telephone conversation) reports; meeting minutes (such as initial and final CCO meetings); memoranda; and other correspondence shall be filed in reverse chronological order under this category and organized under the following five subcategories: Special Problems Reports, Contact (Telephone Conversation) Reports, Meeting Minutes, General Correspondence, and Certification Forms and Instructions for Study Contractors. Not all the forms are required to be completed for each FIS; however, Forms 1, 2, and 3 shall be included with each study. The other forms shall be included if applicable to the specific study. The instructions give guidance as to the need of each form. Information submitted with the certification forms shall be referenced to the form number and item or cross-referenced to other parts of the TSDN.

(b) Engineering Analyses - This category of information includes all coastal and riverine engineering support data that were developed in the preparation of the FIS, such as cross-section and/or transect information, basin characteristics, hydrologic and hydraulic hand calculations, graphs, nomographs, profile and cross-section plots, and any other engineering support data. Information in this category shall be subdivided into three subcategories: Hydrologic Analyses, Hydraulic Analyses, and Key to Cross-Section Labeling or Key to Transect Labeling.

(1) Hydrologic Analyses - All hydrologic support data developed for the FIS shall be stored under this category. Data such as basin characteristics, normal depth calculations, log-Pearson Type III calculations, regional regression equation calculations, frequency-discharge curves, etc., are to be included. The data shall be organized in reverse chronological order, and shall be properly dated and labeled according to the flooding source(s) to which they apply.

Computer-generated input/output results from HEC-1, TR-20, etc., in both paper-copy and computer disk/tape formats, are also being included in this category. However, as is generally the case, the computer-generated results cannot be easily filed in the standard-sized notebook. In that situation, the SC shall follow the proper identification and labeling procedures outlined in the Guide for Preparing Technical Support Data Notebook, and separately organize the appropriate computer products in binders and disk/tape storage containers.

The SC shall prepare and complete the "Hydrologic Analyses Index" sheet(s). The Index sheet(s) will assist the data user in identifying the hydrologic data and information generated during preparation of the FIS. It will also be used to reference the hydrologic data that, due to format, size, or other limitations, cannot generally be physically located within the TSDN itself.
In this instance, the data will be identified on the Index sheet(s) and submitted as an exhibit to the TSDN.

(2) Hydraulic Analyses - All of the hydraulic support data and calculations for riverine and coastal flooding sources that were developed for the FIS shall be stored under this category. Data such as cross section information (area, velocity, and elevation calculations); floodway analyses; transect and surge data; wave height information; cross section plots; computer models; calculations; and execution runs; and any other relevant data shall be organized and filed under this category.

As is the case with the hydrologic analyses, computer-generated input/output results from HEC-2, WSP-2, and WSPRO, etc., are also to be included in this category. Again, since this information generally cannot be maintained in the TSDN, the SC shall clearly identify the computer product in the manner previously specified for the hydrologic data.

The SC shall prepare and complete the "Hydraulic Analyses Index" sheet(s). The Index sheet(s) will assist the data user in identifying the hydraulic data and information generated during preparation of the FIS. It will also be used to reference the hydraulic data that, due to format, size, or other limitations, cannot generally be physically located within the TSDN itself. In this instance, the data will be identified on the Index sheet(s) and submitted as an exhibit to the TSDN.

(3) Key to Cross Section Labeling or Key to Transect Labeling: For each flooding source where a hydraulic analysis was performed, the SC shall complete and maintain a Key to Cross Section Labeling or Key to Transect Labeling forms as applicable. These forms are to be included within the TSDN. Detailed instructions for completing the appropriate forms are given in the Guide for Preparing Technical Support Data Notebook.

(c) FIS Report Data (Draft FIS Report Text) - This category shall contain all relevant FIS components that are prepared for submission by the SC to FEMA for technical review, processing, and publication of the FIS. Included are draft FIS components such as the FIS report data, flood profiles, Summary of Discharges table, Floodway Data tables, Summary of Stillwater Flood Elevations tables, Transect Description tables, surge elevation tables, and any other relevant support data. The information organized and submitted in this section shall only include the most up-to-date record copies of the draft FIS.

(d) Mapping Information - All the mapping data generated during preparation of the FIS shall be organized under this category. Mapping information such as topographic maps, work maps, base maps, aerial photographs, soil and vegetation maps, USGS quadrangle maps, Flood Hazard Boundary Maps, community maps, and all other maps (manual and digital) shall be listed, organized, and stored under this category.

The SC shall prepare and complete the "Mapping Information Index" sheet(s) as explained in the Guide for Preparing Technical Support Data Notebook (TSDN). The Index sheet(s) will assist the data user in identifying the mapping data and information generated in the study process. It will also be used to reference the map data that, due to format, size, or other limitations, cannot generally be physically located within the

TSDN itself. In this instance, the data will be identified on the index sheet(s) and submitted as an exhibit to the TSDN.

In addition to preparing the index sheet(s), the SC shall write a brief narrative to explain any additional procedure used to create the final work maps; for example, whether field inspection or spot surveying was done to enhance the accuracy of the final work maps. All supplemental materials, such as topographic maps, aerial photographs, etc., shall be listed with an accompanying explanation of how that information relates to the final work maps.

If photogrammetric processes were used, the SC may be requested to provide: 1) documentation for the most recent calibration of the aerial camera and stereoplotter(s), 2) details on the flying height and camera focal length, 3) estimated "C Factor(s)" of the stereoplotter(s) used on the project, and 4) Aerial Triangulation Reports described in paragraph A4-6 D(10), Appendix 4.

If GPS surveys were performed, the SC shall provide the GPS documentation described in paragraph A4-6 B.4.b, Appendix 4. This includes data categorized by the National Oceanic and Atmospheric Administration as follows:

- B-file. Project information, station position information, survey measurements, occupation notes, and synchronization information.
- D-file. Station descriptions and/or recovery notes for all new and/or newly occupied stations.
- G-file. Differential coordinates, standard errors, correlations, and related information which are required for a least squares adjustment of a GPS field project.
- R-file. Those files created by the GPS receiver which contain the phase data of each satellite observed, and any other files created by the receiver which are necessary during processing.

(e) Miscellaneous Reference Materials - This category of information allows for the organization and filing of all other essential technical support data that are not included in the categories previously discussed. Support data in the form of reference materials such as flood hazard analyses reports; floodplain information reports; watershed studies; site visit photographs; and miscellaneous data such as community population and demographic studies, tax base reports, legal references, and other relevant material, shall be included in this category.

The SC shall properly identify and label the miscellaneous data submitted in this section. The SC is also required to complete the "Miscellaneous Reference Materials Index" sheets for all essential support data submitted. The index sheet(s) will assist the data user in identifying the miscellaneous reference materials used during preparation of the FIS. It will also be used to reference the materials that, due to format, size, or other limitations, cannot generally be physically located within the TSDN itself. In this instance, the materials will be identified on the index sheet(s) and submitted as exhibits to the TSDN.

2. Data Identification

The SC shall properly identify handwritten data, computer printouts, maps, and other support data that are compiled during preparation of the FIS.

(a) General Documentation, Correspondence, and Support Data - All written documentation, such as general correspondence, memoranda, meeting minutes, contact reports (e.g., telephone conversation records), Special Problem Reports, field notes, field survey notes, photographs, calculations, cross-section plots, and similar items shall be clearly marked with the following minimum information:

- community name and state for which the FIS was prepared
- date of document (day, month, year)
- name of SC
- as applicable, name(s) of flooding source(s)
- any other relevant information that can assist users in identifying the data

Handwritten documentation shall be clearly legible. Pencil and colored pens shall be avoided unless the writing is dark enough to be reproduced on microfilm.

(b) Computer Models - The SC shall submit both paper copies and copies of computer models on diskette. All computer input/output products, such as computer printouts and floppy diskettes, must be properly identified and labeled with the following information:

- community name and state for which the FIS was prepared
- date of document (day, month, year)
- name of SC
- name(s) of applicable flooding source(s) covered by the model
- whether the product is one of several others
- any other relevant information that can assist users in identifying the data

Input and summary output of final runs of computerized hydraulic and hydrologic computations shall be submitted on 3½-inch or 5¼-inch floppy diskettes that meet the following specifications:

- Disks shall be formatted for MS DOS 2.1 or greater and have a capacity of at least 360 kilobytes.

- Input files may not be partitioned to multiple disks.

- An ASCII text file named "README" shall be created for each floppy disk, which includes the name and address of the SC; the name, county, and state of the community studied; the name of the hydraulic/hydrologic program; and the name of each input and output file with the stream name and date of creation. Each floppy disk must be labeled with the same information.

- The "Backup.Com" utility of MS DOS shall not be used to copy files to the floppy disk; files should be created using the "Copy" utility.

The SC shall obtain approval from the Regional PO before using a different format.

It is essential that the SC identify and label all computer product information legibly. Whenever possible, the SC shall include the original copy of the computer input/output information. Using carbon paper or other poor quality copies shall be avoided; FEMA requires the original material or high-quality duplicates to produce clear and legible microfilm records. Extraneous and voided copies of input/output data shall be discarded.

Hydraulic model printouts shall be further annotated to show the applicable cross-section lettering and/or transect numbering used in the draft FIS Report. Identifying the printout with the cross-section lettering and/or transect numbering will allow data users to match it with the corresponding maps and FIS Report.

In conjunction with the cross-section or transect identification on the printouts, the SC shall prepare, as applicable, a Key to Cross-Section Labeling and/or Key to Transect Labeling form. The forms were developed to assist all data users in correlating the corresponding cross section/transect information and lettering/numbering with the data shown in the field survey book, computer model, and draft FIS Report. The SC shall be responsible for completing the applicable SC portion of the form for each flooding source studied in detail.

(c) FIS Report Data (Draft FIS Report Text) - The SC is to ensure that the following criteria is met for all relevant FIS components submitted to FEMA for technical review, processing, and publication of the FIS:

- They must pertain only to the appropriate community FIS.
- They must be legible, properly labeled, and easily identified by community.
- They are prepared on sheets 11"x17" or smaller so that they can be easily microfilmed.
- If data is produced that is, by necessity, larger than 11"x17", those data are to be submitted as clearly labeled exhibits to the TSDN.
- They are complete and of original quality.

(d) Mapping Information - All maps, such as work maps, aerial photographs, topographic maps, base maps, community maps, and any other source maps shall be properly identified with the following information:

- community name and state for which the FIS was prepared
- six-digit community identification number
- date map was prepared and/or published (day, month, year)
- horizontal datum
- vertical datum

- control grid (e.g., State Plane or UTM)
- map scale
- north arrow
- name of SC
- name(s) of applicable flooding source(s) covered
- FIRM panels affected
- whether map is one of several maps
- any other relevant information that can assist users in identifying the data

Because the maps will be used to produce the FIRM and/or will be maintained for future use and reference, the SC shall ensure the clarity and durability of the maps. Any extraneous or duplicate maps shall be discarded; however, if copies are to be retained for record purposes, they must be clearly marked as "void" or "superseded by other material."

(e) Digital Files of Mapping Information - Refer to Appendix 7 for data format, transfer media, file naming, and identification requirements for digital mapping files submitted to FEMA. A completed Digital Data Submission Checklist must accompany all digital data files.

(f) Miscellaneous Reference Materials - The SC is to identify and include any other support data essential to the preparation and processing of the FIS that were not previously covered by the preceding sections of the TSDN including, but not limited to, such data as site visit photographs, field survey notebooks, flood hazard reports, floodplain information reports, etc.

The SC is to ensure that the following criteria are met for these miscellaneous reference materials:

- They must be properly labeled with the SC and community name and be easily identified by flooding source.
- They must include the type of information, the date (day, month, and year) of the information, and the exhibit number(s) assigned to those materials that cannot be included in the TSDN, neatly recorded in pen or dark pencil on the Miscellaneous Reference Materials Index sheet.
- They are prepared on sheets 11"x17" or smaller so that they can be easily microfilmed.
- If data is produced that is, by necessity, larger than 11"x17", those data are to be submitted as clearly labeled exhibits to the TSDN.
- They must pertain only to the appropriate community FIS.
- They are complete and of original quality.

The community name and state are to be typed at the top of the Index sheet(s). Any handwritten information on the remainder of the Index sheet is to be in pen or dark pencil to ensure that the sheet is completely reproducible on microfilm. If more than one community is involved, each FIS TSDN package is to contain a copy of the information.

Copies of materials not physically included within the TSDN due to size limitations are to be bound and labeled separately and identified by exhibit number.

3. Data Submission

The SC will submit the TSDN to FEMA along with the draft FIS submittal. The SC will retain copies of the support data relating to the hydrologic and hydraulic analyses, including the completed Certification Forms, so it will be able to respond to technical issues raised during the review and processing of the FIS.

All materials submitted shall be properly packaged and clearly labeled for mailing. The SC shall ensure that mailing containers such as boxes, tubes, and any other packaging are all properly secured, are sturdy, and are identified by the community name for which the FIS data apply. If the SC determines that, for cost efficiency, several data packages are to be put together for mailing, each community's package shall be individually labeled.

The mailing containers used to ship the information shall be strong enough to withstand bulk fourth class shipment through the postal service. The SC shall also take appropriate precautions when shipping computer products such as floppy diskettes; such fragile information shall be packaged in special mailing containers. For mapping data that cannot be included in the TSDN, special mailing tubes are to be used. The mailing tubes should be clearly marked according to community. A transmittal letter providing an inventory of all of the materials being shipped shall accompany the package.

CHAPTER 12. EXPECTATIONS AFTER DELIVERY OF DRAFT FLOOD INSURANCE STUDY

The SC's responsibilities do not end with the submittal of the draft FIS to FEMA. The SC must continue to provide services through the review and processing phase prior to issuing a preliminary FIS, after the issuance of the preliminary FIS, and at a final CCO meeting.

A. Prior to Issuance of Preliminary Flood Insurance Study

Following submittal of the draft FIS and other items, the FIS will undergo review and processing for publication by FEMA TECs. The TECs will prepare preliminary FIS Reports and maps for SC review, community review, and for the final CCO community meeting. Prior to the final CCO meeting, the TECs will maintain working level contacts with the SCs to resolve questions that arise during the review. During this period, the SC must give immediate attention to review questions and respond in a timely manner. Most questions should be handled by documented telephone calls. For more complex questions, written comments will be sent to the SC by the TEC. In some instances, the SC may be requested to submit detailed computer output printouts or other data to assist the TEC during the review. A period of 15 days will be allowed for SC response to written comments. Material that is unacceptable for processing will be returned to the SC.

B. After Issuance of Preliminary Flood Insurance Study

Approximately 45 days prior to the final CCO meeting, copies of the preliminary FIS and FIRM will be sent to the SC along with formal comments that document changes agreed to during the review and processing period. The SC must review the preliminary FIS and FIRM and prepare to present and support the FIS results at the final CCO meeting.

If the preliminary FIS and FIRM prepared by the TEC do not accurately reflect the floodplain boundaries, flood elevations, and floodway boundaries, the SC should inform the Regional PO within 15 days of the receipt of the preliminary FIS and FIRM, otherwise these materials will be deemed to be correct.

C. Final Community Consultation and Coordination Officer's Meeting

The SC shall present and support the preliminary FIS and FIRM at a final CCO meeting to be held with FEMA and the community. Within 15 days after the final CCO meeting, the SC shall forward to the Regional PO, for transmittal to the TEC, any changes in the technical data that were determined to be necessary at the meeting, or a letter indicating that no changes are necessary. The comments or letter should also note any other information in the preliminary FIS and FIRM that is not accurate. Following incorporation of these changes, the TEC will produce revised study products and the formal 90-day appeal period will start. The TEC will only produce a revised preliminary FIS if warranted, and many of the submitted changes will only be reflected in the final effective FIS and FIRM. If the community appeals or protests the FIS based on scientific or technical data, the SC shall submit to the TEC any available supporting data to assist in resolving the appeal or protest.

When all FISs in a contract have completed their appeals period, the Regional PO will initiate action with the Contracting Officer to close out the contract.

CHAPTER 13. REFERENCES

1. U.S. Department of the Interior, Geological Survey, Interagency Advisory Committee on Water Data, Office of Water Data Coordination, Hydrology Subcommittee, Bulletin No. 17B, "Guidelines for Determining Flood Flow Frequency," September 1981, Revised March 1982.

2. U.S. Army Corps of Engineers, Hydrologic Engineering Center, EM 1110-2-1415, "Hydrologic Frequency Analysis," March 1993.

3. U.S. Geological Survey, Water Resources Investigation 87-4207, "Regionalization of Peak Discharges for Streams in Kentucky," A. F. Choquette, 1987.

4. U.S. Geological Survey, Water-Supply Paper 2207, Flood Characteristics of Urban Watersheds in the United States, V. B. Sauer, W. O. Thomas, Jr., V. A. Stricker, and K. V. Wilson, 1983.

5. U.S. Geological Survey, "Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Streams, 1993," M. E. Jennings, W. O. Thomas, Jr., and H. C. Riggs, 1994.

6. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "Generalized Computer Program, HEC-1," September 1990.

7. U.S. Department of Agriculture, Soil Conservation Service, "TR-20, Computer Program for Project Formulation Hydrology," May 1982.

8. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "Generalized Computer Program HEC-2, Water-Surface Profiles, Users Manual," September 1990, revised February 1991.

9. Federal Highway Administration, "Bridge Waterways Analysis Model Research Report, FHWA/RD," July 1986.

10. U.S. Geological Survey/Federal Highway Administration, "Users Manual for WSPRO - A Computer Model for Water Surface Profile Computations," September 1990.

11. U.S. Department of Agriculture, Soil Conservation Service, "Urban Hydrology for Small Watersheds," Technical Release 55, June 1986.

12. Hydraulic Design Studies, No. 5, "Hydraulic Design of Highway Culverts," FHWA-IP-85-15, September 1985.

13. U.S. Geological Survey, Professional Paper 1395, Map Projections - A Working Manual, 1987.

14. The U.S. Department of Agriculture, Soil Conservation Service,"Computer Program for Water Surface Profiles - WSP2, Part 630 National Engineering Handbook, Chapter 31," October 1993.

APPENDIX 1. COASTAL FLOODING METHODOLOGIES

A1-1 GENERAL METHODOLOGY

FEMA uses a variety of analytical methodologies to establish BFEs and floodplains throughout coastal areas of the United States. These methodologies are too voluminous for inclusion in these Guidelines; therefore, they have been published separately. References for the methodologies currently in use for specific coastal flood hazards are itemized in Section A1-2.

A1-2 REFERENCES

The publications below were prepared for, and are available from, FEMA and will be provided to any Study Contractor preparing an FIS in a specific hazard area.

Northeaster Flooding

Stone & Webster Engineering Corporation, "Development and Verification of a Synthetic Northeaster Model for Coastal Flood Analysis," 1978.

Hurricane Flooding

Federal Emergency Management Agency, "Coastal Flooding Hurricane Storm Surge Model, Volume 1, Methodology," August 1988.

Federal Emergency Management Agency, "Coastal Flooding Hurricane Storm Surge Model, Volume 2, User's Manual," August 1988.

Pacific Northwest Storm Flooding

CH2M HILL, Inc., "Determination of Flood Levels on the Pacific Northwest Coast for Federal Insurance Studies," Journal of the Hydraulics Division, ASCE, D. E. Dorratcague, J. H. Humphrey, and R. D. Black, 1977, Vol. 103, 73-81.

Tsunami Flooding

U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report HL-80-18, "Type 19 Flood Insurance Study: Tsunami Predictions for Southern California," 1980.

This is one of a series of such reports for the Pacific Coast States.

Great Lakes Flooding

U.S. Army Corps of Engineers, "Revised Report on Great Lakes Open-Coast Flood Levels," Phase I and II, April 1988.
U.S. Army Corps of Engineers, "Great Lakes Wave Runup Methodology Study," February 1989.

Wave Height, Runup, and Erosion Analyses

Federal Emergency Management Agency, "Guidelines and Specifications for Wave Elevation Determination and V zone mapping," Draft, July 1989.

Coastal Structures

U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report CERC-89-15, "Criteria for Evaluating Coastal Flood-Protection Structures," December 1989.

APPENDIX 1A. GUIDELINES AND SPECIFICATIONS FOR COASTAL FLOOD STUDY DOCUMENTATION

A1A-1 INTRODUCTION

Study Contractors performing coastal Flood Insurance Studies must fully document the coastal flood hazard determination for each particular coastal Flood Insurance Study. This documentation will identify the methodology employed in the study, as well as the computational approach and the input data used in the calculation of the coastal flood elevations. These Guidelines provide the broad, general technical specifications under which all coastal Flood Insurance Studies will be documented. Various internal and public reports of FEMA outline the approved coastal storm surge elevation methodology. These reports include algorithms, computer codes, guidelines for model use, and examples of model runs. Although some of these reports provide relatively specific information on both the general procedures to be employed in processing the meteorologic and hydrologic data, and the specifics of the hydrodynamic and wind field models to be employed in the study, they contain no information on the application of the methodology to a particular coastal FIS site. Therefore, the specific meteorological and hydrologic data, ocean bathymetry, shoreline characteristics, surface and bottom friction coefficients, and other parameters used in the particular model application must be completely documented. For this purpose, it will be required that an engineering report be produced for each coastal FIS performed by a FEMA SC. This report will be designed to provide detailed site specific data needed by FEMA, or coastal communities, to reconstruct or defend, on technical grounds, the study results. In general, the documentation will require the reporting of input data, modeling approach used, model parameter values, and noting all assumptions, decisions, and judgments that influence model outputs. The following represents the suggested format and material to be contained in this documentation. Although there is an emphasis here on coastal studies incorporating storm surge models, study contractors not using such a model should still adhere to the appropriate sections. Any deviations from these procedures require the approval of the Regional PO.

A1A-2 INTRODUCTORY MATERIAL

In this section, describe the geographic setting of the study site, discuss the local surge-producing climatology of both tropical and extratropical storms, and provide a history of extreme storm surges. Unique aspects of each component of the stillwater flood elevation (SWEL) (for example, inverted barometer setup, wind transport, astronomical tide level, pre-surge anomaly, wave action, and abnormal hydrological conditions) are to be investigated and reported. A short discussion of the coastal Flood Insurance Study results and how they will be used in producing the local FIRMs is to be given.

A1A-3 OUTLINE OF METHODOLOGY

An outline of the basic technical approach employed in the study will form the basis of this section. Topics to be covered include identification of the storm (wind) model, the hydrodynamic model, and the statistical procedure used to determine flood frequencies. The purpose of this section is to outline the relationship between the technical material to be covered in the main body of the engineering report and the basic methodological approach used in the particular FIS. This outline should be logically organized and sufficiently complete so that the detailed documentation that follows can be easily read and understood.

A1A-4 STORM CLIMATOLOGY AND STORM WIND FIELD METHODOLOGY

This section will describe the basic climatological storm data used and the wind field methodology employed in the coastal flood insurance study. Storm paths used in the analysis are to be mapped, tabulated, and discussed in terms of local surge impact. In addition, storm parameters (including the central pressure deficit, the radius to maximum wind, forward speed, shoreline crossing point, and shoreline crossing angle) as used in the analysis are to be tabulated and described in written form. The sources of the basic data used to develop the storm climatology and the method used to sort the data are to be identified. The technique employed to determine the spatial/temporal distribution of storm occurrences (i.e., storms/nautical mile/year), the derivation and discretization of storm intensity parameters, and exceedence probability distributions are to be described. Graphical presentation of the results including an overlay with orientation of coast to storm path/direction should be provided. A discussion of storm parameter independence and any unique storm model treatments is to be given.

The wind field used in the analysis is a key component in the determination of the storm surge elevation. The exact equations used to parameterize the model wind field will be given with any unique values of all the appropriate coefficients and constants used. A discussion of the wind field and coordinate system will include a diagram of the wind field model that gives the surface velocity structure as it changes radially outward from the storm center. A comparative graph depiction of measured windfield(s) and modeled windfield should be provided, if available. The method by which winds are reduced as the storm approaches land and moves inland will be described in detail, and constants used in wind speed reduction will be reported.

A1A-5 THE HYDRODYNAMIC MODEL

The material in this section should address the hydrodynamic storm surge model employed in the coastal Flood Insurance Study. The model used to calculate the surge elevation has been described in detail in various FEMA documents and need only be cited by reference. In this section, unique model characteristics used for the specific study are reported. This will include a discussion of the specific grid system and sub-grid systems employed, the grid used for bottom topography and shoreline, small scale features such as harbors and barrier islands, and the location and conditions applied for the open boundaries to the grid. Adjustment to land features to account for erosion should be fully described and documented. The method used to determine average ground elevations and water depths within the cells of the grid system should be described and documented. This discussion should be augmented by diagrams that show the grid systems as computer listings of the grid data used in the actual model calculations. The method used to relate wind speed and surface drag coefficient is to be described. In addition, the Manning's "n" values used in the calculation of bottom and overland friction will be discussed and given in tabular form. This information will include a discussion of any sensitivity tests used to estimate these values in nearshore water. Nearshore bottom and overland friction is an important part of the overall analysis and should therefore be described with care and sufficient detail. A graphical depiction of the model cells and grid system should be provided as an overlay to the bathymetric charts and topographic maps covering the study area, annotated with the individual cell inputs for the grid system. Special attention should be given to the method by which barriers, inlets, and rivers have been treated. The procedures used to determine inland flooding should be explained. This includes parameterization of local features and selection of the friction factors used for the various terrains.

A1A-6 CALIBRATION AND VERIFICATION OF HYDRODYNAMIC MODEL

Once the hydrodynamic model and grid have been set up, calibration and verification should be performed. Calibration is done to determine the adjustable "tuning parameters" (such as Manning's "n", barrier overflow coefficients, etc.) and to validate the chosen grid schematization. Verification is used to validate the model and grid for situations other than the case used to calibrate the model. Sensitivity runs are used to make sure that small changes in the chosen grid and "tuning parameters," will not give rise to unacceptable large changes in the computed flood and tide levels. Calibration and verification computer runs compare computed results with observed water levels. Sensitivity runs compare computed results with other computed results.
When observed (or model simulation) data are employed to calibrate (or compare) hydrodynamic model results with other available studies, a complete description of this calibration procedure (or model comparison) will be given. This will include a listing of measured and simulated tidal data. Calibration (and model comparison) is an important aspect of the model analysis and should be described with sufficient detail and care to allow an independent reviewer to understand the exact procedures employed and the local historical records employed.

A1A-7 STATISTICAL (JOINT PROBABILITY) METHODOLOGY

When using the method of joint probability, values and combinations used for storm parameters, annual storm density, spacing between storms, and the storm tracks used in the analysis are to be summarized, mapped, and reported. The total number of simulations employed is to be noted. Tidal elevation data, if used, is to be summarized in sufficient detail to remove any doubt as to the values used in the simulations. The method by which this data is convoluted with surge data is to be described including tidal constants employed and tidal records used. Storm occurrence rate, or storm density, definition of storm region used to define storm density, and storm kinematics and intensity are to be described with respect to their use in the joint probability calculation.

Comparisons with long-term gage statistics are to be reported and discussed.

Adjustments to account for the combined probability of coastal and riverine flooding shall be fully described and reported for each area where such approach was taken.

A1A-8 UNIQUE COMPUTER PROGRAMS

Several different computer codes may be used in the wind, hydrodynamic, and joint probability analysis. Some basic computer programs have been given in numerous FEMA reports. Any modifications of these programs and special data inputs used in the study are to be listed and described.

A1A-9 WAVE HEIGHT, RUNUP, AND/OR EROSION ANALYSIS

The standard methodology used by the Study Contractor should be referenced in the report. Any deviation or expansion of that approach should be fully reported and documented. The selection of input data should be described, including a reference to source data and material. All erosion considerations should be fully reported and documented. A transect location map(s) is to be included. The computer printout listings for input and output data should be included as an appendix to the report, keyed to the transect location map(s).

A1A-10 REFERENCES

A complete list of technical references is to be provided, including computer program references, indicating where copies of the exact program can be found, and the location of input data sources used in the analysis.

APPENDIX 1B. INTERMEDIATE DATA SUBMISSION FOR COASTAL FLOOD STUDIES

Coastal analyses involving storm surge modeling are highly specialized and complex and require a highly specialized review process. Experience has shown that attempting to make changes or corrections to coastal storm surge and wave height analyses after they have been run and mapped is not practical due to the time, cost, and contractual problems involved. Many questions and problems which come up in the review process could be answered or resolved much more readily if these issues were raised early in the study process. Therefore, intermediate data submission requirements have been established to permit review of the SC's progress on model development at appropriate milestones. These procedures are not applicable to non-storm surge analyses. The data should be submitted to the TEC (as specified by the Regional PO) in accordance with the following sequence:

A1B-1 BEFORE MODEL CALIBRATION RUNS ARE MADE

a. A large-scale map of the coastal area which delineates both the coarse grid basin(s) and fine grid basin(s).

b. A schematic of each basin (coarse grid and fine grid) showing sub-grid channel locations, widths, bed elevations, and proposed Manning's "n" values for each channel.

c. Historical evidence establishing the importance of various coastal flooding mechanisms; namely, tropical and extratropical storms, rainfall and riverine events, etc.

d. Basic data relating to the study area, such as documented storm erosion, available design analyses for shore protection or other coastal projects, historical shoreline changes, etc.

e. Aerial photographs, coastal setback maps, and any other maps used to determine more accurate topographic-bathymetric values and land cover features in the study area(s).

f. Table listing astronomical tide events and historical storms selected for use in model calibration and verification, and a plot showing the observed storm surge elevation against the predicted tide elevations.

g. Plots of exceedence probability vs. parameter value for the meteorological storm parameters that vary in the joint probability analysis, as developed for the study area following NOAA Technical Report NWS 38. Documentation should also include a tabular presentation of all meteorological storm parameter data used in development of the exceedence probability curves.

h. Table showing storm parameter values and the assigned probabilities.

A1B-2 <u>BEFORE OPERATIONAL STORM SURGE RUNS ARE MADE</u>

a. A map of each basin (coarse grid and fine grid) showing water depths, ground elevations, and Manning's "n" values for each grid cell.

b. A map of each basin (coarse grid and fine grid) showing barrier locations, barrier heights, barrier widths, barrier Manning's "n" values, location of inlets cutting through barriers, inlet widths, inlet bed elevations, inlet Manning's "n" values and inlet entrance and loss coefficients.

c. A computer printout listing of the water depth, ground elevations, and Manning's "n" values referred to in Item a, barrier and inlet input referred to in Item b, and the sub-grid channel input referred to in A1B-1 Item b, and any other input data used in the calibration and verification runs and that will be used in the production runs.

d. Description of sensitivity runs used to optimize model parameters for the study area, for example, in final choices of Manning's "n" values.

e. Tide and storm calibration results (including extreme water elevations and time histories) showing computed results and a comparison of these with observations where such observations are available.

f. Grid overlay and work maps used in storm surge and wave height analyses for all fine and open coast grid basins (work maps should generally be the 7.5 minute U.S. Geological Survey quadrangle maps and the hydrographic charts that were used to gather topographic, bathymetric, roughness, and other input data for the storm surge and wave calculations). These maps should have the grid pattern drawn on them or should use one or more transparent overlays registered to the work map(s) to indicate where the grid cells fall with respect to various map features. The location and extent of each wave transect should be indicated on these overlays or work maps.

g. Written documentation, including justification, of any modifications made to the standard FEMA storm surge methodology and a listing of the computer source code annotated where the modifications were made.

A1B-3 <u>BEFORE OPERATIONAL WAVE HEIGHT CALCULATIONS ARE MADE</u>

a. Document conclusions on the interaction between storm surge and astronomical tide.

b. Output of PROBS program for all open coast and fine grid basins.

c. Grid showing 10-, 50-, 100-, and 500-year stillwater flood levels for each open coast and fine grid basin.

A1B-4 BEFORE WAVE HEIGHT CALCULATIONS ARE MAPPED

a. Copy of all wave height transect computations.

FEMA will provide written comments within 30 days of receipt of each data submission. The SC shall establish an FIS work plan so that the interim review does not cause any delay in the submission of the draft FIS.

APPENDIX 1C. GUIDELINES FOR GREAT LAKES WAVE RUNUP COMPUTATION AND MAPPING

A1C-1 INTRODUCTION

Contractors performing FISs for lakefront communities along the Great Lakes shoreline, which requires wave runup analysis should use Guidelines for Great Lakes Wave Runup Computation and Mapping (Reference 1) as guide. These guidelines provide a wave runup study flow chart, the detailed study procedure steps, sample computations, and mapping policies.

A1C-2 WAVE RUNUP CALCULATION PROCEDURES

These guidelines for Great Lakes wave runup calculation have emerged from methodologies recommended by the Detroit District of the U.S. Army Corps of Engineers (USACE) in the study report entitled Great Lakes Wave Runup Methodology Study (Reference 2). The major goal of these guidelines is to facilitate study procedures by consolidating all relevant information in one document. The figures and tables that follow have been drawn from various references cited in the USACE, Detroit District study report.

Three types of shorelines are considered: a natural beach profile and two types of armored shoreline profiles; namely, a vertical wall structure and a rock revetment structure. Therefore, three runup methodologies corresponding to the three shoreline types are employed. A flow chart that indicates the entire calculation procedure is shown on page A1C-3. The flow of tasks begins with site profile data-gathering, tracks through various intermediate steps, such as the 100-year flood level determination, and the calculation of the deep water and shallow water significant wave height, and ends with the wave runup determination for each type of shoreline.

A1C-3 WAVE RUNUP COMPUTATION STEPS AND SAMPLE CALCULATIONS

When the site location is identified, the following step-by-step study procedures should be followed to determine the maximum wave runup elevations which will be used in Flood Insurance Study map delineations.

Step 1. Profile Data Gathering
Step 2. 100-year Flood Level Determination
Step 3. Offshore (Deep Water) Wave Height Determination
Step 4. Nearshore (Shallow Water) H_{mo} and H_s Computation
Step 5. Wave Runup Computation
Step 6. Determination of Maximum Wave Runup Elevation

Two sites, Woodlawn, New York, and Luna Pier, Michigan, were selected for the sample wave runup computations. The Woodlawn site was used as an example for computing wave runup on a beach profile. The Luna Pier site was used as the example to compute wave runup for both a vertical wall structure and a revetment structure.

A1C-4 DELINEATION AND MAPPING POLICY

Six (6) general policies and twelve (12) specific-case mapping policies accompanied with illustration diagrams are recommended to be used in the FIS map delineation for Great Lakes coastal communities. The general policies should be applied to all cases. The specific-case policy is only applied to a certain special situation. Three types of shorelines profiles, as described below, which are typical in the Great Lakes region are used to classify the cases:

- Beach Profile with a Natural Dune System
- Beach Profiles with a Bluff System
- Beach Profile with Coastal Structures

For each type of shoreline profile, four separate cases are considered, depending on the computed wave height profile, wave runup height, 100-year stillwater level, and the predicted post-storm erosion profile. For other special cases that cannot be covered by the above policies, the Study Contractors should consult with the Regional Project Officer.

A1C-5 REFERENCES

1. Federal Emergency Management Agency, Federal Insurance Administration, Guidelines for Great Lakes Wave Runup Computation and Mapping, December 1990.

2. U.S. Army Corps of Engineers, Detroit District, Great Lakes Wave Runup Methodology Study, June 1989.

APPENDIX 2. SHALLOW FLOODING

A2-1 INTRODUCTION

Shallow flooding of different types commonly occurs throughout the United States. Areas of shallow flooding include unconfined flows over broad, relatively low relief areas, such as alluvial plains; intermittent flows in arid regions that have not developed a system of well-defined channels; overbank flows that remain unconfined, such as on delta formations; overland flow in urban areas; and flows collecting in depressions to form ponding areas. These have been loosely and inconsistently referred to as "sheet flow" or "ponding." Alluvial fan flooding is to be analyzed using procedures outlined in Appendix 5 and not the procedures outlined in this Appendix.

For purposes of the NFIP, shallow flooding conditions are defined as flooding that is limited to 3.0 feet or less in depth where no defined channel exists.

A2-2 STUDY SCOPE

The state of the art for determining shallow flooding hazards, and the cost effectiveness of these determinations, are quite limited. As a result, certain study parameters should be used by the SC to limit the detail of study for shallow flooding determinations.

Drainage area size should be considered in determining shallow flooding hazards. Flooding conditions resulting from drainage areas of less than 1 square mile are not generally studied in detail. Calling the community's attention to these hazards by use of approximate study and delineation (described in more detail later in this Appendix) is sufficient. Flooding from sources with drainage areas less than 1 square mile is considered to be a local drainage problem.

Depths of flooding determined from detailed study of shallow flooding hazards need be computed only to the nearest whole foot.

Detailed study should be limited only to those areas that have a history of destructive flooding or that have a significant potential for the damage of future development, and where expected 100-year flood depths are 1.0 foot or greater.

A2-3 DEFINITION OF FLOOD HAZARD ZONES

Flood hazard zones that are relevant to areas susceptible to shallow flooding are listed and described below.

Zone XZone X is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500-year floodplain, areas of 100-year flooding where average depths are less than 1 foot, areas of 100-year flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees. No BFEs or depths are shown within this zone. The Study Contractor should distinguish between Zone X areas that are within the limits of the 500-year floodplain (shaded on the work map) and the Zone X areas outside the limits of the 500-year floodplain (unshaded on the work map).

Zone A Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs or depths are shown within this zone.

Zone A0 Zone A0 is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone AH Zone AH is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot BFEs derived from the detailed hydraulic analyses are shown within this zone.

A2-4 SHALLOW FLOODING CLASSIFICATION AND DESCRIPTION

Shallow flooding can occur as the result of several phenomena. However, the following classification of two broad types of shallow flooding, into which almost all individual cases can be assigned, has been determined as an appropriate level of detail for purposes of the NFIP.

A. Ponding

Ponding is the result of runoff or flows collecting in a depression that may have no outlet, subterranean outlets, rim outlets, or manmade outlets such as culverts or pumping stations. Impoundments behind manmade obstructions (levees, road fills, railroad grades, canal banks, and other similar structures) are included in this type of shallow flooding as long as they are not backwater from a defined channel, or do not exceed 3.0 feet in depth.

B. Sheet Runoff

Sheet runoff is the broad, relatively unconfined downslope movement of water across sloping terrain that results from many sources, including intense rainfall and/or snowmelt, overflow from a channel that crosses a drainage divide, and overflow from a perched channel onto deltas or plains of lower elevation. Generally, it enters a channel or drainage system that intersects its flow, but occasionally it dissipates before reaching a channel. Sheet runoff is typical in areas of low topographic relief and poorly established drainage systems.

A2-5 SHALLOW FLOODING STUDY PROCEDURES

A. General Guidelines

The general guidelines cited are applicable to all areas of shallow flooding. They are indicative of the general approach taken to the study of shallow flooding problems in order to fulfill the requirements of the NFIP.

Small-scale topographic variations should be averaged across inundated areas in determining depths to keep the effort and results commensurate with the obtainable accuracy of shallow flooding study methods.

Flood hazard zone designations should extend across the entire inundated area, without separate designation of X zones at the edges of A0 or AH zones. Thus, X zones should be used only when the average depth across the entire inundated area is less than 1 foot. An AO zone should not be used at the edge of an AE zone where the depth is less than or equal to 3 feet.

Shallow flooding is often characterized by highly unpredictable flow direction because of low relief or shifting channels and debris loads. Where such conditions exist, the entire area susceptible to this unpredictable flow should be delineated as an area of equal risk.

Small-scale topographic relief that is not evident on existing topographic mapping and that might lead to "islands" of one flood hazard zone within larger areas of another should be ignored. Individual property owners will be issued Letters of Map Amendment in this situation when necessary.

Shallow flooding areas are designated as Zones A0 or AH depending on the relative accuracy with which flood depths or elevations can be determined. Ponding areas with a constant flood elevation are always delineated as Zone AH with a BFE. Areas of sheet runoff are usually delineated as Zone A0 with average flooding depths above the ground surface indicated on the work map. However, where the slope of the water surface is extremely low and uniform BFEs can be established for large land areas, Zone AH with a BFE is preferred. For mapping purposes, in areas of shallow flooding with Zone AH designations, whole-foot BFEs would be shown and in Zone AO areas, average depths rounded to the nearest whole-foot would be shown.

The 10-, 50-, or 500-year flooding delineations, floodways, and profiles should not be determined in shallow flooding areas. If these items can be readily determined, shallow flooding procedures should not be used.

Historical information, local citizen reports, existing physical features, and previous reports discovered during the bibliography search should all be assessed for information on possible flooding conditions. Where any information shows possible local flooding depths, or other hazards more severe than those determined by the study procedures in these Guidelines, that information and reference must be included in the FIS Report to fully alert the community to the potential hazard.

B. Approximate Study Methods

Areas of expected shallow flood hazard that have no significant development pressure for the near future should be studied by approximate methods.

Normally, only the designation Zone A should be used in these areas, with two possible exceptions. In many areas of 100-year shallow flooding, average flood depths can often be readily determined to be below 1 foot by simple and inexpensive methods. In this situation, with a very limited study, shallow flooding areas may be designated as Zone X. Zone X should also be used whenever the contributing drainage area causing shallow flooding is less than 1 square mile.

C. Detailed Study Methods

(1) Ponding. Areas of ponding can be identified through historic data on past flooding, local inquiries, examination of topographic maps, and field reconnaissance. The SC should determine inflow to, and outflow from, the ponding area and calculate the storage volume and elevations using a simple reservoir routing analysis. Hydrographs, empirical formulas, and design equations for culverts and other manmade structures should be considered. Determination of stage-storage relationships requires some topographic information. Wherever adequate contour interval mapping is available, the SC should determine storage volumes directly from those maps. Otherwise, a limited number of cross sections should be surveyed to determine storage volumes. The number of cross sections needed will depend on the size of the ponding area, but usually one along the major axis and two perpendicular to that axis will be sufficient.

Where volumes of inflow to ponding areas are sufficient to fill the available storage volume behind low dikes or other large, uniform obstructions, their crest elevation will determine the elevation of flooding in the ponding area. Such areas can usually be delineated based on field reconnaissance, in conjunction with an examination of topographic maps, without detailed calculations or field surveys.

One BFE should be placed under the Zone AH designation for each ponding area. Whenever BFEs are required, the SC shall establish or confirm ERMs as described in Chapter 3, Section 1.

(2) Sheet Runoff. Areas of sheet runoff can be identified from historic data and local inquiries, supplemented by field reconnaissance and examination of topographic maps and aerial photographs. However, the lack of adequate data (e.g., small contour interval mapping) and costly analytic methods pose problems for detailed study of these areas.

Sheet runoff typically takes place across broad areas of low relief. This situation makes it likely that sheet runoff depths will be less than 1 foot. For flood insurance purposes, once a determination has been made that flooding depths are less than 1 foot, the area should be designated as Zone X and more detailed analysis is not required. In certain situations, however, sheet runoff depths may average more than 1 foot. Such may be the case, for instance, when the channel capacity of a perched stream is exceeded, as on a delta formation. The SC should identify those areas where depths averaging more than 1 foot could occur and then should undertake a more detailed analysis of these areas. In the unlikely occurrence of sheet runoff with an average depth of more than 3 feet, the SC should contact the Regional PO for guidance. The SC should select the specific methods to be used in the detailed analysis; however, normal depth calculations are usually used, with effective flow areas established using available topographic information, historical information, and engineering judgment. Losses through ground infiltration normally should not be considered.

The SC should determine the 100-year flood discharge at the head of a sheet flow area by an appropriate method. In the absence of a permanent manmade channel or large-scale topographic features to restrict its flow, this discharge should be routed uniformly across the entire area susceptible to sheet flow. Cross section and slope information must be obtained to determine average flood depths across the area. Whenever small-interval contour mapping exists, cross sections should be developed directly from those maps; otherwise, a limited number of cross sections should be taken across the area to determine average flood depths. Cross sections should be maintained perpendicular to flow over the surface. Methods of determining what areas to include in a particular shallow flooding zone can vary significantly based on the available data, type of study, and analysis used. Typically, average flood depths from representative cross sections taken from available topographic information are used in determining a weighted reach. When determining the average flow depths at cross sections in a shallow flooding (AO Zone) area, a weighted average across the entire cross section should be used. A weighted average of all cross sections within an entire reach length would be used to define the extent of shallow flooding zones. For NFIP mapping purposes, areas of shallow flooding with average depths of 1.0 foot or less would be designated as Zone X. Areas of shallow flooding with average depths between 1.0 and 1.5 feet would be designated as Zone AO depth 1, average depths between 1.5 and 2.5 feet would be designated as Zone AO depth 2, and areas with average depths between 2.5 and less than 3.0 feet would be designated as Zone AO depth 3. Only after the average depth for an entire shallow flooding area is determined would that value, for NFIP mapping purposes, be rounded to the nearest whole foot.

In urban areas, sheet runoff is affected by buildings, sewer and drainage systems, and street design. In many cases, storm sewer and street systems are intended to carry the total discharges of only relatively frequent floods. Less frequent floods, including the 100-year flood, will often result in shallow flooding as the capacity of designed drainage networks is exceeded. Such problems, if amenable to detailed study at all, would be exceedingly costly to analyze. Because such areas are already developed, improved drainage systems may be the only short-term solution to the problem. Analysis of local drainage problems is considered beyond the scope of FIS preparation. Therefore, the SC should rely on historic data and the reports of local engineers and residents to identify such areas, and use field reconnaissance and engineering judgment to delineate them.

The procedures outlined in this Appendix will be adequate to determine areas susceptible to sheet flow flooding, but they may not indicate the severity of the possible local hazard. Any available information, including reports of local residents, historical data, and especially photographs of past floods, should be included in the FIS Report to document the possible velocity, depth, debris, and shifting channel hazards that may exist.

APPENDIX 3. ANALYSIS OF ICE JAM FLOODING

A3-1 INTRODUCTION

An ice jam may be defined as an accumulation of ice in a stream that reduces the cross-sectional area available to carry the flow and increases the water-surface elevation. The accumulation of ice is usually initiated at a natural or manmade obstruction or a relatively sudden change in channel slope, alignment, or cross-section shape or depth. In northern regions of the United States, where rivers can develop relatively thick ice covers during the winter, ice jamming can contribute significantly to flood hazards. When historical records are examined, ice jams are typically found to occur in the same locations. This is because the necessary conditions for genesis of an adequate ice supply and obstruction of its downstream transport determine the specific areas where ice jams will occur. In areas likely to be selected for a detailed FIS, historical documentation is usually available that will indicate if ice jam-caused flooding is a significant factor warranting consideration in the FIS. In cold regions of the country, where ice jams are typical, the SC should investigate historical floods for evidence of ice jam contribution as part of the study reconnaissance effort. Where ice jams historically contributed to flooding in a community, they should be evaluated using the procedures described in this Appendix (when appropriate).

A3-2 TYPES OF ICE JAMS

Ice jams have been classified in numerous ways by various investigators. Calkins (Reference 1) has classified ice jams as freezeup or breakup types, moving or stationary types, and floating or grounded types. Freezeup-type jams are associated with the formation and accumulation of frazil ice, which eventually forms a continuous ice cover. Freezeup-type jams usually do not need to be addressed in a FIS because they are not associated with large discharge events, which are necessary to cause flooding problems. However, the SC should be aware of possible exceptions. Breakup-type jams are frequently associated with rapid rises in river stage, resulting from rainfall and/or snowmelt, and usually occur in the late winter or early spring. Because of the large volumes of ice that may be involved and the greater discharges associated with them, breakup-type jams are predominant in ice jam-caused flooding and are typically the type requiring investigation in an FIS.

Moving ice does increase water levels; however, these effects are minor compared to those of stationary jams and usually do not need to be considered in an FIS. Floating-type ice jams are considered to be those where the ice is not grounded to the channel bottom and significant flow takes place beneath the ice cover. Grounded-type jams are characterized by an ice cover that is partially grounded to the bed of the channel, with most of the flow being diverted into the overbank and floodplain areas. Grounded-type jams are typical of shallow, confined stream sections, while floating-type jams are typical of deeper rivers. Both of these stationary-type ice jams can cause significant backwater effects and should be addressed in an FIS.

A3-3 RECONNAISSANCE

While conducting the reconnaissance effort for a FIS, the SC shall determine whether ice jamming has historically resulted in flooding within the community under study. Where such flooding has occurred, the reconnaissance effort should be intensified to acquire as much data as possible concerning ice jam events in the community, on the streams being studied, and in the region. Such data should include, but not be limited to: locations of ice jams, dimensions, ice volumes, causes, associated river stages and discharges, frequency of occurrence, lateral and upstream extent of flooding, season of occurrence, and other contributing or correlative factors. The nature of ice jamming common to the site should also be investigated (i.e., whether freezeup- or breakup-type jams are typical and whether grounded- or floating-type jams are typical). Because very little documented data are usually available, all possible sources of information must be investigated, including photographs, local residents, newspapers, community officials, State agencies, and Federal agencies.

During the field reconnaissance, the SC should investigate physical evidence of ice jams, such as high-water marks, damage to structures, or scars on trees, which may provide useful data for the analysis or support for the study results.

A3-4 ANALYSES

Different methods may be used for establishing flood elevations in areas subject to ice jam flooding, depending on the availability of data and the nature of the ice jamming phenomena that occur at the site of interest. The methods outlined herein are applicable primarily to stationary-type (floating or grounded) ice jams that occur during periods of ice breakup. These types of jams have historically resulted in major flooding in certain regions of the United States. The SC should be aware of conditions that may warrant alternate analytical methods, and should seek approval of alternate methods from the Regional PO before proceeding.

The approaches below are based on the development of stage-frequency relationships for two different populations (ice jam flood stages and free flow flood stages), which are then combined into a single composite curve for flood stages at a site under study. Depending on the availability of ice jam stage information, ice-jam stage-frequency relationships may be determined directly or indirectly as discussed below. The direct method is preferred where applicable.

A. Direct Approach

If sufficient data exist at the site of interest, an ice-jam stage-frequency distribution can be established directly by fitting a frequency curve to historical ice stage data. This approach is recommended where ice jam stages are available for more than two significant events (i.e., overbank flooding) that span more than a 25-year period of record and where hydraulic conditions have not changed appreciably since those events. Historical stages will permit the computation of plotting positions and fitting a frequency curve on probability paper. Weibull plotting positions are recommended for this purpose.

This approach is preferred over the indirect approaches discussed in the following sections of this Appendix because the joint probabilities of various hydrologic and hydraulic factors, such as discharges, ice volumes, and ice thickness, are inherently included in the frequency analysis.

To apply the direct approach, certain steps should be taken. First, a discharge-frequency curve should be established, using annual peak flows or a suitable regional method, using procedures specified in these Guidelines.

Second, standard hydraulic techniques should be used to establish corresponding free-flow stage-frequency curves for each of the cross sections in the reach where ice jams are to be considered.

Usually the analyses of standard return intervals used in a FIS (i.e., 10-, 50-, 100-, and 500-years) will be sufficient to establish the free-flow stage-frequency curve on normal probability paper. Third, an ice-jam stage-frequency curve should be established by assigning Weibull plotting positions to historical ice jam stages and fitting a curve to these points on normal probability paper.

Fourth, where ice-jam stage-frequency information must be developed for reaches upstream or downstream of the location where a direct analysis can be made, the hydraulic techniques discussed in the following sections on indirect approaches should be used and calibrated to match the ice-jam stage-frequency curve developed for the site with available data. The calibration for floating-type jams would be accomplished by assuming equilibrium ice thickness (as discussed in Section A3-4b(1)) at the location where the ice-jam stage-frequency curve was developed and establishing a combination of discharge, equilibrium ice thickness, and roughness that would correspond to that stage. The calibration for grounded-type jams would be accomplished by assuming complete blockage of the main channel at the point of obstruction, with equilibrium ice thickness upstream, and then establishing the combination of discharge, equilibrium ice thickness, and roughness that would correspond to that stage. This will permit the HEC-2 ice cover option to be used for estimating corresponding ice jam stages upstream or downstream of the point where historical data are available.

Finally, for each cross section subject to ice jam flooding, the free-flow stage-frequency curve, established as described above, must be combined with the ice-jam stage-frequency curve established as described above, assuming the events are independent. Thus,

$$P(s) = P(si) + P(sq) - P(si) \times P(sq)$$

where P(s) = probability of a given stage being equaled or exceeded from either an ice jam event or a free flow event

P(si) = Probability of that stage being equaled or exceeded from an ice jam event

P(sq) = Probability of that stage being equaled or exceeded from a free flow event

This provides the composite stage-frequency curves at each cross section, which are used to develop flood profiles and maps for the FIS.

B. Indirect Approaches

(1) Assumptions. The indirect approach to ice-jam stage-frequency analysis may be used where available data are insufficient to establish a stage-frequency distribution directly. This approach makes use of several assumptions.

Ice-jam stage frequency is a function of ice jam season discharge frequency.

Ice jams are of the breakup type.

Ice jams are of the stationary type.

For all jams, the ice thickness will be given by the equilibrium relationship developed by Pariset et al. (Reference 2) and the stage-discharge relationship will be determined by adjusting the standard step-backwater technique for flow under an ice cover of equilibrium thickness.

For grounded-type jams, the stage-discharge relationship at the point of ice jam formation will be that resulting from complete or nearly complete blockage of the normal channel, with flow being carried in the overbank floodplain areas.

(2) General Procedures. To apply the indirect approach, certain procedures are used. First, a free-flow stage-frequency distribution is established for each cross section by using standard backwater modeling to establish stage-discharge relationships. Usually, the four standard discharges (10-, 50-, 100-, and 500-year return intervals) will provide sufficient points to establish the stage-frequency curve for each cross section on normal probability paper.

The water year is then separated into an "ice jam season" and a "free flow season" based on the historical occurrence of ice jams in the region and, in particular, in the stream under study. The season should encompass the period when breakup-type ice jams normally occur and will likely vary with the latitude and elevation of the stream being studied.

Ice jams tend to be associated with one of the seasonal peak flows because ice jams typically form during rises in river stage that break up the ice sheet. All ice jam season annual peak flows should be fitted to a frequency curve. Weibull plotting positions are recommended for this purpose. For ungaged streams, ice jam season discharge-frequency relationships must be established by regional analysis of seasonal flows for gaged streams. Usually, the establishment of regional ice jam season discharge-drainage area curves will be sufficient for this purpose.

The ice jam season discharge-frequency curve is then converted to a conditional (given that an ice jam occurs) stage-frequency curve. This is done at each cross section subject to ice jam flooding using the HEC-2 program, with the ice cover option. This option takes into account the hydraulic aspects of flow under ice, such as a reduction in flow area, increased wetted perimeter, and ice roughness. Inputs required to utilize this option include the normal HEC-2 input, the thickness of ice in the channel and overbanks, Manning's "n" value for the underside of the ice cover, and the specific gravity of the ice. The SC is referred to documentation prepared by the U.S. Army Corps of Engineers, Hydrologic Engineering Center (Reference 3) on the use of this option. The recommended ranges for "n" values are from 0.015 to 0.045 for unbroken ice and from 0.04 to 0.07 for ice jams. The specific gravity of normal ice is approximately 0.92, which is the recommended value for this analysis. Where major floods are caused by ice jams, the assumption of equilibrium ice thickness is probably reasonable because sufficient upstream conditions exist to generate the ice volumes needed. Unless there is strong evidence to the contrary, the ice thickness used in the analysis should be the approximate equilibrium thickness as defined by Pariset et al. (Reference 2). Where equilibrium ice thickness is not appropriate, the SC should justify the thickness used in the analysis.

The composite stage-frequency curve for establishing the elevations of the various return interval floods at each cross section is then obtained by combining the free-flow stage-frequency distribution and the ice-jam stage-frequency distribution as follows:

$$P(s) = (P(s)|S=F) \times P(S=F) + (P(s)|S=J) \times P(S=J) - ((P(s)|S=F) \times P(S=F)) \times ((P(s)|S=J) \times P(S=J))$$

The probability (P(s)|S=F) is the conditional probability that a given stage(s) is equaled or exceeded given that an annual maximum stage is a free flow event. This conditional probability is the stage-frequency curve for free flow events as derived above. The probability (S=F) is simply the fraction of all annual maximum stages that are free flow events. Likewise, the probability (P(s)|S=J) is the conditional probability that a given stage(s) is equaled or exceeded given that the annual maximum stage is an ice jam event. This conditional probability is obtained as described above. The probability (S=J) is simply the fraction of all annual maximum stages that are ice jam events.

The fraction of annual maximum stages that is attributable to ice jams should then be established through an analysis of historical data at the site, other sites on the same stream, and other sites in the region. An analysis of peak stages at gaged sites is often useful for this purpose because peak stages affected by ice are usually documented. Note that, in this indirect procedure, only the relative frequencies of maximum annual stages from ice jam and non-ice jam events need to be estimated. The actual ice jam flood elevation, which is often more difficult to ascertain, is not needed.

The above analysis provides the composite stage-frequency curves for establishing the elevations of the various return interval floods at each cross section. These are then used to establish the flood profiles and floodplain delineations for the FIS.

C. Grounded Jams

The SC should document that grounded-type ice jams have occurred historically before grounded-type jam behavior is assumed. The procedures for establishing stage-frequency relationships for stream sections subject to grounded-type ice jamming are identical to those cited earlier except for the hydraulic analysis. Grounded-type jams may occur at confined sections, such as bridges, and at shallow sections. The hydraulic analysis assumes that a high percentage of the normal flow area of the channel (or bridge) is obstructed and that most of the flow is in the overbank areas.

Hydraulic effects at the point of obstruction and upstream should be modeled using step-backwater methods modified for ice cover. The U.S. Army Corps of Engineers HEC-2 program, with the ice cover option, is recommended for this purpose (Reference 3). At the point of obstruction, the use of an actual or hypothetical bridge section will permit the special bridge routine to be used to facilitate the analysis. The low chord of the bridge (HEC-2 variable ELLC) and the net flow area (HEC-2 variable BAREA) may then be adjusted to achieve different degrees of blockage of the main channel. The SC should normally assume between 95 and 100 percent blockage of the channel unless sufficient evidence exists to support another assumption. In that case, the alternative should be documented and justified. Upstream from the site of grounding, equilibrium ice thickness, as computed according to the Pariset formulation (Reference 2), should be assumed unless alternate thicknesses can be justified.

A3-5 PRESENTATION OF RESULTS

A. FIS Report

A discussion of historic ice jam flooding should appear in Section 2.3 (Principal Flood Problems) of the FIS Report.

Section 3.1 (Hydrologic Analyses) of the FIS Report should include a discussion of any discharge-frequency analysis for the ice jam season, if used. Similarly, the statistical treatment of stage-frequency analyses for ice jam and non-ice jam events should be discussed. The historical data used in the analyses should be referenced in the discussion along with its source and how it was used. The Summary of Discharges table should be based on analysis of the full year and footnoted to that effect.

Section 3.2 (Hydraulic Analyses) of the FIS Report should include a discussion of how free flow and ice jam stages were computed, whether stages were computed directly from stage-frequency analyses or indirectly analyzed. The approximate channel blockage assumed and assumed ice thickness should be discussed, if used. The relationship of the computed ice jam stages to historic floods should be discussed. An example of stage-frequency curves for combined floods should be provided for the point of obstruction, or a representative cross section within the community should be provided if the former is outside the corporate limits. The discussion should also indicate that floodways were computed only for free flow conditions.

The "Regulatory" column of the Floodway Data table should be prepared using the 100-year flood elevations established from the composite ice-jam and free-flow season stage-frequency curves and footnoted to that effect. All other columns in the Floodway Data table shall be based on the 100-year free flow conditions.

B. Profiles

The flood profiles shown in the FIS shall be based on the elevations established from the composite ice-jam and free-flow stage-frequency analysis.

C. Maps

The FIRM shall be developed based on the elevations established from the composite ice-jam and free-flow stage-frequency analyses performed at each cross section. Floodways shall be established and plotted based on the 100-year flood discharges and hydraulics assuming free flow conditions. The lateral extent of a major historic ice jam may be indicated on the work map if it is well documented, does not hamper interpretation, and is appropriately annotated as such.

A3-6 REFERENCES

1. U.S. Army Cold Regions Research and Engineering Laboratory, Technical Note, "Methodology for Ice Jam Analysis," D. J. Calkins, October 1980.

2. E. Pariset, R. Hausser, and A. Gagnon, "Formation of Ice Covers and Ice Jams in Rivers," Journal of the Hydraulics Division, ASCE, November 1966.

3. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "Analysis of Flow in Ice Covered Streams Using Computer Program HEC-2," February 1979.

APPENDIX 4. AERIAL MAPPING AND SURVEYING SPECIFICATIONS

A4-1 INTRODUCTION

This Appendix presents FEMA photogrammetric mapping and surveying guidelines and specifications that have been established to specify the quality of the spatial data products to be produced, including Flood Insurance Rate Maps (FIRMs), cross-sections, Digital FIRMs (DFIRMs), and DFIRM-Digital Line Graphs (DFIRM-DLGs). The term "FIRM" is also used generically herein to specify this "family" of FEMA spatial products.

These guidelines and specifications are drawn largely from recognized industry standards, to include U.S. Army Corps of Engineers (USACE) Engineer Manual 1110-1-1000, *Photogrammetric Mapping*, dated 31 March 1993; *Large-Scale Mapping Guidelines*, published by the American Society for Photogrammetry and Remote Sensing (ASPRS) and the American Congress on Surveying and Mapping (ACSM), reprinted, with minor revisions, from U.S. Department of the Interior, U.S. Geological Survey (USGS), National Mapping Division, Open File Report 86-005, Reston, Virginia, 1986; and *Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques*, Federal Geodetic Control Committee (FGCC), Version 5.0, August 1, 1989.

This Appendix sets forth the accuracy standards to be used in FEMA for photogrammetrically derived products. Minimum requirements to meet these accuracy standards are given for critical aspects of the photogrammetric mapping and mensuration process, such as maximum flight altitudes, C-Factor ratio limitations, and aerotriangulation adjustment criteria.

Mapping accuracy standards are associated with the final development scale of the map -- both the horizontal "target" scale, normally 1"=500', and vertical relief, normally 4' contour interval, for newly published FIRMs and Study Contractor (SC) FIRM workmaps. The use of computer aided design and drafting (CADD) equipment by FEMA's Technical Evaluation Contractors (TECs) allows the ready separation of planimetric features and topographic elevations to various layers, and depiction at any scale.

The specified accuracy of FIRM workmaps produced by FEMA SCs must be sufficient to assure that the final FIRMs produced by FEMA can be reliably used for the purpose intended. However, the accuracy of a mapping product should not surpass that required for its intended functional use. Specifying map accuracies in excess of those required results in increased costs to FEMA, delays in project completion, and reduction in the total numbers of new or revised products. It is absolutely essential that mapping accuracy requirements originate from functional and realistic accuracy requirements.

A4-2 PHOTOGRAMMETRIC MAPPING STANDARDS

There are three generally recognized industry standards relevant to FEMA that could be used for specifying spatial mapping products and resultant accuracy

compliance criteria:

- Office of Management and Budget (OMB) "United States National Map Accuracy Standards (NMAS)," published in 1947.

- American Society for Photogrammetry and Remote Sensing (ASPRS) "ASPRS Accuracy Standards for Large-Scale Maps (ASPRS 1990)," published in 1990.

- U.S. Federal Geographic Data Committee (FGDC) "U.S. National Cartographic Standards for Spatial Accuracy (NCSSA)," currently in draft form but scheduled to be published in 1994 as a replacement for the NMAS.

Each of these standards has application to different types of functional products. Their resultant accuracy criteria (i.e., spatial errors in X-Y-Z), including QC compliance procedures, do not differ significantly from one another. In general, use of any of these standards for a photogrammetric mapping contract will result in a quality product. The ASPRS 1990 standards, relevant to digital spatial data, are currently the preferred standards for new FEMA products, including DFIRMs and DFIRM-DLGs.

A4-3 FEMA OBJECTIVES

The objective of this Appendix is to establish aerial mapping and surveying specifications that are consistent with standard professional practice whereby: (1) vertical and horizontal control procedures, within floodplains and adjoining 1,000' buffer zones, are appropriate for 1"=500' (1:6,000-scale) maps, with 4-foot contour interval, which meet the ASPRS 1990 standards; (2) quality control (QC) procedures are clear, realistic and consistently followed within the professional community; and (3) modern technology is exploited, especially the Global Positioning System (GPS) and GPS photogrammetry.

In general, photogrammetric methods should be selected for use when the 100-year floodplain cannot be delineated using the available map information to an accuracy equivalent to that ordinarily obtainable with a 4-foot or smaller contour interval topographic map which meets the NMAS or ASPRS 1990 standards. ASPRS 90 Class 1 standards are normally mandatory for FEMA contracts; however, the Regional Project Officer can specify Class 2 or Class 3 standards if additional costs for Class 1 products are determined to be excessive.

Standard photogrammetric methods can provide the information needed to prepare a Flood Insurance Study (FIS), including cross-sectional data and topographic contours of the floodplain. Other secondary benefits of aerial survey techniques include the updating of base map features, estimation of Manning's roughness coefficients, identification of hydraulic control structures, and selection of cross-section locations. FEMA is not chartered, however, to produce base maps significantly outside of potential floodplains; in such areas, FEMA uses the most accurate base mapping data available from the U.S. Geological Survey (USGS), local communities, or other sources. Wherever accurate digital base maps do not exist from USGS or community sources, FEMA does allow base mapping within floodplains and in a 1,000' "buffer zone" adjoining floodplains.

Photogrammetry becomes more economical as the required number of cross sections increases. Its advantages are greatest where accurate topographic maps do not exist; where terrain is rough or swampy, making ground surveys difficult or impossible; or where clearing survey lines on private property is a problem.

Schedule requirements are an important consideration in the decision regarding the applicability of aerial photogrammetry. In many areas, good aerial photography can be obtained only during short periods of the year, when foliage does not obscure the landscape, the ground is free of snow, and the sky is clear. Poor weather and difficult terrain conditions can also delay required ground surveys. However, these factors have no effect on the schedule for determination of cross sections and contours by photogrammetry once photography and ground control have been completed. The study schedule should reflect these considerations to avoid delays in completing the study.

The guidelines herein shall be followed in performing photogrammetric surveys. Should the SC also perform the photogrammetric work, then any reference herein to Photogrammetric Subcontractor should be understood to mean Study Contractor.

A4-4 American Society for Photogrammetry and Remote Sensing (ASPRS 1990).

The current recommended standard for FEMA photogrammetric mapping is the ASPRS 1990 Class 1 standard; when finalized and published, the NCSSA -- based on the ASPRS 1990 standards -- are expected to become the new recommended or mandatory standard for production of FEMA products. ASPRS 1990 standards were developed by and are generally recognized by the photogrammetric industry, and they are specifically relevant to definitions of spatial accuracies which satisfy FEMA requirements. This standard is intended for mapping scales larger than 1:20,000. A major feature of these ASPRS standards is that they indicate accuracy at ground scale, rather than as a function of map scale as in the past; thus, digital spatial data of known ground-scale accuracy can be related to the appropriate map scale for graphic presentation at a recognized standard. Another advantage over prior standards is that it contains more definitive statistical map testing criteria, which, from a contract administration standpoint, is desirable. Emphasis is placed on the final spatial accuracies that can be derived from the map in terms most generally understood by users. The ASPRS standards are applicable to GPS and conventional surveying applications.

The Root Mean Square Error (RMSE) used throughout this document is defined to be the square root of the average of the squared discrepancies between map-derived (from mylar reproducibles) and check-survey coordinates, computed separately for X, Y, and Z values. For example, the RMSE in the X coordinate direction can be computed as:

$RMSE_x = \sqrt{(Dx^2/n)}$ where

$D_x^2 = d_{x1}^2 + d_{x2}^2 + d_{x3}^2 + \ldots + d_{xn}^2$ (for all X coordinates)

D_{x1} = difference in X coordinate of point 1 as derived from the mylar map reproducible and as determined by a check survey of higher accuracy

D_{x2} = difference in X coordinate of point 2 as derived from the mylar map reproducible and as determined by a check survey of higher accuracy

D_{x3} = difference in X coordinate of point 3 as derived from the mylar map reproducible and as determined by a check survey of higher accuracy

D_{xn} = difference in X coordinate of point n as derived from the mylar map reproducible and as determined by a check survey of higher accuracy

n = total number of points checked in the X direction

A. Map Classes. Three map accuracy classifications are prescribed in the ASPRS 1990 standards. Class 1 maps are the most accurate. Class 2 maps have twice the root mean square error (RMSE) of a Class 1 map; Class 3 maps have thrice the RMSE of a Class 1 map. Maps may be one class in horizontal accuracy and another in vertical. Furthermore, multiple accuracies on the same map are allowed, provided a diagram is included which clearly relates map segments with the appropriate map accuracy class. This is especially relevant for FIRMs where workmap data within floodplains may be significantly more accurate than base map data outside of floodplains. Class 1 standards, both vertical and horizontal, are implied for FEMA products within floodplains unless the Regional PO specifies a requirement for a less expensive, lower accuracy classification for a given project. The new NCSSA standards, when published, are expected to equate to ASPRS Class 1 and Class 2 standards, but not Class 3.

B. Horizontal Accuracy Criteria. The ASPRS planimetric standard makes use of the RMSE as being ". . . defined to be the square root of the average of the squared discrepancies." It goes on to state: ". . . the discrepancies are the differences in coordinate or elevation values as derived from the map and as determined by an independent survey of higher accuracy (check survey)." The RMSE is defined in terms of feet or meters at ground scale rather than in inches or millimeters at the target map scale. This results in a linear relationship between RMSE and target map scale; as map scale decreases, the RMSE increases linearly. The RMSE of a FIRM panel is the cumulative result of all errors including those introduced by the SC or subcontractor in performing ground surveys, aerial triangulation, and map compilation; digitization by the TEC; and final extraction of ground dimensions from the mylar map reproducibles. The limiting RMSEs shown in Table A4-1 are the maximum permissible RMSEs established by this standard for 1"=500' FIRMs and FIRM workmaps with 4' contour intervals. These limits of accuracy apply to well-defined planimetric points only.

C. Vertical Accuracy Criteria. Vertical accuracy is defined relative to the required contour interval (CI) for a map. The ASPRS vertical standard also uses the RMSE, but only for well-defined features between contours containing interpretative elevations, or spot heights including elevation reference marks (ERMs) and elevation reference points (ERPs). Contours in themselves are not considered as well-defined feature points. The RMSE for Class 1 elevations derived from contours is one-third of the CI. The RMSE for Class 1 spot heights is one-sixth of the CI. Class 2 and Class 3 accuracies are twice and thrice those of Class 1, respectively. Testing for vertical map compliance is also performed by independent, higher accuracy survey methods, such as differential leveling or differential GPS. Table A4-1 summarizes the limiting vertical RMSEs for well-defined vertical points, as checked by independent surveys at the full (ground) scale of the map.

TABLE A4-1 - ASPRS 1990 STANDARDS APPLICABLE TO FIRM WORKMAPS

	Class 1	Class 2	Class 3
Horizontal Accuracies for 1" = 500' maps			
Limiting RMSE in X and Y	5 ft	10 ft	15 ft
Horiz. Survey Standards (Order/Class)			
Control and Check Surveys	3rd/Cl I	3rd/Cl II	3rd/Cl II
Relative Accuracies	1:9,000	1:4,500	1:3,000
Vertical Accuracies for maps produced from 4' Contour Interval workmaps			
RMSE for well defined features:			
* Interpolated between workmap contours	1.33 ft	2.67 ft	4.0 ft
Spot heights, ERMs, ERPs	0.67 ft	1.33 ft	2.0 ft
Vertical Survey Standards (Order)			

Control and Check Surveys	3rd order	3rd order	3rd order

<u>Photogrammetric Planning with</u>
<u>Analytical Plotter, 6" focal length</u>

Maximum C-Factor (denominator)	2,000	2,200	2,500
Maximum flight height (H)	8,000'	8,800'	10,000'
Aerotriangulation Accuracy Criteria (1☞)			
Horizontal RMSE at control/test points	H/10,000	H/8,000	H/6,000
Vertical RMSE at control/test points	H/9,000	H/6,000	H/4,500
Maximum allowable errors, both horizontal and vertical	3 RMSE	3 RMSE	3 RMSE

* For checking of workmap contours only; published FIRMs do not include contours.

D. Accuracy Labeling. Horizontal and vertical accuracy of FIRM workmaps and final FIRMs can be checked by comparing measured coordinates or elevations from mylar reproducibles (at their intended target scale, normally 1"=500) with coordinates determined by a check survey of higher accuracy. Check surveys are described in paragraph A4-7.C below.

1. Data tested for both horizontal and vertical accuracy should be labeled as follows to report RMSE:

Tested RMSE __ feet in X
__ feet in Y
__ feet in Z

2. Data produced according to established procedures should be labeled as follows to report intended RMSE:

Compiled to meet RMSE __ feet in X
__ feet in Y
__ feet in Z

3. If accuracy information cannot be provided in terms of RMSE, other useful information may be provided to give the user an idea of how well the data fits the requirements of an application. This information may include accuracy expressed in terms of other statistics, including the 90% circular map error defined in the NMAS. It must include information about the source material from which the data was compiled, accuracy of ground surveys associated with compilation, digitization procedures, equipment, quality control procedures used in data production, etc.

A4-5 U.S. National Cartographic Standards for Spatial Accuracy (NCSSA). These draft standards define positional accuracy as it pertains to spatial data. When finalized and published by the Federal Geographic Data Committee (FGDC), they will supersede the NMAS issued June 10, 1941, and most recently revised on June 17, 1947, by the former U.S. Bureau of the Budget. Considerable review and correction to the current draft is expected prior to final publication.

A4-6 SPECIFICATIONS

A. Aerial Photography

Aerial photography specifications are outlined in the USGS 86-005 Large Scale Mapping Guidelines and in the forthcoming ASPRS "Considerations for an Aerial Photo Project." The area to be flown and the approximate location and vertical ranges of the cross-sectional information needed to represent all reaches under study must be determined by the SC.

In planning for photogrammetry, the SC should make an approximate analysis to estimate the 100- and 500-year flood elevations for every reach for which detailed study is required in order to estimate the extent of horizontal aerial photo coverage required. Where available, FIA FIRMs, USGS flood-prone area maps, or similar studies may be used for this purpose.

Figure A4-1 provides an example of a Location Map showing the detailed study areas and buffer zone (generally 1000 feet greater than the estimated 500-year flood limits) to be covered by stereophotography. The aerial photogrammetric subcontract generally includes establishment of the following:

- Photogrammetrically obtained stream and valley cross sections (portions above water).
- Planimetric compilation manuscript map copy.
- Contours (4-foot) of floodplains from the waterline to the nearest 4-foot contour above the 500-year flood elevation line.
- Contiguous contours.
- Contours of 100- and 500-year floodplain elevations (if profiles have been determined from previous studies).
- Tabulations of elevation reference mark (ERM) information.

The floodplain area for which detailed study is required must be outlined by the SC. A 1,000' buffer zone is then added for insurance against uncertainties. The Photogrammetric Subcontractor should obtain stereoscopic photography of the detailed study area plus buffer zone outlined on the location maps (Figure A4-1) adequate to determine ground point elevations, within limits of accuracy described in Sections A4-4 as appropriate. The photography should be flown while the sun angle is above 30 degrees, when there is no snow cover, the streams are in the main channels, and leaves are off the trees.

Normally, special photography must be flown for each community being studied. Stereophotographic coverage of the floodplains and buffer zones must be obtained by using a first-order 6-inch (approximately 153 mm) focal length aerial camera calibrated within the last 3 years by USGS. (See the article by Donald Light, entitled "The New Camera Calibration System at the U.S. Geological Survey," in the February 1992 issue of *Photogrammetric Engineering and Remote Sensing*.) A wide-angle aerial camera with a planigon, pleogon, or avigon lens (or their equal) having radial distortions of less than 10 micrometers, and area weighted average resolution (AWAR) of at least 63 line pairs per millimeter, is acceptable. A data chamber, imaged at the edge of each photograph, will display flying height, time, date, and level data. If the chamber is either malfunctioning at the time of flight or not available, then a manual log of the information must be maintained.

The SC should ascertain the ability of the photogrammetric equipment and personnel used for the project, and then decide on the necessary flight height that will achieve the required accuracies. The photographic flight height above the stream elevation must be no higher than that calculated by multiplying the C-factor by the desired contour interval (4-feet). Within the photogrammetry profession, the C-factor is understood to be that value, used to compute the flying height, which will produce photography satisfactory to obtain the desired vertical accuracy in the map. A C-factor can be assigned to a photogrammetric system only after sufficient mapping has been produced by the system and its operators to permit an analysis of the vertical accuracy that is obtained. Caution must be exercised in the use of standard C-factors, provided by equipment vendors, since they tend to be exaggerated and result from analyses performed under ideal conditions that rarely occur in actual practice. Although C-factors up to 2500 are advertised, it is rare for even the best analytical or digital photogrammetric systems and operators to achieve legitimate values in excess of 2200. Maximum allowable C-factors for analytical plotters are listed in Table A4-1. A reasonable C-factor for an encoded analog plotter, e.g., AG-1 or PG-2, is about 1800.

Aerial surveys should be carried out under the direct supervision of a registered civil engineer, registered land surveyor, or certified photogrammetrist. It is recommended that the SC obtain a signed statement from the Photogrammetric Subcontractor indicating the personnel and equipment that will be utilized for the project (see Figure A4-2), and the estimated C-factor and proposed flying height.

The Photogrammetric Subcontractor should store the film negatives in appropriate temperature- and humidity-controlled environment for 3 years after completion of the contract, and the film negatives will be available to FIA without cost during that period. The negatives should not be destroyed until authorized to do so by the Regional Project Officer.

B. Ground Control. The Global Positioning System (GPS), when used in the differential mode, is the preferred method for extending any survey control network unless satellite visibility is obscured (e.g., dense forest) or severe radio frequency disturbances are present.

1. Vertical Control. The Photogrammetric Subcontractor must perform necessary field surveys to maintain vertical photogrammetric control, with all elevations referred to the National Geodetic Vertical Datum of 1929 (NGVD 29) or the successor North American Vertical Datum of 1988 (NAVD 88). The vertical datum may be either NGVD 29 or NAVD 88, but not mixed within a single study. It is recommended that all new studies be referenced to NAVD 88. The SC must coordinate with FEMA prior to beginning any survey work to determine whether to use NAVD 88. See Appendix 6 of this document for further guidance on the use of NAVD 88.

These surveys must use differential GPS procedures or third-order (or better) differential or trigonometric leveling. Vertical control points, for leveling of photogrammetric stereo models, are to be established with elevations accurate to within ±0.4 feet, relative to the bench marks of third-order or higher accuracy used for the survey. For county-size and smaller areas, the GPS is preferred for establishing vertical control points if precise Differential GPS (DGPS) techniques are used, including Static, Rapid Static, Real-Time Kinematic, Pseudo-Kinematic, or Stop-and-Go (Semi-Kinematic) positioning procedures (see Section A4-8, Glossary), with the base station receiver simultaneously measuring the elevation of a local bench mark of third-order or higher accuracy, and with base station corrections applied to the roving GPS receiver simultaneously observing the same four GPS satellites (minimum).

Primary control will consist of a network of DGPS control points or control levels (see Section A4-8, Glossary) adequate to produce maps with a 4-foot contour interval. Enough points should be included in the primary network so that no stereo-model ground-surveyed control point (picture point) is farther than 15,000 feet from the nearest primary control point in that network. Sufficient points will be used to produce a stable aerotriangulation solution.

Points will be located in areas where they can be read from as many stereomodels as possible, except in cases where the point lies within one-third inch of the edge of the stereomodel. In no case will the number of stereomodels without vertical control points exceed two. Points will be located and numbered on the image side of the contact print and located, numbered, and described on the reverse side. Points will be selected under the supervision of a Certified Photogrammetrist to ensure sufficient and accurate selection.

The National Geodetic Survey (NGS) has published a national geoid model and PC-based computer software, called GEOID93, which converts from ellipsoid heights (derived from GPS) to orthometric heights (derived from precise leveling) nationwide with a standard deviation of 10 cm for points spaced 100 km apart. GEOID95 will have a standard deviation of 1 cm so that the equivalent of third-order leveling can clearly be accomplished nationwide with DGPS. When DGPS techniques are used within a single county, this correction for variable height of the geoid above the ellipsoid in nonmountainous areas is insignificant. NGS has also published another PC-based software program, called VERTCON, which converts NGVD 29 values to NAVD 88. Both of these programs can be obtained at nominal cost by calling the National Geodetic Information Branch at (301) 713-3236 or by Fax at (301) 713-4172. See Appendix 6 for more details.

2. Horizontal Control. At a minimum, all horizontal control should be to an accuracy level of NGS Third Order Class I or better. All basic horizontal control should be established by traverse or DGPS. Federal Geodetic Coordinating Committee (FGCC) standards for

instrumentation, field observations, and data reduction will be followed as applicable to the order and class of survey.

Each horizontal control point should be accurate to one one-hundredth (1/100) of an inch at map scale to be consistent with ASPRS 90 standards. In order to meet 4-foot contour interval requirements, maps are normally compiled at 1"=150' to 1"=200'. Therefore, DFIRM-DLGs can meet ASPRS 1990 standards within floodplains if horizontal control used for compilation of 4-foot contour interval maps is accurate to ±1.5 foot. This horizontal accuracy is easily achievable when DGPS procedures are used.

3. Photo Control Contact Prints. All horizontal and vertical control will be located and identified on the contact prints by the Photogrammetric Subcontractor. All vertical photo-identifiable control should be selected and symbolized on the face of the appropriate contact prints, with the location precisely symbolized, described, and diagrammed as necessary on the back of the photo. Control points will be finely pinpricked and symbolized on the face of the appropriate contact prints, and the location precisely described with a sketch showing the exact location of the point and the surrounding details as seen on the photograph.

4. Survey Records. Upon completion of the project, the following information should be delivered, upon request, to the Regional PO.

a. Field Notebooks. Field notebooks should be carefully and neatly prepared, identified, indexed, and preserved. All data regarding the establishment and extension of vertical and horizontal control, including descriptions of all established and recovered monuments, should be recorded. Where existing control points are recovered by the SC in extending the basic control, the field notebooks should contain the following: (1) information as to the general condition of the recovered mark; (2) the original description; (3) exact letter and numbers stamped (not cast in) on the mark and amended description, if applicable; (4) additional tie data, if any; and (5) a sketch of the location as appropriate to facilitate future recovery. The field notebooks should contain the name and the field address/location of the party chief, the identity of the survey instruments, and appropriate calibration data. Each field notebook should be numbered and marked with a brief description of the contents on the cover, should be carefully indexed, and should have all pages numbered. Each horizontal traverse line and vertical control line should be identified by number and brief description in the field book. The first page used on each day of field work should be dated. Each field notebook should be free of erasures; any line of horizontal and vertical control may be rejected by the Regional PO if any erasure is made in recording the data for that line. If the field notes are electronically recorded, printouts of the electronically recorded field notes should be provided.

b. GPS Documentation. GPS documentation procedures will be comparable to those prescribed in the *Guidelines for Digitizing Project and Station Occupation Information Using Program CR8BB*, from the Space and Physical Geodesy Branch, National Oceanic and Atmospheric Administration, Version 3.0, July 26, 1990, in which the following data sets are prescribed:

- B-file. Project information, station position information, survey measurements, occupation notes and synchronization information.

- D-file. Station descriptions and/or recovery notes for all new and/or newly occupied stations.

- G-file. Differential coordinates, standard errors, correlations, and related information which are required for a least squares adjustment of a GPS field project.

✐ R-file. Those files created by the GPS receiver which contain the phase data of each satellite observed, and any other files created by the receiver which are necessary during processing.

c. Computations. All computations and adjustments of horizontal and vertical control data should be referenced to the field notebooks by book and page number. All field records and computations, and all results, should be delivered to the Regional PO with the control data upon completion of the work. Computations must be made in accordance with the published standards of the FGCC.

d. Control Diagram. The SC should furnish a schematic control diagram of the survey records on a photo index for all basic horizontal and vertical control pertinent to the project. The schematic diagram must show all existing and established control points properly identified in their approximate location. It will also show all traverse lines with their designations to include the beginning and ending points.

5. Bridges and Hydraulic Structures. Surveys of all bridges and hydraulic structures and underwater sections will be obtained by the SC from reliable available sources, or by field surveys where no information exists. Bridges and hydraulic structures may not be surveyed in part, or in total, by aerial photogrammetric methods.

C. Airborne GPS Control. Although GPS ground control surveying is the current standard of acceptance, airborne GPS is the surveying technology of the future. Recent advances in GPS technology, including On-the-Fly (O-T-F) software, allow Airborne GPS techniques to control the aerial photography, minimizing the need for ground control which may be more expensive and time consuming. Airborne GPS techniques can provide accurate measurements of the 3-dimensional locations of the aerial camera's projection center, at each instant of film exposure, rather than using extensive ground control to compute the camera locations. Aerial survey firms may utilize Airborne GPS techniques as a substitute for full ground control for all FEMA mapping, provided independent ground DGPS survey techniques are utilized to prove that quality control requirements of the project are satisfied, as explained in section C.3 below.

1. Equipment. Only GPS receivers capable of receiving carrier phase measurement on both the L1 and L2 frequencies, and the pseudorange on both frequencies will be acceptable for airborne control of mapping. The GPS receiver must be capable of receiving and recording (either internally or externally) satellite data at a one-second interval. In addition to other criterion, aerial cameras will be capable of measuring the precise instant of exposure of each photograph, and outputting a signal to the GPS receiver or another recording device. An airborne calibration of the collection system should be used to ensure the accuracy of airborne GPS surveys; the Ohio Department of Transportation, Bureau of Aerial Engineering, (614) 275-1357, can be contacted for use of their calibration and test range in the Madison County area. Several other states also have suitable test ranges.

2. Software. The position of the aerial camera will be computed at the instant of the mid-opening of the shutter for each exposure. This position may be interpolated from the nearest one-second positions. The software must be capable of using the dual-frequency phase data and the dual-frequency pseudorange data and be capable of fixing the carrier phase integer biases while the aircraft is in motion, and thus be capable of computing the difference in position between the fixed ground station and the aircraft. The software should also model the troposphere to correct for the difference in signal delay between the ground (base) and tracking (airborne) station.

3. Procedures. All Airborne GPS mapping will be conducted using DGPS techniques, with the ground receiver being placed over a point that has been tied into the National Geodetic Reference System. This ground reference receiver will be placed within the project site (preferably near the center) to minimize the errors in the geoid heights. In addition to the GPS tracking, a minimum of four ground control points (surveyed by ground DGPS methods), located at the

corners of the area to be mapped, will be used to check the airborne analytical solution holding the four corner control points as fixed, and solving for the positions of each photograph. Ninety (90) percent of the Airborne GPS positions must check the aerotriangulated positions within ±1.0 foot.

The 3-dimensional offset between the camera projection center and the GPS antenna's phase center should be measured prior to the flight and the offset should be applied to the GPS antenna position to arrive at the position of each photograph. Depending on the size of the spatial separation of the antenna's phase center from the camera's entrance node, the mount angles may also be required. The camera exterior orientation angles about the x, y and z axes (ω, ϕ, κ) will be computed from the block adjustment and applied in the normal manner during compilation. Exterior orientation of the photographs by a 3-dimensional GPS system will be allowed if test data can be shown to document accuracy equivalent to the analytically solved values.

D. Analytical Triangulation. Fully Analytical Aerial Triangulation (FAAT) must be used of the entire floodplain area and buffer zone for which stereo coverage is required. No analog or semi-analytical aerotriangulation procedures will be used. Extensive aerotriangulation data exist from the USGS topographic quadrangle mapping effort; photogrammetric subcontractors may, at their discretion, incorporate the existing aerotriangulation data from USGS into the development of their aerotriangulation solution. USGS data of a larger or equivalent photo scale should be used since the transfer from smaller scale photography would dilute accuracy.

1. Standards. At a minimum, the positional accuracy of horizontal and vertical photo control established by FAAT must meet or exceed each of the following conditions:

- The horizontal root mean square (RMS) error of the final block adjustment must not exceed 1/10,000 (one ten thousandth) of the flight height.
- The vertical root mean square (RMS) error of the final block adjustment must not exceed 1/9,000 (one nine thousandth) of the flight height.
- The maximum allowable error of any vertical or horizontal point must not exceed 3 RMSE.
- The mean of all points (taking into account positive and negative signs) must not exceed 1/15,000 (one fifteen thousandth) of the flight height.

2. Coordinate System. All ground positions determined by aerotriangulation may be in either Universal Transverse Mercator (UTM) or State Plane coordinates, so long as the coordinate system is clearly defined.

3. Control Photographs. All control points to be used in aerial triangulation should be pin-pricked and symbolized on the image side and symbolized, labeled, and diagrammed on the reverse side of one set of photo-controlled contact prints of the aerial negatives.

4. Passpoints. Passpoint location will be manually selected by reviewing the control photographs with a pocket stereoscope or other suitable stereo-viewing device. Selected passpoints should be located, symbolized, and labeled on the image side of the control photographs. All selected passpoint locations will lie on unobscured, level ground whenever topographic conditions permit. Passpoints will not be placed in areas of very bright background which could render a passpoint unusable (not locatable) on negatives.

For fully analytical aerial triangulation, individual frames will carry a minimum of nine passpoints, with the exception of end frames of flight lines, which will carry a minimum of six passpoints. One point will lie near the corner of each neat model, and one point will lie near each nadir position of each neat model. It is recognized that deviation from the ideal distribution may be necessary for those photographs covering bodies of water and areas of heavy ground cover. Tie points between strips will occur with a frequency of at least one per frame. As a general rule, wing passpoints within lines of flight will also serve as tie points between strips. No points should be closer than 5 mm to the photo edge.

5. Quality Control and Checkpoints. The Photogrammetric Subcontractor will check for the presence of gross errors and take preventative measures during the intermediate adjustment procedures. Ground control checkpoints should be used to verify the ground control survey and aerotriangulation. After the accuracy has been verified, the checkpoints will then be included in the final aerotriangulation and in all subsequent stereomodel setups.

6. Diapositives. All diapositives will be printed from original aerial photography negatives (i.e., not from duplicate negatives). Film positives will be printed on 9 1/2" cut sheets of Kodak Aerographic Duplicating (Estar Thick Base) Film No. 4421, or equivalent, on a printer having a flat platen. Film diapositives must be prepared emulsion up. Outdated emulsions will not be used under any circumstances. Because most auto dodging printers are unable to uniformly make contact between the negative and the diapositive materials, a flat glass plate should be used both below and above the negative/diapositive pair in the printer.

7. Point Marking. All point marking will be performed on the diapositives. Under no circumstances will any marking be performed on the original negatives. As a general rule, horizontal control points will not be marked, except where poorly defined on the diapositives. Maximum care should be exercised in the passpoint selection, marking, and transfer process.

All passpoints and checkpoints must be well-defined, and symmetrical patterns drilled, punched, or otherwise marked on the emulsion. A stereoscopic point marking and transfer instrument should be used. When parallel flight strips are being used, all passpoints should be transferred from one flight line to each adjacent flight line using a point marking and transfer device. The only exception to this requirement will be applicable to points falling in side-laps, but which are not intended to be used as strip tie points.

8. Point Mensuration. All ground control points, passpoints and checkpoints will be measured with a stereocomparator or a first order analytical stereoplotter having a least count of one micrometer or less and an intrinsic accuracy (calibration applied) of at least two micrometers (RMS).

9. Aerial Triangulation Program. The program used for aerial triangulation computations must be capable of adjusting strips as well as large blocks of photos. It must also have the facility for removing systematic errors and for detecting gross errors.

10. Aerial Triangulation Reports. Upon completion of all aerial triangulation work, the Photogrammetric Subcontractor will prepare an aerial triangulation report for submission to the Regional PO. The report will include, but will not necessarily be limited to, the following: flight lines; exposure stations or model layout; all control points appropriately labeled with station designations, computer designations (if any), and agency responsible for establishing the stations. Aerial triangulation results will include the following:

a. All misclosures at ground control points with and without use of checkpoints.

b. Computer printout of the final adjusted aerotriangulation solution to horizontal and vertical ground control. The printout should contain the final State Plane and/or UTM coordinates for all ground control points, pass points, and check points.

c. Identification of all points which were included in the initial solution and were subsequently discarded, with an explanation of the reasons for being discarded.

d. Identification of the weighting factors applied to all points used in the final solution.

e. A DOS diskette containing the coordinate data in ASCII format.

f. The report will include a brief narrative explaining the above solutions as well as descriptions of equipment, procedures, and computer programs used. RMS error summaries will be given for bundle adjustment photographic measurement residuals or strip tie point residuals and misclosures at control/check points. In addition, significant misfits encountered at control points, and steps taken to analyze such misfits and to rectify the discrepancies, will be described.

E. Photogrammetric Compilation. Photogrammetric compilation for a FIS normally includes determination of floodplain cross section geometry; plotting of 4-foot contours in the floodplain; and preparation of a planimetric manuscript map. The compilation requires high-precision photogrammetric equipment, hardware/software, and experienced operators.

1. Cross Sections. The Photogrammetric Subcontractor will provide the SC with: a photoindex of all photography on a sheet that is no larger than 24 inches x 36 inches; one set of black and white contact prints of photographs on resin-coated, neutral-toned, medium-weight paper with matte surface; two sets of black and white prints of alternate photographs enlarged 2x on resin-coated, neutral-toned, medium-weight paper with matte surface; and one set of black and white prints of alternate photographs enlarged 2x and screened on frosted, 0.004-inch-thick mylar with emulsion on back. All must provide complete single coverage of the flight area. The screen must be appropriate so that quality blue lines of a pilot sheet can be made and accepted prior to quantity production. On the 2x photographs, the SC will designate the position, approximate termini, and minimum range in elevation for each cross section to be read, and the position of approximately two photo-identifiable ground points near each cross section. The range in elevation is the vertical distance from the water surface at the time of photography to the upper limit of the cross section. If the channel is dry, the lowest point in the streambed is used to define the range.

Each cross section must cross the entire 500-year floodplain and should be carefully selected to be representative of reaches that are as long as possible, without permitting excessive conveyance change between sections.

One copy of each annotated 2x photograph should be returned to the Photogrammetric Subcontractor.

2. Plotting and Presentation of Elevation Points. The Photogrammetric Subcontractor, using a first order stereoplotter or digital stereo photogrammetric workstation, will read an elevation for the top of each identifiable ground point designated by the SC and a profile for each designated cross section. The approximate terminus of each cross section will be extended by the Photogrammetric Subcontractor until the range in elevation of that cross section exceeds the minimum range marked on the annotated photograph print by no more than 10 percent. Elevations to read to the nearest 0.5 foot will be taken at the three most significant gradient breaks on each bank and at enough intermediate points to satisfy the following criteria: (1) no adjacent points separated vertically by more than 20 percent of range; (2) no adjacent points separated horizontally by more than 5 percent of the complete channel cross-section width; and (3) no adjacent points in the main channel separated by more than 10 percent of main channel width or 2 feet, whichever is greater. Specified spacing is illustrated on Figure A4-3 (Figures 1 and 2). Elevations and stations must be read at each edge of water. The Zero Station (initial point) for each cross section will be the finally adopted terminus on the left bank (looking downstream). Stations should be the distance to the nearest foot measured along the straight, curved, or zig-zag alignment of the cross

section. The Photogrammetric Subcontractor will furnish the information, in the format illustrated by Figure A4-4, where the stream is within the low water channel. Where the channel is dry, the "RIGHT BANK" subtitle will be eliminated and the tabulation will be one continuous array of stations and elevations. Where the stream is in more than one channel, separate arrays of stations and elevations, headed by the subtitle "ISLAND" should be inserted, one for each island, between the LEFT BANK and RIGHT BANK arrays. The plotting and listing should be done using a line printer, as illustrated by Figure A4-4, or a continuous automatic plotter if the plot is confined without breaks to the one sheet and the tabulation is contained on the same sheet, or by manual plotting and tabulation on an 8.5-inch x 11-inch sheet similar to Figure A4-4. By convention, the plot must be viewed looking downstream. Elevations of designated identifiable ground points should be written on the map manuscript sheet only.

3. Planimetric Map Manuscript. The Photogrammetric Subcontractor should compile a planimetric manuscript map on 4-mil, mylar-type material at a scale of 1 inch = 500 feet (1:6,000-scale), or smaller scale if approved for the final map scale by the Regional Project Officer (PO). The map will be used to control transfer of flood boundaries and to update base map information and should include the areas within the compilation limits of the stereo-models required for cross section measurement, and need not go beyond the buffer zone area plotted on the location maps. The map will show the alignment of all cross sections read, with zero stations plotted and labeled; low water outlines of streams; all bridges, dams, dikes and levees; all streets, highways, and railroads; locations and elevations of all elevation reference marks (ERMs) or bench marks specified; and any contours that are specified.

4. Contours. The Photogrammetric Subcontractor will then compile contours of the areas shaded on the location map (see Figure A4-1). Digital Elevation Models (DEM) with uniformly spaced elevation points, Digital Terrain Models (DTM) with non-uniformly spaced elevation points and breaklines, and Triangulated Irregular Networks (TIN) may be used to generate contours so long as the resulting contours satisfy the specified vertical accuracy requirements. The contours will start at the next even foot elevation above the water surface and continue at 4-foot intervals until the shaded area edge is reached. The specified format is illustrated in Figure A4-5. The compilation manuscript will include 4-foot contour lines on each bank of each stream for which cross sections were read. The contours will be used by the SC to delineate floodplain boundaries between cross sections after precise flood elevations are computed. In situations where the 100- and 500-year flood elevations are available, or can be closely approximated in advance of the photogrammetric compilation, the SC should consider the use of "bracketing contours" that cover only the ranges of elevations near those of the floods to be delineated on the work maps. Compilation costs can often be reduced in this manner by eliminating the plotting of contours above or below the expected range of these floods. The SC should bring the potential use of this approach to the attention of the Regional PO and obtain approval prior to its use.

5. Compilation Deliverables.

a. Mylar Plots. The Photogrammetric Subcontractor should prepare final composite black-and-white mylar plots of material specified in the subcontract (planimetry, contours, cross sections, elevation points, etc.) for the compilation manuscript and furnish two copies of the plots. The mylar plots should be prepared at 1" = 500' (1:6,000 scale) or smaller scale if approved by the Regional PO. They should be in a set of sheets each no larger than 24 inches x 36 inches, screened at about 120 dots per inch, or equivalent produced by electrostatic or other plotter, so that line work on the copies furnished is 30 percent black and 70 percent transparent, on 4-mil mylar with matte finish. The screened linework facilitates the SC's subsequent addition of flood data to the subdued base information. A sample screened product should be approved by the Regional Project Officer prior to quantity production. Each sheet should contain a simple legend indicating community name, scale, and north arrow. A diagram indicating placement of each sheet within the set should be included either on each sheet or on a separate index sheet. The specified format is illustrated in Figure A4-5. These mylar plots may subsequently be compared with test surveys to determine if SC deliverables satisfy ASPRS 90 standards.

b. Digital Files. The Photogrammetric Subcontractor will furnish digital files containing the photogrammetrically compiled information (planimetry, contours, cross sections, and elevation reference points) in one of the digital file formats specified in Appendix 7 below. A completed Digital Data Submission Checklist (Figure A7-1) must accompany all digital data files submitted to FEMA. In addition, a Data Quality Report, as outlined in Appendix 7, is required.

6. Bench Marks and ERMs. The Photogrammetric Subcontractor will furnish a list of descriptions and elevations of enough points, bench marks, or ERMs, readily identifiable in the field at a future date, whose elevations are known or have been determined to third-order accuracy by the Photogrammetric Subcontractor. As a general rule, ERMs should be documented within or near the 100-year floodplain for areas studied in detail with an approximate density of two per mile of stream length or four per square mile of floodplain, as appropriate. The marks are required for future use by the public in determining first-floor elevations; therefore, a good engineering description of the mark location should be furnished by the Photogrammetric Subcontractor. Only marks on such permanent structures as fireplugs, culvert walls, and bridge abutments are considered readily identifiable. If curbs or sidewalks are used, 0.5-inch diameter holes should be drilled or an "X" that is at least 2 inches by 2 inches should be chiseled in the concrete at least 0.25-inch deep. Any newly established ERMs must be done during the normal courses of obtaining cross sections or vertical control surveys.

A4-7 QUALITY CONTROL AND QUALITY ASSURANCE

A. General

FEMA uses qualifications-based criteria for SC selection, recognizing that quality FIRM workmaps result from professional SCs with superior engrained QC procedures that are routinely adhered to. Overall QC is the responsibility of the SC and is exercised at specific stages of the map production process. FEMA's role during data acquisition and map/data base compilation should generally be limited to performing QA, which may involve only cursory spot-checking of the FIRM workmaps and supporting data, or to performing formal field map testing using FEMA or third-party forces.

Quality control on photomapping work may be divided into two categories: process control and product assurance.

1. Process Quality Control. Process QC is primarily the responsibility of the SC. This includes SC QC reviews of flight alignments, photographic quality, stereocompilation and completeness of supporting data, e.g., cross sections and profiles. The degree of QC required of the SC will be governed by the contract specifications.

2. Product quality assurance. FEMA's primary role is that of product QA. Product quality will be assured by FEMA using a variety of inspection and testing techniques on the final deliverables. FEMA may perform product QA using Government employees, TECs or other third-party contractors. Product assurance checks, tests, or field inspections are called for in the contract; however, FEMA has the option to waive any or all tests and accept the delivered product without formal field testing/checking.

The SC will be responsible for internal QC functions involved with field surveying, photography and laboratory processing, aerial triangulation, stereocompilation and field checking and editing of the photogrametrically made measurements and compiled maps to ascertain their completeness and accuracy. Also, the SC will make the additions and corrections that are required to complete the FIRM workmaps, cross sections, profiles, etc.

B. Quality Assurance of FIRM Workmaps. The SC is responsible for assuring, through QC efforts, that deliverables meet the required accuracy and content specifications. FEMA may perform such QA checks as necessary to verify the quality of maps by final inspection and/or testing of the delivered products. Due to FEMA resource and economic limitations, formal QA checking or testing is optional, even though it may be called for in the contract. On many projects, the SC's QC program may be deemed sufficient to assure the adequacy of the product. Cursory field spot checks by FEMA may be adequate on other projects. If excessive errors or omissions are suspected or uncovered, then formal field testing by an independent survey firm may have to be performed and the SC made to correct any deficiencies.

1. The FEMA standards described above will be the applicable standards for QC and subsequent QA map testing of all map or spatial data products delivered.

2. FEMA will complete all QA checks or tests as quickly as practical. Each map sheet will be accepted, returned for correction, or rejected for recompilation as soon as possible. The SC will correct returned map sheets and/or replace rejected map sheets within 30 days after receipt of the returned sheet or notice of rejection.

3. Tests for accuracy will be made on the mylar map reproducibles at the target scale specified in the contract. All maps compiled by the SC may be subject to map testing by FEMA, by a TEC or other independent third-party forces, to ensure that they comply with the applicable accuracy requirements. Map test results will be statistically evaluated relative to the contract-defined accuracy criteria (e.g., ASPRS 90, Class 1), and a pass/fail determination will be made accordingly. The decision of whether or not to perform rigid map testing on any project rests with the Regional PO and may be based on recommendations from the TEC if significant mismatches are encountered.

4. Map compilation will normally be checked by field inspection. Horizontal and vertical accuracy checks, using the DGPS, traverse, triangulation, and differential leveling methods will be made to test selected points or features on the mylar reproducibles of the completed FIRM workmaps. If the supplemental control survey for the project is by aerotriangulation, coordinates of points to be used for testing may be produced as part of the supplemental control survey. Point data can be produced for testing planimetry, spot elevations, or stereoplotter setup for testing. FEMA may verify the accuracy of stereoplotter map testing performed by the SC by requiring the SC's operator to report the horizontal and vertical coordinates of specified readily identified points. FEMA can then measure the coordinates of these points by DGPS or ground check surveys of higher accuracy.

C. Check Surveys. Horizontal and vertical accuracy of FIRM workmaps and final FIRMs are checked by comparing measured coordinates or elevations from mylar reproducibles (at their intended target scale, normally 1"=500') with coordinates determined by a check survey of higher accuracy. These check surveys can be performed with either conventional surveying (horizontal Third Order Class I, or vertical Class 3) or Global Positioning System (GPS) techniques; but differential GPS techniques, described below, are rapidly becoming the norm.

> NOTE: The SC does not need to apply any of the formulas below for performing check surveys. The remainder of Section C explains Federal Geodetic Control Committee (FGCC) procedures, applied with typical FIRM parameters, and prove that Third Order Class I horizontal survey procedures, and Third Order vertical survey procedures, or better, are required for control and check surveys on FEMA projects. Examples for check survey planning, and tips for improving the accuracy of GPS vertical control surveys, are also provided.

1. Conventional Horizontal Check Surveys. When horizontal control is classified with a particular order and class, the National Geodetic Survey (NGS) certifies that the geodetic latitude and longitude of that control point bear a relation of specific accuracy to the coordinates of all other points in the horizontal control network. This relationship is expressed as a distance accuracy, 1:a. A distance accuracy is the ratio of relative positional error of a pair of control points to the horizontal separation of those points. A distance accuracy, 1:a, is computed from a minimally constrained, correctly weighted, least squares adjustment by:

$a = d/s$ where:

a = distance accuracy denominator,

s = propagated standard deviation of distance between survey points obtained from the least squares adjustment, and

d = distance between survey points

For horizontal points, the check survey should produce a standard deviation equal to or less than one-third of the limiting RMSE selected for the map. This means that the relative distance accuracy ratio of the check survey must be less than one-third that of the limiting RMSE, expressed as a function of the distance measured across the map panel (not overall project or design file) diagonal. When published, the new NCSSA standards are expected to extend beyond individual maps to "spatial data," and the formula for computation of the distance accuracy denominator (a) may change; but these changes are not expected to alter the survey classification (e.g., Third Order, Class I) required for conventional horizontal check surveys.

TABLE A4-2 - Distance Accuracy Standards

Horizontal Survey Order/Class	Minimum distance accuracy
Order AA (GPS only)	1:100,000,000 (0.01 ppm)
Order A (GPS only)	1:10,000,000 (0.1 ppm)
Order B (GPS only)	1:1,000,000 (1 ppm)
First-order	1:100,000 (10 ppm)
Second-order, Class I	1:50,000 (20 ppm)
Second-order, Class II	1:20,000 (50 ppm)
Third-order, Class I	1:10,000 (100 ppm)
Third-order, Class II	1:5,000 (200 ppm)

2. GPS Horizontal Check Surveys. Alternatively, differential GPS (DGPS) techniques may be used to provide centimeter-level horizontal accuracy of check surveys, relative to the location of the DGPS fixed base stations(s) used to determine the positions of the roving GPS receiver(s). Normally, horizontal positions, with centimeter-level accuracy can be obtained when DGPS techniques are used and the GPS base stations are in the same county as the points to be surveyed with the roving GPS receiver(s). Differential GPS techniques, now used nationwide for over 99% of all horizontal control surveys, are more than adequate for establishing horizontal control for FEMA photogrammetric projects and for horizontal check surveys.

3. Conventional Vertical Check Surveys. When a vertical control point is classified with a particular order and class, NGS certifies that the orthometric elevation at that point bears a relation of specific accuracy to the elevations of all other points in the vertical control network. That relation is expressed as an elevation difference accuracy, b. An elevation difference accuracy is the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along existing level routes. An elevation difference accuracy, b, is computed from a minimally constrained, correctly weighted, least squares adjustment by:

b = $S/\sqrt{d}$ where:

b = elevation difference accuracy

d = approximate horizontal distance in kilometers between control point positions traced along existing level routes.

S = propagated standard deviation of elevation difference in millimeters between survey control points obtained from a least squares adjustment.

Note: the units of b are mm/√km.

TABLE A4-3 - Conventional Elevation Difference Accuracy Standards

Vertical Survey Order/Class	Maximum elevation difference accuracy
First-order, Class I	0.5
First-order, Class II	0.7
Second-order, Class I	1.0
Second-order, Class II	1.3
Third-order	2.0

For vertical points, the check survey (i.e., differential leveling or electronic total station trig elevations) should produce an RMSE not greater than 1/20th of the Contour Interval, expressed relative to the longest diagonal dimension of a standard FIRM panel (approximately 30 inches). The map position of the ground point may be shifted in any direction by an amount equal to twice the limiting RMSE in horizontal position.

Conventional Third-Order leveling procedures and standards will be of sufficient accuracy to provide reliable check surveys for all photogrammetric map classes with a Contour Interval of 1 foot or larger. As with horizontal check surveys, conventional vertical check survey accuracies are relative to the area on a given map sheet, not to the overall project dimension. The same survey datums must be used for both the mapping and check surveys. Although the new NCSSA standards, when published, are expected to extend beyond "maps" to "spatial data," and the formula for computation of the elevation difference accuracy (b) may change, these changes will not alter the survey classification (Third Order) required for conventional vertical check surveys.

4. <u>GPS Vertical Check Surveys</u>. Alternatively, differential GPS (DGPS) techniques may be used to provide centimeter-level vertical accuracy of check surveys, relative to the location of the DGPS fixed base stations(s) -- bench mark(s) -- used to determine the vertical positions of the roving GPS receiver(s). Normally, vertical positions, with centimeter-level accuracy, can be obtained when DGPS techniques are used and the GPS base stations (bench marks) are in the same county as the points to be surveyed with the roving GPS receiver(s).

GPS techniques yield geodetic heights (h) relative to the reference ellipsoid, while conventional survey techniques (differential or trigonometric leveling) yield orthometric heights (H) relative to the geoid. Orthometric heights (H) are computed from geodetic heights (h) by subtracting the geoid height (N) -- the height of the geoid relative to the ellipsoid -- at each point in question. The values of N for any point in the U.S. can be computed from the National Geodetic Survey's geoid model based on known gravity measurements. NGS's GEOID93 model is not accurate enough to compute orthometric heights equivalent to Third-order leveling across long distances exceeding 100 miles, but GEOID93 is adequate for Third-order equivalent vertical surveys within county-size areas. NGS's geoid model (GEOID93) is currently being refined with high-resolution measurements using dense local gravity anomalies and improved digital terrain models. When GEOID95 is published in 1995, NGS believes that DGPS "on-the-fly" techniques will become the preferred method for measuring Third-order orthometric heights, even across very long base lines.

The following data was extracted from Appendix E of the *Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques*, FGCC, August 1, 1989:

TABLE A4-4 - GPS Elevation Difference Accuracy Standards
(95 percent confidence level)

p_H Minimum Elevation Difference	p Minimum Geometric Relative Position	p_N Minimum Geoid Height Difference

Survey Order/Class	Accuracy Standard	Accuracy Standard	Accuracy Standard
Order AA	1:500,000 (2 ppm)	0.1 ppm	1:500,000 (2 ppm)
Order A	1:500,000 (2 ppm)	0.1 ppm	1:500,000 (2 ppm)
Order B	1:200,000 (5 ppm)	1 ppm	1:200,000 (5 ppm)
First-order	1:67,000 (15 ppm)	10 ppm	1:100,000 (10 ppm)
Second-order, Class I	1:50,000 (20 ppm)	20 ppm	1:100,000 (10 ppm)
Second-order, Class II	1:20,000 (50 ppm)	50 ppm	1:50,000 (20 ppm)
Third-order	1:10,000 (100 ppm)	100 ppm	1:25,000 (40 ppm)

NOTE: These elevation difference accuracy standards are to be used only for elevation differences determined indirectly from ellipsoid height difference measurements (GPS). For direct vertical measurement techniques such as differential or trigonometric leveling, use only the accuracy standards given in section 2.2, pages 2-2 and 2-3, of the Federal Geodetic Control Committee, *Standards and Specifications for Geodetic Control Networks*, National Geodetic Information Center, NOAA, Rockville, Maryland, 20852, September, 1984.

The following steps will assist in improving the accuracy of GPS-derived geodetic and orthometric heights:

- Use post-processed ephemerides for actual rather than predicted satellite locations.

- Use 25 degree elevation masks to avoid near-horizon satellites which dilute the accuracy of vertical GPS measurements.

- Avoid observations during unstable climatic conditions which impact the GPS base station(s), roving GPS receiver(s), or any points between.

- Use dual frequency receivers and fixed height tripods.

- Use geodetic ground-plane antennas to eliminate multi-path interference.

- Select satellites so that the constellation quality has a vertical dilution of precision (VDOP) of 4 or less.

5. Example for Check Survey Planning. For an example of using Tables A4-1, A4-2 and A4-3 for designing a check survey (selecting an order and class), assume that a survey is to be designed to check a FIRM panel which is intended to possess a planimetric (horizontal) RMSE of 5 feet (target map scale of 1"=500') and spot height RMSE of 0.67 feet (contour interval = 4'). In contrast to survey accuracies, which are stated in terms of relative horizontal distances to adjacent points, map features are intended to possess accuracies relative to all other points appearing on the map. Therefore, for purposes of the check survey, the distance between survey points (d) is taken as the diagonal distance on the ground across the area covered by the map. A 30 inch diagonal distance on a 1"=500' FIRM equals 15,000 feet ground distance, or 2.95 Km. According to the Federal Geodetic Coordinating Committee (FGCC) survey standard, this is the distance across which the "minimum distance accuracy" and "maximum elevation difference accuracy" is required (see Tables A4-2 and A4-3 above).

a. Planimetric Check Surveys.

(1) The ASPRS standard states: "Horizontal and vertical accuracy is to be checked by comparing measured coordinates or elevations from the map (at its intended target scale) with coordinates determined by a check survey of higher accuracy. . . For horizontal points, the check survey should produce a standard deviation equal to or less than one-third of the limiting RMSE selected for the map. This means that the relative distance accuracy ratio of the check survey must be less than one-third that of the limiting RMSE, expressed as a function of the distance measured across the map sheet (not overall project or design file) diagonal." Furthermore,

ASPRS 90 states that "A minimum of 20 check points shall be established throughout the area covered by the map and shall be distributed in a manner agreed upon by the contracting parties."

(2) For a conventional planimetric check survey, the diagonal distance on the ground covered by a FIRM is 15,000 feet (30 in x 500 ft/in). The propagated standard deviation (s) required for the check survey is one-third of the intended RMSE of 5 feet, or 1.67 feet (5 ft/3) in this example. Then, the distance accuracy denominator is computed as follows:

a = d/s = (15,000 ft) / (5 ft/3) = 9,000

Thus, ground surveys with accuracies of 1:9,000 or better are required, i.e., Third-order, Class I per Table A4-2. This also indicates that Third-Order, Class I field surveys should be adequate for establishing horizontal control for the photogrammetric project.

(3) For a GPS planimetric check survey, all differential GPS techniques routinely produce horizontal accuracies that greatly exceed one part in 9,000 between the base reference station GPS receiver antenna(s) and the roving GPS receiver antenna(s). Because of the superior cost effectiveness, DGPS techniques are now used for nearly all horizontal control and check surveys.

(4) Preferably using DGPS techniques, 20 or more clearly defined horizontal points, within the floodplain, should be surveyed to determine the accurate horizontal ground coordinates for these points. The ground coordinates of these same points, as computed from FIRM mylar reproducibles, are then compared with the check survey measurements in order to compute the horizontal standard deviation. For horizontal points, the check survey should produce a standard deviation equal to or less than one-third of the limiting RMSE of the FIRM. If the horizontal standard deviation is 1.67 feet or less (5 ft/3), the FIRM meets ASPRS Class 1 standards for horizontal accuracy. If the horizontal standard deviation is greater than 1.67 feet, doubling or tripling this number would indicate limits on whether the FIRM meets ASPRS Class 2 or Class 3 horizontal standards, or fails to meet any ASPRS horizontal standard.

(5) Where available, the actual horizontal standard deviation should be made a part of the Technical Support Data Notebook (TSDN) so that the TEC, which completes the digitization of the DFIRM and contributes additional error to the process, knows how much of the total allowable "horizontal error budget" has already been used by the SC.

b. Vertical Check Surveys

(1) The ASPRS standard states: "For vertical points, the check survey (i.e., differential leveling or electronic total station trig elevations) should produce an RMSE not greater than 1/20th of the CI, expressed relative to the longest diagonal dimension of the map. The map position of the ground point may be shifted in any direction by an amount equal to twice the limiting RMSE in horizontal position."

(2) For a conventional vertical check survey, the distance (d) is also taken as a diagonal ground distance across the map to account for the fact that elevation accuracy pertains to all mapped features. The propagated vertical RMSEs (S) for spot heights, ERMs and ERPs should not exceed 1/20th of the (4') contour interval:

S = 1/20th of 4 ft = 0.20 feet or 61 mm.

Then, the elevation difference accuracy $b = S/\sqrt{d}$

$b = 61 \text{ mm}/\sqrt{2.95 \text{ Km}} = 35.5 \text{ mm}/\sqrt{(\text{Km})}$

From Table A4-3, Third-order leveling can yield a maximum elevation difference accuracy of 2.0, far better than the 35.5 required for this example.

(3) For a GPS vertical check survey, all differential GPS (DGPS) techniques should yield vertical accuracies that exceed Third-order leveling accuracies.

(4) Preferably using DGPS techniques, 20 or more clearly defined vertical points (ERMs or ERPs) within the floodplain should be surveyed to accurately measure their geodetic heights. Geodetic heights must then be converted to orthometric heights using the latest available NGS GEOID model. The orthometric heights of these same points, from FIRM workmap measurements, are then compared with the check survey measurements in order to compute the vertical RMSE. If the vertical RMSE is 0.22 feet (0.67 ft/3) or less, the FIRM workmap clearly meets ASPRS Class 1 standards for vertical accuracy. If the vertical RMSE is greater than 0.22 feet, ASPRS 90 allows the horizontal position of ground points to be shifted in any direction by an amount equal to twice the limiting horizontal RMSE (i.e., 10 feet for Class I maps at 1"=500'). Determinations can then be made on whether the vertical accuracy meets ASPRS Class I, Class II or Class III standards.

(5) Where available, the DGPS-tested vertical RMSE should be made a part of the TSDN so that the TEC, which completes the digitization of the DFIRM and contributes additional error to the process, knows how much of the total allowable "vertical error budget" has already been used by the SC.

(6) The complexity in converting between geodetic heights (above the ellipsoid) and orthometric heights (above the geoid) may cause complications until DGPS procedures become routine and the high resolution GEOID95 goals are achieved. For this reason, the SC may use the conventional vertical check survey procedures, from paragraph b (2) above, to augment and/or over-ride the DGPS vertical check survey results, should the survey indicate failure to meet ASPRS 90 vertical standards. Should this option be used, both computations of vertical RMSE (conventional and DGPS) should be made a part of the TSDN.

D. Testing of Features.

1. Planimetry. The accuracy of the planimetric map feature compilation will be tested by comparing the ground coordinates (X and Y) of at least 20 well-defined map features per test per map sheet, as determined from measurements on the map mylar reproducible at publication scale, to those for the same points provided by a DGPS or other check survey of higher accuracy. The check survey will have an order of accuracy and procedures as specified for establishing the mapping control. Maps will also be examined for errors and/or omissions in defining features, structures, and other nomenclature, or for total gaps in compilation/coverage. The minimum of 20 points will be distributed primarily throughout the floodplain mapped although several may be in the extended buffer zone. Tests will be made on well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as intersections of roads or railroads. In general, what is well-defined will also be determined by what is plottable at the scale of the map within 1/100th inch. Points that are not well-defined are excluded from the accuracy test. The selection of well-defined points will be made through agreement between FEMA, TEC and SC. Generally, it may be more desirable to distribute the points more densely in the vicinity of important structures or drainage features and more sparsely in areas that are of lesser interest. The locations and numbers of map test points and/or test profiles will be mutually agreed to by the SC and Regional Project Officer.

2. Spot elevations. A minimum of 20 points will be checked. These points will either be distributed throughout the floodplain and buffer zone or concentrated in critical areas. Spot elevations will be compared with elevations determined by field or photogrammetric methods. The test for vertical accuracy will be performed by comparing the elevations at well-defined points determined from the map mylar reproducible to corresponding elevations determined by a survey of higher accuracy.

3. Contours. The accuracy of contouring on FIRM workmaps will be tested by comparison of a photogrammetrically-derived cross section on the FIRM workmap with a cross section by ground survey. The location of each test traverse will be designated by FEMA. The elevation and station will be recorded for each break in the terrain and for each contour elevation. Ground-surveyed cross sections will be at least 6 in. long at final map scale, with an elevation

measured at least every 100 ft on the ground, and should cross at least 10 contour lines when possible. Cross sections should start and close upon map features or previously established control points. In flat areas and at principal road and rail intersections, spot elevations may be checked. In general, one cross section per map sheet is sufficient.

E. <u>Acceptance/Rejection</u>. A FIS project will be accepted when FEMA or its designee has performed sufficient testing to assure that each phase of the mapping meets FEMA standards and specifications. When a series of FIRM workmaps are involved in a FIS, the existence of errors (i.e., map test failure) on any individual sheet will constitute prima facie evidence of deficiencies throughout the project (i.e., all other sheets are assumed to have similar deficiencies); and field map testing will cease. The following criteria will be used for the acceptance, return for correction, or rejection for recompilation of a FIRM workmap:

1. <u>Control points</u>. Any error beyond specification tolerance (1/100 in) in plotting or any error in labeling the elevation of control points may be cause to reject the FIRM workmap for recompiling.

2. <u>Horizontal positions</u>. A FIRM workmap will not be rejected for recompiling because of error in the horizontal position of planimetric or topographic features or spot elevations (not control points) unless at least 20 points were tested. If fewer than 20 points were tested and excessive errors were found, the FIS may be returned for correction of errors.

3. <u>Elevation rejection</u>. A FIS will not be rejected for recompiling because of errors in labeling the elevations of spot elevations (not control points) but may be returned for correction.

4. <u>Test cross section for contours</u>. The contours of a section of a FIRM workmap may be accepted on the basis of a single test cross section, performed by differential leveling or trigonometric leveling.

5. <u>Additional test cross sections</u>. When the first ground surveyed test cross section indicates that a FIRM workmap fails to comply with accuracy requirements, an additional test cross section will be made. This cross section will be generally parallel to the first cross section at a distance from the first as specified by FEMA. No FIRM workmap will be rejected unless the sum of the lengths of the test cross sections completed is 12 inches or more at final map scale. To determine acceptability of the contouring, the data from all the cross sections will be combined and treated as a unit.

F. <u>Intensity of Testing</u>. The standards set forth above do not state the intensity of the tests to be made. The following guidance is applicable only should FEMA exercise its option to perform full field map testing on a given contract:

1. <u>FIS project</u>. At least one map will be tested for each FIS project.

2. <u>Area mapping</u>. Test points will average at least one for every 10 square feet of map at finished map scale, with a minimum of 20 points.

3. <u>Additional tests</u>. Additional tests will be made when there is reason to suspect the quality of the mapping in general or at any specific location.

4. <u>New contractors</u>. When FEMA has no previous experience with a SC's products, a more extensive inspection may be performed than for the products of established SCs.

A4-8 <u>GLOSSARY</u>

The following terms, as used in this Appendix, are defined as follows:

<u>Airborne GPS</u> - A technique which enables the 3-dimensional location of aerial camera exposure stations (at the instant that each photograph is exposed) to be accurately measured

by utilizing Differential Global Positioning System (DGPS) methods, minimizing the requirement for ground survey control in the aerial triangulation process.

Bench Mark (BM) - A permanent monument established by any Federal, State, or local agency, whose elevation and description are well documented and referenced to NGVD 29 or NAVD 88.

Breakline - A linear feature in a digital terrain model (DTM) or triangulated irregular network (TIN) that describes a change in the smoothness or continuity of the terrain surface. "Hard breaklines" define interruptions in surface smoothness; they are used to define streams, shorelines, dams, ridges, building footprints, and other locations with abrupt surface changes. "Soft breaklines" do not define interruptions in surfce smoothness, but they ensure that known z values along a linear feature are maintained. They ensure that linear features and polygon edges are maintained in a TIN surface model by enforcing the breaklines as TIN edges.

Centimeter-Level Accuracy - A term used to imply an unofficial GPS accuracy standard of less than a decimeter. Depending on DGPS techniques used, available satellite geometry and other variables, "centimeter-level accuracy" normally means 1 cm + 1 part per million (ppm) at worst for horizontal measurements, and 1 cm + 2 ppm at worst for vertical measurements. The term "ppm" refers to the distance between the DGPS base station and the roving receiver. See also the Federal Geodetic Control Committee (FGCC) standards entitled: *Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques*, Version 5.0, August 1, 1989.

Connecting Levels - A line of differential or trigonometric levels run to half-tenths of a foot between a control point and a cross section, with closure that, in the SC's judgment, will not cause errors to exceed specified tolerance, but in no case greater than 0.3 foot.

Control Levels - A line or network of BMs, ERMs, or elevation reference points (ERPs) run to hundredths of a foot by differential or trigonometric leveling methods to third-order accuracy limits (0.05 foot x square root of distance in miles), or DGPS-derived vertical control of equivalent accuracy, to serve as starting elevations for connecting levels to determine picture point control elevations.

Differential GPS (DGPS) - GPS positioning techniques which use two or more GPS receivers, with a base station on a position of known location, and one or more roving receivers taking GPS measurements at unknown locations. GPS coordinates for the base station are compared with the known coordinates for the base station, and the differences (errors) are inserted into the calculations for the roving GPS receivers locked onto the same four satellites (minimum) as used by the base station for its GPS position. Since most error sources are the same for all GPS receivers in the same general area locked onto the same GPS satellites at any given instant, these errors can be measured and subtracted from all such GPS solutions. DGPS procedures enable centimeter level horizontal and vertical accuracies to be achieved, compared with errors of 16 to 100 meters when DGPS procedures are not used.

Differential Levels - The determination of elevations by successive measurement of vertical distances between ground points and horizontal planes projected by an engineer's level.

Digital Elevation Model (DEM) - The digital cartographic representation of the elevation of the land (z value) at regularly spaced intervals in x and y directions (eastings and northings). DEM "elevation posts" are often connected by lines in order to form a rectangular grid or lattice which helps the viewer to visualize the 3-D shape of the terrain. DEMs are also used to "drape" raster images so they can be viewed in 3-D.

Digital Terrain Model (DTM) - Digital elevation data which incorporates the elevation of significant topographic features on the land and change points (breaklines) which are irregularly spaced.

Elevation Reference Mark (ERM) - A permanent monument not included in the National Geodetic Survey or USGS network but whose elevation has been determined by levels or differential GPS positioning from a BM, with copy furnished of field notes or documented summary of procedures.

Elevation Reference Point (ERP) - A temporary mark whose elevation has been determined by levels or differential GPS positioning from a BM or ERM, with copy furnished of field notes or documented summary of procedures.

Flight Height - The height of the aerial survey camera in feet above the mean elevation of the floodplain.

Floodplain - The portion of a river valley that is inundated only during floods.

Global Positioning System (GPS) - A satellite-based navigation and positioning system operated by the Department of Defense which enables horizontal and vertical positions to be determined. Because GPS is usually cheaper, faster, more accurate, and easier to use, DGPS is today the preferred method for most control surveys (which provide the standard of accuracy for subsequent surveys and photogrammetric mapping).

Gradient Break - A point along the cross section where the slope of the ground changes suddenly, such as the edge of the floodplain or bottom of the main channel bank. The three most significant gradient breaks on each bank of a smooth cross section are usually the most important points to be surveyed.

Left Bank - The stream bank on the left side when looking downstream.

Main Channel - That portion of a stream channel that conveys all flow when the stream is below bank-full stage, generally a narrow portion of the valley with steep banks.

Pseudo-Kinematic - a form of differential GPS positioning which tolerates loss of satellite lock, allows the roving receiver to be turned off while moving between points, and provides a quality control "double check" of elevation values. With this method, the base station receiver remains at the known control point (bench mark) while the roving receiver occupies all remote sites in sequence, simultaneously observes the same four satellites (minimum) as the base station, and collects measurements for five minutes per site. Approximately one hour later, the roving receiver reoccupies each remote site in sequence and again records observations for five minutes, repeating the process while the same four GPS satellites (minimum) are at different directions in the sky. The data are then post-processed as before and compared. Duplicate elevation values that agree within ±0.2 foot are averaged and accepted; if these values do not agree within ±0.2 foot, they are rejected.

Quality Control Surveys - The surveys made to verify accuracy of elevations, or cross section locations, contours, or planimetric features.

Range (In Elevation) - The vertical distance in feet from the water surface at time of photography to the upper limit of the cross section.

Rapid-Static - also known as Fast-Static - a form of DGPS positioning which is similar to Static Positioning, described below, but with a much shorter static period for observations. The reduction in observation time results from faster ambiguity resolution using redundant carrier-phase measurements from multi-channel receivers that track all visible satellites. By simultaneously processing all redundant carrier-phase measurements in conjunction with advanced statistical analysis procedures, the resolution of ambiguity can be accelerated significantly. The geometric distribution of visible satellites will impact the success of this method.

Real-Time Kinematic - a form of DGPS positioning that allows the operator to instantly determine the position of the roving GPS unit. The base station configuration uses one GPS receiver and radio to transmit the satellite observations to the roving unit on the project site. The roving unit configuration also has one receiver and radio, as well as a handheld data collector interface. The rover sub-system makes its satellite measurements and also receives the base receiver's satellite data via the radio. Once the rover has all of these data, it computes its precise position relative to the base station. This process requires a short initialization procedure and continuous four satellite tracking. If satellite lock is lost, the receiver is reinitialized at the last known point prior to loss of lock. A loss of radio contact, however, does not mean that the survey must be reinitialized. During a real-time kinematic survey, it is possible to lose lock with the reference (base station) radio and regain carrier phase differential positioning when radio contact is re-established. So long as both receivers maintain constant four satellite tracking, centimeter-level positioning is possible.

Static Positioning - the most accurate form of DGPS positioning. With this procedure, the base station (at the bench mark) and roving GPS receivers simultaneously receive signals from the same four (or more) satellites, recording data for 30 minutes to an hour or more. All data is simultaneously postprocessed to determine the differential position between the receivers (Δ latitude, Δ longitude, and Δ height), including carrier phase ambiguity numbers. If all known and unknown points are in a local area, then real-time kinematic, rapid-static or pseudo-kinematic procedures will yield comparable results but with significant reductions in observation times.

Stop-and-Go (Semi-Kinematic) a form of DGPS positioning which uses either an *antenna swap* at two nearby known points, to initially calibrate the system, or performs a static measurement over a known baseline to resolve initial cycle ambiguities. The ambiguity numbers remain constant so long as both receivers maintain lock on a minimum of four satellites during the entire period of observation; but this method is useless if the surveyor traverses a "shaded" area where loss of lock occurs to one of the satellites. Following calibration to determine the carrier phase ambiguity, the "roving" receiver traverses to all unknown points, preferably using a double-run or triple-run procedure for redundancy, while the base station receiver remains over the known control station (bench mark). The roving GPS receiver temporarily remains motionless over each point to be positioned and observes for about 90 seconds per point. The roving receiver measures carrier phases continuously at a predetermined rate. Measurements are postprocessed to determine discrete differential positions along the path of the roving receiver.

Terminus (Termini) - The end(s) of a cross section axis.

Topology - A digital data structure that defines the way in which points, lines and areas are digitally formed and conected so that logical relationships (adjacency, proximity, and connectivity) can be automatically determined by geographic information system (GIS) software.

Triangulated Irregular Network (TIN) - A set of adjacent, non-overlapping triangles, in a digital terrain model (DTM), computed from irregularly spaced points with x/y coordinates and z values, The TIN data structure is based on irregularly-spaced point, line, and polygon data interpreted as mass points and breaklines. The TIN model stores the topological relationship between triangles and their adjacent neighbors, i.e., which points define each triangle and which triangles are adjacent to each other. This data structure allows for the efficient generation of surface models for the analysis and display of terrain and other types of surfaces.

Trigonometric Levels - An indirect technique for measuring elevation differences by measuring the vertical angle and slope distance, between two points, with a "total station" survey instrument, or equivalent. Total station instruments electronically sense vertical angles and slope distances and automatically apply trigonometry to compute horizontal distances and elevations.

Zero (0) Station - The left bank terminus from which station is measured.

APPENDIX 5. STUDIES OF ALLUVIAL FAN FLOODING

A5-1 INTRODUCTION

"Alluvial fan flooding" means flooding occurring on the surface of an alluvial fan or similar landform, which originates at the apex and is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and unpredictable flow paths. For the purposes of the NFIP, "apex" means a point on an alluvial fan or similar landform below which the flowpath of the major stream that formed the fan becomes unpredictable and alluvial fan flooding can occur. The degree to which the processes that characterize alluvial fan flooding are present can vary greatly. For example, the fact that active deposition has not recently occurred on some portion of the fan surface does not necessarily preclude the use of FEMA's methodology for determining hazards from alluvial fan flooding.

The methodology follows directly from the definition of the 100-year flood as the flood having a 1-percent chance of being exceeded (at the point at which the definition is being applied) in any given year. Because the path of an alluvial fan flood is unpredictable, the probability of the point in question being inundated by a flood, given that that flood is realized at the apex, contributes to the definition of the 100-year flood. Therefore, if H denotes the event of the point in question being flooded, then, by definition, the 100-year flood discharge at that point is the q_{100} given by

$$.01 = \int_{q_{100}}^{\infty} P(H|Q=q) f_Q(q)\,dq \qquad (1)$$

where P(H*Q=q) is the probability of the point being flooded, given that a flood with a magnitude of q cubic feet per second (cfs) is realized at the apex; and $f_Q(q)$ is the probability density function (pdf) of the discharge Q occurring at the apex. Replacing Q with D or V and q with d or v in equation (1) to denote depth or velocity yields the definition of the 100-year flood depth or flood velocity, respectively. Note that when the flood path is predictable, then P(H*Q=q) = 1 and the 100-year flood discharge, q_{100}, is determined by the definition familiar to those who model riverine flooding:

$$.01 = \int_{q_{100}}^{\infty} f_Q(q)\,dq \qquad (2)$$

If the flowpaths cannot be predicted with certainty, then equation (1) (i.e., the methodology) must be applied. The reader should note that equation (1) is not an assumption, but is rather the definition of the 100-year flood discharge.

The methodology was first described by Dawdy (Reference 1). In his paper Dawdy uses three assumptions to solve equation (1) for q_{100}.

1. The pdf, $f_Q(q)$, is log-Pearson Type III. This assumption is in accordance with the recommendation of the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data (Reference 2).

2. The conditional probability, $P(H|Q=q)$, on any contour is equal to the width of the channel carrying the discharge divided by the width of the area subject to flooding measured along the contour. That is, the locations of flowpaths are uniformly distributed within the area subject to flooding. This assumption follows from the reasoning that the alluvial fan was formed, over "geologic" time, by the accumulation of sediment deposited during flood events. Thus, over the long term, one can assume that points, where there is an equal accumulation of sediment (i.e., on the same contour), have experienced, and will experience in the future, the same frequency of flooding. The modeler must exercise caution when considering this assumption to be valid for "engineering" time scales.

3. The width of the "channel" followed by the flood is proportional to the four-tenths power of the flood discharge. This relationship is based on observations in New Mexico that floods on alluvial fans flow at critical depth in wide approximately rectangular channels and that the depth of flow decreases until a further decrease results in a 200-fold increase in the width. Further investigations of alluvial fan flooding in California and Nevada (Reference 3) support the relationship. From that relationship, one can compute not only the width of the flood path but also the depth and velocity of the flow if the discharge is given.

Consequent to adopting the methodology outlined by Dawdy, FEMA commissioned DMA Consulting Engineers to investigate the validity of the aforementioned assumptions. The results of that investigation indicate that the assumptions were reasonable in the upper regions of the alluvial fan flooding studied, but that on many alluvial fans, the flowpaths in the upper regions (single-channel regions) split into several paths in the lower regions (multiple-channel regions) (Reference 3). That study further indicated that the combined width of those multiple channels was consistently approximately 3.8 times the width of the single channel from which they were formed. The study also indicated that the flow within those multiple channels was not at critical depth but rather was at normal depth.

The SC shall assess the reasonableness of each assumption given above in light of the existing conditions of the particular area being studied. That assessment must be fully documented. If the assessment indicates that one or more of the aforementioned assumptions should be modified, the SC shall explain, in writing, the proposed modifications and how they would be used to determine flood depths and velocities. That explanation must be approved by the Regional PO before the modifications are implemented.

A5-2 MAPPING OF ALLUVIAL FAN FLOOD HAZARDS

Before analyzing alluvial fan flooding, the SC should review the available literature on the subject--especially those documents that discuss the methodology or its application. Several such documents are listed in the References and Bibliography section of this Appendix.

The SC may obtain a copy of FAN: An Alluvial Fan Flooding Computer Program, including the user's manual and the compiled program on a 5¼" disk, from FEMA by writing to:

Federal Emergency Management Agency
Mitigation Directorate
Hazard Identification Branch
500 C Street, SW
Room 422
Washington, DC 20472

A5-2A Reconnaissance

When it is determined that an area in a community is subject to alluvial fan flooding, a thorough reconnaissance of the area should be made in order to determine the source of flooding, the apex, the boundaries of the area, the limits of entrenched channels and the locations of barriers to flow (natural or manmade) that render some areas more flood prone than others, and locations of single- and multiple-channel regions. The reconnaissance should make use of available topographic, geologic, and soil maps; aerial photographs; historic records; and site inspections.

A5-2B Channel Location

As stated in the introduction, the degree to which the processes that characterize alluvial fan flooding are present can vary greatly. The following description is intended to help the reader understand the use of equation (1) in determining the flood hazards associated with alluvial fan flooding. It is not a set of conditions to be used as a prerequisite for applying the methodology.

During a major flood event on an active fan, flow does not spread evenly over the fan, but is confined to only a portion of the fan surface that carries the water from the apex to the toe of the fan. In the upper region of the fan, flood flows are typically confined to a single channel, which is formed by the flow itself through erosion of the loose material that makes up the fan. Because of the relatively steep slopes in the upper region, flood flows are at critical depth and critical velocity. Below the apex of the fan, the flood follows a random path down the fan surface; under natural conditions, the flood is no more likely to follow an existing channel than it is to follow a new flowpath. The flowpath has an approximately rectangular cross section for which depth, width, and velocity of flow can be expressed as functions of discharge.

In the lower region of the fan, flood flows may split and form multiple channels. Normal flow conditions exist in the multiple-channel region.

A5-2C Depth of Flooding

For purposes of mapping alluvial fan flooding, the depth of flooding is the depth of flow in the channel that carries a given discharge plus the velocity head associated with that flow.

A5-2D Velocity of Flooding

For purposes of mapping alluvial fan flooding, the velocity of flooding is the velocity of flow in the channel that carries the given discharge.

A5-2E Avulsions

During a flood event, the flow may abandon the path it has been taking and follow a new one. That occurrence, termed an avulsion, can result from floodwater overtopping a channel bank and creating a new channel. The overtopping may be caused by the sudden deposition of sediment and/or debris or by undercutting and subsequent failure of a channel bank. Because points below the avulsion may be in the path taken by the floodflow either before or after the avulsion occurs, the probability of those points being inundated by the flood is greater than if the avulsion had not occurred.

A5-2F Coalescent Areas

In areas subject to alluvial fan flooding from more than one flooding source, flood depths and velocities are computed by assuming that the event of inundation by a flood from any canyon is independent of the event of inundation by a flood from any other canyon. Thus, the union of such events, which has a probability of 0.01, is used to define depths and velocities in areas where multiple alluvial fans intersect.

A5-3 FLOOD HAZARD ZONES

Special Flood Hazard Areas subject to alluvial fan flooding are identified as Zone AO with the following definition:

Zone AO: Special Flood Hazard Areas inundated by types of 100-year shallow flooding where average depths are between 1.0 and 3.0 feet.

Alluvial fan flood hazard areas are shown on the Flood Insurance Rate Map as Zone AO, and average depths and velocities of flow are shown. In those areas, the 100-year flood depths may exceed 3.0 feet. Development on alluvial fans is subject to a more severe flood hazard than would normally be encountered in Zone AO because the velocities of flows on the alluvial fan are high and the locations of the flowpaths on the alluvial fan are unpredictable.

The Special Flood Hazard Area on each alluvial fan is subdivided into separate AO zones. Those zones are labeled with depths and velocities rounded to the nearest whole foot and foot per second, respectively. For example, all points that are subject to alluvial fan flooding with a 100-year depth between 1.5 and 2.5 feet and a 100-year velocity between 6.5 and 7.5 feet per second are included in an area labeled Zone AO (Depth 2 FT, Velocity 7 FPS).

A5-4 COMPUTATIONS

The solution to equation (1) for the discharges associated with the depths and velocities that define the flood hazard zone boundaries may be obtained through the use of FEMA's computer program (Reference 4). That program solves equation (1) under the simple boundary conditions described in the introduction. The net results of those computations are the values of the widths of the area subject to alluvial fan flooding at which 100-year depths equal n + 0.5 foot and 100-year velocities equal n + 0.5 foot per second (where n is an integer). Other data given in the output of the program can be used to determine the flood hazard zone boundaries under more complicated boundary conditions (such as entrenched channels and barriers to flow). If, however, because of field conditions, the program is of no use, the SC shall describe in writing the field conditions, the reason those conditions render the use of the program to be of little value, and the proposed alternative.

A5-5 INTERMEDIATE DATA SUBMISSION FOR ALLUVIAL FAN FLOODING SOURCES

Alluvial fan flooding analyses are performed in three basic steps. Those steps are.

1. Determine the flood frequency curve at the apex [i.e., $f_Q(q)$ in equation (1)].

2. Determine the boundaries of the area subject to flooding from the apex and the probabilities of points within that area being flooded by a given discharge [i.e., $P(H \mid Q{=}q)$ in equation (1)].

3. Calculate the 100-year discharges from equation (1).

Because the accuracy of the results of Step 3 depends on that of Steps 1 and 2, an intermediate data submission is required in an alluvial fan flooding FIS. After notifying the Regional PO, the SC shall submit the data described in A5-5A and A5-5B below. The SC will be informed of the results of that review within 45 days of the intermediate submission.

A5-5A Step 1: Define the Flood Frequency Curve and Apex for Each Flooding Source

The following information shall be submitted in support of the flood frequency curve defined at each apex:

1. A topographic map showing the boundary of the drainage area above the apex, as well as the location of the apex.

2. An explanation demonstrating that flowpaths below the apex are unpredictable.

3. A report describing in detail the hydrologic analysis performed to determine the flood frequency curve.

4. Data and references used in the hydrologic analysis.

5. A plot of the flood frequency curve on log-normal probability paper (including the name of the flooding source, the drainage area above the apex, and the mean, standard deviation, and skew coefficient of the curve).

A5-5B Step 2: Determine the Boundaries of the Area Subject to Alluvial Fan Flooding

The following information shall be submitted in support of the conditional probabilities of points subject to alluvial fan flooding being inundated by a flood, given the flood's magnitude:

1. A topographic map showing the boundaries of the areas subject to alluvial fan flooding. If barriers (either natural or manmade) to the possible flowpaths or channels exist and warrant consideration in defining the conditional probabilities, they should be shown and clearly labeled (including any "threshold" discharges or depths necessary to breach them). This map should also show the division between the single-channel and multiple-channel regions.

2. An aerial photograph (if available) at the same scale as and showing the same information as that described for the topographic map.

3. A soils classification map (if available) at the same scale as and showing the same information as that described for the topographic map.

4. A report describing the topographic and geomorphologic analysis performed.

5. Data and references used in the analysis.

The report should describe, in detail, and justify the use of all assumptions made in the analysis. (Those described by Dawdy can serve as a starting point.)

A5-5C Step 3: Determine and Delineate Flood Insurance Zone Boundaries

After all issues raised during the technical review of Steps 1 and 2 have been resolved and upon receiving approval from the Regional PO, the SC shall proceed with the computations of the 100-year depths and velocities that are to be shown on the FIRM. The results of this analysis are the final product to be submitted as the draft FIS.

The following information shall be submitted to complete this final step:

1. A topographic map showing the flood insurance zones, including 100-year depths and velocities.

2. Backup data and calculations supporting those depths and velocities.

3. A draft FIS Report with adequate descriptions of the analyses performed in the appropriate sections.

A5-6 BIBLIOGRAPHY AND REFERENCES

1. Dawdy, D. R., "Flood Frequency Estimates on Alluvial Fans," Journal of the Hydraulics Division, ASCE, Vol. 105, No. HY11, pp. 1407-1413, November 1979.

2. U.S. Department of the Interior, Geological Survey, Interagency Advisory Committee on Water Data, Office of Water Data Coordination, Hydrology Subcommittee, "Guidelines for Determining Flood Flow Frequency," Bulletin No. 17B, September 1981, Revised March 1982.

3. DMA Consulting Engineers, Alluvial Fan Flooding Methodology - An Analysis, for the Federal Emergency Management Agency, August 1985.

4. Federal Emergency Management Agency, FAN: An Alluvial Fan Flooding Computer Program, September 1990.

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APPENDIX 6. CONVERSION TO THE NORTH AMERICAN VERTICAL DATUM OF 1988

A6-1 INTRODUCTION

The National Geodetic Survey (NGS) has determined that it is necessary to readjust the national vertical control network. With that decision, many elevations that form part of FEMA's products will be affected. Many other affected Federal agencies will be making the same transition as situations and fiscal constraints allow. This appendix provides direction for implementing the use of NAVD 88 in lieu of NGVD 29 for FIS efforts.

A. Background

1. Local Mean Sea Level. The use of this designation in FISs has decreased since the introduction of NGVD 29 and will continue to do so as NAVD 88 becomes the datum of reference for all Federal mapping efforts. Local mean sea level has the inherent drawback of varying from location to location in the areas of concern to the NFIP. Its use will continue as a local datum, but will no longer be referenced as a datum for use in FIS efforts.

The initial use of local mean sea level as a datum reference was based on the readily observed tidal cycles of mean hourly water elevations observed over a 19-year period (the National Tidal Datum Epoch). The arithmetic mean of these observations provided the level used as local mean sea level. However, there are many variables that affect the determination of local mean sea level, and it has been demonstrated since the adoption of NGVD 29 that differences between local mean sea level and NGVD 29 vary from location to location and from time to time. To assist in evaluating these local differences, geodesists have been searching for a datum definition that would more closely represent the true shape of the geoid.

2. National Geodetic Vertical Datum of 1929. During the 1920's, the U.S. Government undertook a project to combine a series of precise leveling surveys. The network was referenced to 21 tide gages in the U.S. and five in Canada. The object of the network was to provide a fixed datum that was supposed to bring a consistent relationship to all vertical determinations in the U.S. Initially known as the "Sea Level Datum of 1929," it provided a continental datum that eliminated the periodic changes inherent in local tidal datums. To avoid confusion over the differences in local tidal datums, the name was changed in 1973 to the "National Geodetic Vertical Datum of 1929 (NGVD 29)." Until now, NGVD 29 has been the datum of reference for the vast majority of FIS work.

3. Preparation for NAVD 88. As newer data were incorporated into NGVD 29, surveyors became dissatisfied with the inconsistencies in NGVD 29. The assumption of zero NGVD as being mean sea level at the 26 appointed tide stations produced a "warped" geoid from their point of view. In order to remove the distortion in the network, a definition that could be reproduced readily at any location needed to be established. That definition is an equipotential surface, that is, the surface represented by a constant value of the acceleration due to gravity. The decision was made by the NGS and its counterpart agencies in Mexico and Canada to adopt a vertical datum based on a surface that will closely approximate this equipotential surface.

4. Data Collection for NAVD 88. Approval and funding to establish the new datum was received in 1978. The readjustment of the North American Vertical Control Networks is called the North American Vertical Datum of 1988, denoted as NAVD 88. The major effort to accomplish NAVD 88 was the releveling of 81,500 km of existing first-order leveling lines to strengthen the network in the conterminous United States. When completed, the releveling was correlated with the total network and adjusted by the method of least squares. The adjusted network includes about 600,000 permanent bench marks. It is important to note that *only a few* non-NGS bench marks have initially been included in this network. For the most part, bench marks established by other Federal, state, or local government agencies and

organizations and not in the NGS data base, were not included in this effort, e.g., third-order U.S. Geological Survey (USGS) bench marks.

A6-2 Scope

Because some of the procedures for determining NGVD 29 and other older datums may have been unreliable, the ultimate goal is to convert all FISs to NAVD 88. However, the conversion will by necessity be gradual and be driven by the opportunity to republish FISs and FIRMs for other substantive reasons. There are a number of factors that must be considered before the decision of whether or not to convert an FIS can be made. These factors include costs associated with the conversion as well as available information, data, and resources.

The question of whether an FIS shall be referenced to NAVD 88 shall be resolved prior to commencement of any work on the FIS. The decision shall be made in consultation with the Regional PO considering the following criteria:

- extent of changes that will occur as a result of the FIS;
- whether or not the conversion factor for the restudied community is constant;
- usability of NAVD 88 by the restudied community;
- costs associated with converting an existing FIS to NAVD 88; and
- FEMA's ultimate goal of converting all FISs to NAVD 88.

It is necessary for all detailed flooding sources within a given community's FIS to be referenced to the same datum. Therefore, if an FIS is not a complete restudy, the non-restudied flooding sources must also be converted to NAVD 88. In fact, the expeditious conversion of non-restudied flooding sources is a critical, and possibly the deciding, factor in the decision of the Regional PO. There are several reasons why the use of mixed datums is impractical. There would be uncertainty when attempting to superimpose backwater effects from a restudied flooding sources referenced to NAVD 88 onto a non-restudied flooding sources referenced to an older datum, such as NGVD 29, or vice versa. In addition, the use of mixed datums could lead to confusion among map users not familiar with the differing datums and could lead to misinterpretation of the maps. For example, the use of mixed datums in computing flood insurance premiums could result in significant inequities to either the insured or the insurer, depending on the error.

Therefore, it is essential for the Regional PO and SC to initially make a sound decision about which datum can and should be used when preparing an FIS. The sections below provide procedures and guidance to select the proper datum when preparing an FIS restudy.

When so directed by the Regional PO, the study contractor is responsible for assuring that the vertical data used in preparing the FIS are properly referenced to NAVD 88. Work already in progress shall not be affected by these guidelines, except when ordered by the Regional PO.

Specifications for "Surveys," as given in Chapter 3, Section D, Guidelines and Specifications for Study Contractors, shall continue to apply.

Requirements for Flood Insurance Studies

When commencing work on an FIS restudy or LMMP, the SC shall investigate and answer the following questions to assist the Regional PO's decision as to whether or not the ongoing FIS shall be referenced to NAVD 88 or the effective FIS datum.

Criteria	Yes	No
1. Does the community have or will soon have the ability to use NAVD 88 with its own benchmark system?		
2. Will less than approximately 50 percent and no more than approximately 20 miles of non-restudied detailed study from the effective FIS have to be converted to NAVD 88?		
3. Will no more than approximately 5 percent of the total printed FIRM panels for the community have to be revised solely to convert non-restudied streams to NAVD 88? (Note: if the ongoing FIS restudy will result in the initial preparation of a FIRM for the community or a countywide FIRM, all panels will be revised and the answer to this question is "yes")		
*4. Is the maximum difference between conversion factors, which is defined as the difference between NAVD 88 and the effective FIS datum, within 0.1 foot for all locations within the community?		

*Note: If the ongoing FIS is a comprehensive restudy of detailed flooding sources on the effective FIS or the ongoing FIS is the initial preparation of detailed study for the community (i.e., there would be no detailed flooding sources to convert), the restudy should be referenced to NAVD 88 regardless of whether or not the bias factor is constant, i.e. within 0.1 foot, if the answers to 1-3 are "yes." In such cases, the answer to 4 can be considered as "yes" without checking the conversion factors.

The above criteria are provided for general guidance to aid the Regional PO and SC in making a technically sound, cost-effective decision. One of the primary intentions of these criteria is to, as much as possible, minimize the costs involved with converting non-restudied flooding sources to NAVD 88. Therefore, if the answers to the four questions outlined above are "yes," the FIS should be conducted using NAVD 88. The necessary conversion to NAVD 88 of non-restudied streams will be performed by the technical evaluation contractor.

In cases where the answer to one or more of the above questions is "no," the SC shall inform the Regional PO before proceeding with work on the study. The SC shall also provide the Regional PO with all pertinent data needed to evaluate the study including information regarding the extent of detailed non-restudied flooding sources to be converted, number of FIRM panels impacted by the restudy, conversion factors, and utility of NAVD 88 for the community. The Regional PO should then assess, on a study by study basis, whether or not it will be cost-effective and technically justified to convert the study to NAVD 88. Based on this assessment, the Regional PO shall advise the SC which datum shall be used for the ongoing study or restudy.

Utility of NAVD 88: At the initial CCO meeting, it should be determined if the community has or soon will have the ability to use NAVD 88 with its own benchmark system. If the community does not have the ability to use NAVD 88, the FIS restudy should be conducted referenced to the same datum as the effective FIS.

Conversion Factor: The conversion factor is the difference between NAVD 88 and the effective FIS datum at any given location. The study contractor should determine if the conversion factor is constant throughout the restudied community. For purposes of FIS work, the conversion factor can be considered to be a constant value if the maximum difference between conversion factors at all locations within the community is 0.1 foot.

The conversion factor must be a constant value to allow for the simple conversion of the BFEs to NAVD 88 for non-restudied flooding sources by applying the constant bias factor. If the conversion factor is not constant, the TEC will determine which ERMs were used to analyze specific reaches of detailed flooding sources in the original FIS hydraulic analyses. Once this determination is made, the BFEs would have to be adjusted by the appropriate conversion factor for the corresponding ERM. For many older studies for which original survey data are no longer available or where the survey data or number of ERMs are voluminous, it may be impractical to convert to NAVD 88. The 0.1 foot tolerance is necessary because that is the degree of accuracy used to issue flood hazard determinations for individual properties.

Figure A6-2.1 is a map showing the contours of the preliminary conversion factors from NAVD 88 to NGVD 29 for the continental United States. The 0 foot contour represents the areas where the NAVD 88 and NGVD 29 elevations are equal. The negative contours represent areas where the NGVD 29 elevation is greater than the NAVD 88 elevation. The converse is true for the contours with positive numbers. In areas where the contours are spaced closely, it is much more likely that the conversion factor will not be constant for a given community in comparison to areas where the contours are spaced further apart.

However, Figure A6-2.1 is provided for general information and should not be used to make the final determination whether or not the conversion factor is constant for a given community. Rather, a more definitive analysis should be conducted by the SC, such as the National Geodetic Survey's Vertical Conversion Transformation (VERTCON) program. This program provides conversions from NGVD 29 to NAVD 88 at locations input by the user at a specific latitude and longitude. The SC may select a minimum of four locations encircling the community for use in the VERTCON program. To ensure that the entire community is considered, it is suggested that, at a minimum, the four corners on the U.S. Geological Survey Quadrangle maps depicting the community on the northeast, northwest, southeast, and southwest "corners" of the community be used as test points. Additional points may also be tested at the discretion of the Regional PO or SC. If the resulting conversion factors are all within 0.1 foot of each other, the conversion factor can be assumed to be constant for the community.

Deliverables

When not converting to NAVD 88

For restudy and/or new detailed study to be completed using the same datum as the effective FIS, the draft FIS materials should be submitted referenced to the FIS datum. In addition, the conversion from the FIS datum to NAVD 88 for the restudy ERMs should be submitted to allow for future conversion of the study.

When Converting to NAVD 88

For restudied and/or new detailed studied flooding sources, the profiles, floodplain mapping with BFEs, and floodway data tables should all be referenced to NAVD 88. In addition, for the ERMs used to prepare the restudy, the elevations should be provided in both NAVD 88 and the FIS datum.

A6-3 CONVERSION METHODS

This section addresses the methods to be used in providing FIS elevations based on NAVD 88. The level of effort required will vary with the type of FIS or map action involved. Variations from these methods will be accepted if approved by the Regional PO in advance of submission of materials.

A. Requirements for Flood Insurance Studies.

When performing any type of FIS surveys, the vertical control network to be used for establishing ERMs shall be properly tied to an NGS primary bench mark, as provided from the NGS data base of NAVD 88 adjusted bench marks. If no primary NGS bench mark(s) adjusted to NAVD 88 are available within an economically reasonable leveling distance, the use of other Federal or state agencies' bench mark(s) that have been converted to NAVD 88 shall be acceptable. If none of the above control points are available within an economically reasonable leveling distance, then the conversion of existing NGVD 29 elevations to NAVD 88 by use of one of the below-mentioned methods shall be acceptable. Indication of how the conversion of the bench mark(s) was accomplished shall be included in the contractor's vertical control data. See Section A6-6 for guidance on submission of data relating to NAVD 88 conversion.

B. Conversion Methods and Example.

There are three basic conversion methods available for users of the new datum, with varying levels of accuracy involved: 1) least squares adjustment of original leveling data into NAVD 88; 2) rigorous transformation of bench mark heights for a specific area using datum conversion correctors; and 3) simplified transformation using average conversion shift factors.

1) Least squares adjustment. This method will be used for conversion of existing bench marks into NAVD 88, which were not included in the original adjustment. For FIS mapping work, results of these conversions may be used for initial vertical control for FIS control surveys. Mapping contractors should not have occasion to resort to this method for conversion without prior approval of their Regional PO.

2) Rigorous transformation using datum conversion correctors. This technique also may be used for converting existing leveling networks to the NAVD 88 adjustment, but will usually prove more time consuming than providing the data in computer-readable form for NGS to incorporate into their Integrated Data Base (IDB). Use of this method will also require prior approval of the Regional PO.

3) Simplified transformation using conversion shift factors. Use of this method will provide sufficient accuracy for FIS mapping projects. Conversion shift factors are available from the NGS through the National Geodetic Information Center or the Vertical Network Branch (see Section A6-5 **Sources of Assistance**).

Section A6-7 of this appendix provides samples of the instructions and data published by NGS.

C. Subsidence and Crustal Motion Areas.

Areas of the conterminous United States that have been identified by the NGS as having non-uniform vertical displacements have limited adjustment data from the primary network available at this time. The last three pages of sample data shown in Section A6-7 illustrate how bench marks not yet adjusted to NAVD 88 will be shown. These areas will also be referenced to NAVD 88 on all FEMA maps.

D. Non-NGS Bench Mark Data.

As other Federal agencies adjust their bench marks, more data within floodplain areas will be available. These data when published and documented will be acceptable for use in establishing NAVD 88 elevations and ERMs for FEMA mapping projects.

The USGS and U.S. Army Corps of Engineers are among other major Federal agencies being affected by the conversion to NAVD 88 and their adjusted bench mark data can probably be obtained soon after the adjustments are made.

A6-4 OTHER AREAS AFFECTED

Hawaii, the Pacific Trust Territories, the Commonwealth of Puerto Rico, and the U.S. Virgin Islands, will all have their datums adjusted based on releveling work done there. Although not connected by mainland network ties, the datum in these areas will be designated NAVD 88 that will be constrained at a single point of reference determined by local mean sea level based on the 1960-78 tidal epoch.

A6-5 **SOURCES OF ASSISTANCE**

In seeking assistance with the conversion process for FEMA mapping projects, first consult the Regional PO. If the Regional PO cannot resolve the issue, request referral to the next source. The NGS Vertical Network Branch will undoubtedly receive numerous inquiries nationwide for assistance with conversion activities. Therefore, please refrain from automatically calling them with each issue as it arises. FEMA contractors should use the following "chain-of-command" to guide inquiries.

1. Contract Project Officer/Government Technical Monitor
2. Regional Office Engineer
3. FEMA HQ Project Engineers
4. Chief, Hazard Identification Branch
5. National Geodetic Information Center, NGS
6. Vertical Network Branch, NGS

This appendix includes a listing of addresses and telephone numbers of the various contact points. Also listed is additional information regarding other Federal and state agencies involved in the NAVD 88 conversion process. Depending on the nature (i.e., administrative, procedural, technical, etc.) of the response needed, contact should be made with the appropriate person, usually beginning with the Regional PO.

REGIONAL OFFICES

REGION 1

(Connecticut, Maine, Massachusetts,
New Hampshire, Rhode Island, Vermont)

FEMA, Mitigation Division
J. W. McCormack Post Office and
Courthouse Building, Room 462
Boston, Massachusetts 02109
(617) 223-9561

REGION 2

(New York, Puerto Rico, New Jersey)

FEMA, Mitigation Division
26 Federal Plaza, Room 1351
New York, New York 10278
(212) 225-7200

REGION 3

(Delaware, D.C., Maryland,
Pennsylvania, Virginia, West Virginia

FEMA, Mitigation Division
Liberty Square Building
(Second Floor)
105 South Seventh Street
Philadelphia, Pennsylvania 19106
(215) 931-5512

REGION 4

(Alabama, Florida, Georgia, Kentucky,
Mississippi, N. Carolina, S. Carolina, Tenn.)

FEMA, Mitigation Division
1371 Peachtree Street, Northeast
Suite 736
Atlanta, Georgia 30309
(404) 853-4400

REGION 5

(Illinois, Indiana, Michigan
Minnesota, Ohio, Wisconsin)

FEMA, Mitigation Division
175 West Jackson Boulevard,
Fourth Floor
Chicago, Illinois 60604
(312) 408-5552

REGION 6

(Arkansas, Louisiana, New Mexico,
Oklahoma, Texas)

FEMA, Mitigation Division
Federal Regional Center
800 North Loop 288
Denton, Texas 76201-3698
(817) 898-5165

REGION 7

(Iowa, Kansas, Missouri, Nebraska)

FEMA, Mitigation Division
Federal Office Building
911 Walnut Street
Kansas City, Missouri 64106
(816) 283-7002

REGION 8

(Colora)do, Montana, N. Dakota, S. Dakota,
Utah, Wyoming)

FEMA, Mitigation Division
Denver Federal Center
Building 710, Box 25267
Denver, Colorado 80225-0267
(303) 235-4830

REGION 9

(Arizona, California, Hawaii, Nevada)

FEMA, Mitigation Division
Presidio of San Francisco, Building 105
San Francisco, California 94129
(415) 923-7100

REGION 10

(Alaska, Idaho, Oregon, Washington)

FEMA, Mitigation Division
Federal Regional Center
130 228th Street, S.W.
Bothell, Washington, 98021-9796
(206) 487-4600

FEMA Headquarters Engineers
Hazard Identification Branch
Mitigation Directorate
500 C Street, S.W.
Washington, D.C. 20472
(202) 646-3680

National Geodetic Information Center
National Geodetic Survey, N/CG17
National Ocean Survey, NOAA
1315 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3242

Vertical Network Branch, NGS
National Geodetic Survey, N/CG13
National Ocean Survey, NOAA
1315 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3191

A6-6 ADDITIONAL DATA SUBMISSION REQUIREMENTS FOR NAVD 88 FLOOD STUDIES

The conversion of the vertical reference datum from the National Geodetic Vertical Datum of 1929 (NGVD 29) to the North American Vertical Datum of 1988 (NAVD 88) requires that documentation of vertical control efforts be provided with Flood Study results. If a Flood Study is completed with ERMs referenced to NAVD 88, the conversion method and results shall be a part of the deliverable items with that Flood Study. The question of whether a Flood Study shall be referenced to NAVD 88 shall be resolved prior to the commencement of any work on that Flood Study.

The following information shall be included with the survey data provided in the TSDN:

1. One copy of the NGS published (or NGS data base hard copy) bench mark(s) description and elevation, including the date of recovery or establishment and last adjustment date.

2. One copy of the methodology and computations used in lieu of NGS published (or NGS data base) elevations. If a computer program is used for the computations, the program name and location where an exact copy of the program may be found.

3. One copy of leveling field notes for vertical leveling surveys from/to published bench mark(s).

A6-7 EXAMPLES OF DATA PROVIDED BY NGS

See following pages for examples of data provided by NGS.

APPENDIX 7. DIGITAL PRODUCT DELIVERY SPECIFICATION

A7-1 INTRODUCTION

The purpose of this appendix is to provide guidance and specifications to be used by the Study Contractor (SC) when preparing digital files for transfer to the Federal Emergency Management Agency (FEMA). It is not in any way intended to dictate in-process compilation or digitizing procedures.

Because of the variety of commercially available mapping and/or survey software packages and their varying formats, FEMA applications of SC digitally prepared mapping and survey data should be a prime consideration when "collecting" the information. To ensure transportability of graphics and database files from one platform to another, mapping features must be digitally captured into a schema (layer/level or attribute structure) and must be capable of being translated into a common spatial data exchange format.

The transportability of digital data should be of prime consideration during the planning phase of a project. Also of concern is the data structure itself. Digital data must be arranged or segregated within the base map and Flood Insurance Study files in such a manner that features are separated onto topical layers/levels or by attributes that conform to the user's needs. This will eliminate the need for later efforts to separate the graphic elements for further work.

A major aspect of transportability of mapping or survey files to a Geographic Information System (GIS) is horizontal and vertical position on the earth. Mapping data must be controlled to a grid or geographic projection and referenced, both to horizontal and vertical datums. These positional references are established prior to the surveying process. Survey control is expressed in the form of horizontal and vertical position plotted on a geographic projection or control grid (either State Plane or Universal Transverse Mercator (UTM)). All planimetric and topographic features must be collected/compiled and referenced to this survey control. See Appendix 4 for a detailed discussion of aerial mapping and surveying specifications, including horizontal and vertical control for new mapping.

Considerations for transfer of digital data are the file structure of the data itself, the transfer medium (computer diskette or magnetic tape), the export/import device and the operating systems of the host and receiving systems (DOS, UNIX, VAX, etc).

In summary, the key issues to consider when digitally compiling mapping or survey information intended for export to a defined user group are:

1. Compatible common spatial data exchange format.
2. Compatible file structure.
3. Defined horizontal and vertical datums.
4. Referencing system (Control grid or projection).
5. Transfer media and equipment.
6. Hard copy requirements

A7-2 SCOPE OF STUDY

A complete digital Flood Insurance Study (FIS) submittal will be comprised of the following mapping items:

- Digital base map files(s)
- Digital Flood Insurance Study files (separate from the base map files)
- Digital Elevation Model (DEM) or Digital Terrain Model (DTM) if used
- Work maps (plots)
- Map index
- Metadata file

All other requirements for deliverable items outlined in these Guidelines apply to digital FIS submittals.

The SC is responsible for obtaining and providing all of these materials, and assuring that the accuracy of the data in the submitted files, at a minimum, meets or exceeds National Map Accuracy Standards for maps at a publication scale of 1:24,000, and that the data meet FEMA's criteria for release of digital data. If new mapping is produced using photogrammetric processes, the standards detailed in Appendix 4 must be met. The data must be segregated within the base map and Flood Insurance Study files by layer/level or attribute, and be provided in a format readily usable by others. Complete documentation of file names, sizes, and contents is required.

SC coordination with FEMA is recommended before beginning a digital FIS submission, and a planning meeting is advised. This meeting should serve to coordinate the digital capture of the restudy data and facilitate production of digitally generated FIRMs in a timely fashion. Data format is an important consideration to be discussed prior to data capture, as changing data format after the fact can be both time consuming and costly.

A7-3 DATA COLLECTION AND COORDINATION

As specified in Chapter 3, Data Collection and Coordination, initial research must be performed to avoid duplication of effort. This is especially critical for digitally prepared FISs, as data capture is a costly item. Existing digital data should be identified and utilized whenever possible, while still maintaining the expected level and quality of work.

It is recommended that as part of the initial coordination effort, the SC identify available digital data and obtain data sets and hard copy plots as necessary for restudied areas. Potential sources of digital base map or floodplain boundary data may be state, county, or local government agencies responsible for GIS; planning or real estate assessment agencies; etc. Digital floodplain data may also be available from FEMA, if the area has been previously converted to digital format.

If pre-existing data are available and utilized by the SC, it shall be made to conform with one of the digitizing specifications options listed in Figures A7-3, A7-4, or A7-5, or complete documentation shall be provided of its level/layer schema or attribute definitions.

If it is available from state, county, or local agency, at a reasonable cost, digital base map data covering an entire county should be obtained and submitted to FEMA, even if the restudied area does not cover the entire county. This will facilitate later efforts to digitize and match non-restudied areas to the digital files being submitted.

As part of the digital coordination and submission, the SC must document the data sources, date of collection or digitizing, scale of digitizing, projections, horizontal datum, vertical datum, working units, global origin, etc. of all digital data received and submitted. The attached form (Figure A7-1) must accompany all data submittals. In addition, a Metadata file documenting data sources is required (see Figure A7-2 for Metadata file format requirements).

All newly collected digital data must be tied into any existing digital data files so that a seamless transition is effected. Hardcopy deliverables should reflect both the existing digital data in the non-restudied areas and the new digital data in the restudied areas. If no existing digital floodplain data is currently available from FEMA, deliverables should reflect the new digital data only.

Existing digital data may affect the choice of scale of data compilation. If community base mapping is available at a scale greater than 1" = 400' (e.g. 1" = 200') the SC may choose to compile and digitize the restudied data at that scale. Checkplots may be delivered at a scale other than the compilation scale.

It is recommended that prior to beginning work, the SC coordinate with FEMA to determine if public domain software has been developed and is available for whatever hardware platform is chosen by the SC for his digital work. Software may be available to assist in data capture, data coding, layer/level assignment, quality control, and plotting.

It is recommended that the SC submit to FEMA a sample of the digital files being prepared, at approximately the 10 percent completion milestone. This will enable FEMA to review the data files for ease of use and will enable any modifications to digital capture procedures to be implemented by the SC at an early production stage.

A meeting between the SC, FEMA, and FEMA's TEC is also recommended at this milestone, in order for all parties to be familiar with any unique conditions in the data files.

FIGURE A7-1

DIGITAL DATA SUBMISSION CHECKLIST

Please fill out completely and submit this checklist with any digital data that you submit to FEMA. This information will greatly facilitate data processing. If your system output capabilities do not fall within these catagories, you must coordinate with FEMA and the data recipient before submitting digital files.

TRANSFER MEDIUM:

___ 9 Track Tape
Density: __ 6250 B.P.I.
__ 3200 B.P.I.
__ 1600 B.P.I.
__ 800 B.P.I.

* ___ 8mm Tape

___ 2.7 gigabyte
___ 5.0 gigabyte

___ 4mm DAT tape

___ 1/4" Cartridge Tape

___ 150 mb
___ 60 mb

___ 3 1/2" Diskette

___ DOS
___ UNIX
Specify single or double sided,
low or high density

___ 5 1/4" Diskette

__ DOS
__ UNIX
Specify single or double sided,
low or high density

TAPE FORMAT, including complete command syntax used to create the tape:

* ___ Tar
___ CPIO
___ SCPIO
___ VMS Backup
___ VMS Copy
___ Other Specify

*Preferred Transfer Format

FIGURE A7-1

DIGITAL DATA SUBMISSION CHECKLIST

DISKETTE FORMAT:

____ CPIO
____ Tar
____ To_flop
____ dd
____ DOS backup Specify DOS Version
System
Backup Package

Please provide the utility to uncompress files, if a file compression utility was used.

FILE FORMAT:

___ DLG (specify version by date _____)
___ DXF Specify Version
(Please provide DXF files with headers)
___ DGN (Intergraph Design Files)
Specify Global Origin
Working Units

___ DWG (AutoCAD Drawing Files)
Specify Version

___ EOO (ARC/INFO Export Files) ARC/INFO Version
Please provide uncompressed export files of coverages.

YOUR SYSTEM HARDWARE:

Mainframe (Type)
Workstations (Type)
PC
Other (Specify)

YOUR OPERATING SYSTEM:

UNIX
VAX
DOS
Other (Specify)

YOUR SYSTEM SOFTWARE:

MicroStation
Version
ARC/INFO

FIGURE A7-1

DIGITAL DATA SUBMISSION CHECKLIST

Version
AutoCAD
Version

OTHER (Specify)

YOUR DATABASE SOFTWARE:

INFO
ORACLE
INFORMIX
OTHER (Specify)

FILE CONTENTS:

Please list file names and their contents for each tape/disk you submit. You may submit this information on a separately attached list. A maximum of 8 characters is recommended for all file names. It is further recommended that the file name clarify the file contents.

CONTENTS	TEXT?	FILE NAME
___ Floodplain Boundaries	Y ___ N	
___ Hydrography	Y ___ N	
___ Political Boundaries	Y ___ N	
___ Map Panel Neatlines	Y ___ N	
___ Base Flood Elevations	Y ___ N	
___ Cross Sections	Y ___ N	
___ Elevation Reference Marks	Y ___ N	
___ Contours	Y ___ N	
___ Roads	Y ___ N	
___ Railroads	Y ___ N	
___ Building Outlines	Y ___ N	
___ Other _______	Y ___ N	
___ Other _______	Y ___ N	
___ Other _______	Y ___ N	

FIGURE A7-1

DIGITAL DATA SUBMISSION CHECKLIST

___ Other _______ Y ___ N

DIGITIZING OPTION USED:

Option 1 ___ Option 2 ___ Option 3

LEVEL/ATTRIBUTE LIST:

Please enclose a listing of all features and their layer/level, color and attributes.

SOURCE MAP INFORMATION:

Date of Compilation/Publication _____________ Type(s)
Projection of Source Maps
(If projection is State Plane, please indicate
zone ______)

DIGITAL DATA INFORMATION:

Date of data collection/digitizing
Projection

(If projection is State Plane, please indicate
zone______)

Horizontal Datum:

___ NAD 27
___ NAD 83

Vertical Datum:

___ NGVD 29
___ NAVD 88
___ Other Specify

X Shift, Y Shift if used

INDEX MAP:

Please provide an index map, showing areas mapped.
Point of contact for any questions regarding data:

Signed:
Telephone:

FIGURE A7-2

METADATA FILE

In order to facilitate the use of the Federal Spatial Data Transfer Standard (SDTS) to transfer data files between users, a Metadate file shall accompany all digital data submissions. Only one Metadata file is required for each FIS, however, data providers may find it advisable to submit one Metadata file for each submitted file type (base map files, FIS files, etc.) as each file type may have very different origins. The Metadata file shall be in the form of a read.me file on the electronic medium containing the data files. It should follow the following format and contain all listed items.

Read.me Metadata File Specifications

- Data Set Identity: Digital Flood Insurance Study
  or Base Map
  or DEM, etc.

- County and State: Name of county and state covered by enclosed files

- Theme Keywords: Flood Insurance Study
  or Base Map
  or DEM, etc.

- Representation Model: Vector, raster, vector topologic, etc.

- Spatial Object Types: Point, node, tic, chain, arc, polygon, cell, etc.

- Data Set Size: In megabytes

- Transfer Format: DXF, DLG, DGN, EOO, or DWG

- Data Set Description: A description of the data set.

- Intended Use: Synopsis of the purposes or applications for which the data set was created.

- Data set extent: The limits of coverage of the data set expressed as latitude and longitude in decimal degrees, followed by the horizontal datum.

  Example: 41.125, -87.875, 41.25, -87.5 North American Datum of 1927

- List of file names included: A complete listing of all file names included.

- Intended Scale of Use: The scale at which the data can most accurately be applied, based on the scale or resolution of the source data used to generate the data set.

- Resolution of Data: The dimension of the smallest resolvable object in the data set.

- Projection Name: VTM, State Plane, Geographic, etc.

- Horizontal Datum: The coordinate system used for horizontal control.

FIGURE A7-2

METADATA FILE

	Example:	North American Datum of 1927
Vertical Datum:	The reference system for the Z component of spatial coordinates.	
	Example:	National Geodetic Vertical Datum of 1929
Projection Units:	Meters, feet, etc.	
Zone Number:		UTM or State Plane zone number. Plus sign is used to indicate Northern Hemisphere.
	Example:	UTM +16
Coordinate Precision:	Single or Double	
Contact Type:	Originator, distributor, etc.	
Contact organization:		
Contact person and title:		
Contact mailing address:		
Contact telephone:		
Transfer Mode:	8mm tape, 9-track tape, diskette, etc.	
Transfer Instructions:	Type and density of tape or disk, archiving instructions, etc.	
Computer Type and Operating System:		
Completion Status:		Status of completion of the county studied.
Completion Date:	Month, year.	
Geographic Area Completed:	Name(s) of county area(s), streams, etc., completed.	
Hardcopy Product Availability:	Enclosed	
Copyright Status:	Public domain, copyrighted, etc.	
Policy Status:	Description of ownership policy if data set is not in the public domain.	
Table Definition	Source document from which data base tables were	

FIGURE A7-2

METADATA FILE

Source: defined.

✐ Attribute Definition Source document from which feature attributes were Source: defined. FEMA, Guidelines and Specifications for Study Contractors, etc.

*✐ Source Name: Descriptive name of source material

*✐ Source Scale: Expressed as a ratio, e.g., 1:12,000

*✐ Source Medium: Mylar, paper, electronic medium, etc.

*✐ Creator of Source:

*✐ Date of Source Material: Day, month, year.

*✐ Source Projection: Projection name and parameters of source material.

*Note: All source data is to be repeated as necessary.

✐ Processing Procedures: Include Root Mean Square Error if transformations were performed.

✐ Procedure Tolerances: Description of processing tolerances applied.

✐ Positional Accuracy: ± a value

✐ Positional Accuracy Method: Method by which positional accuracy was determined.

✐ Attribute Accuracy: Measure of confidence in percentage.

✐ Data Model Integrity: Explanation of integrity of relationships between objects in the data set.

Example: Data is topologically structured polygon data with nodes at all intersections.

✐ Completeness: Information about selection criteria, etc.

Example: Streams less than 100 meters long were not included.

✐ Metadata Date: Day, month, year.

✐ Metadata Contact:

A7-4 DIGITAL FLOOD INSURANCE STUDY PREPARATION

A. General

All horizontal information will be compiled on either the North American Datum (NAD) 1927 (Clarke 1866 ellipsoid) or NAD 1983 (Geodetic Reference System 1980 -- GRS 80 ellipsoid); however, it is critical that horizontal datums not be mixed within a study. All vertical information will reference either the National Geodetic Vertical Datum of 1929 (NGVD 29) or the North American Vertical Datum of 1988 (NAVD 88); however, it is critical that vertical datums not be mixed within a study. Any exceptions to the above must be coordinated in advance with the Regional PO.

Maps used for engineering analyses must meet all requirements specified in these Guidelines.

B. Data Format

Graphics files may be exported by the SC in any one of the following standard formats:

- ARC/INFO export format
- DLG (Digital Line Graph)
- MicroStation (DOS or UNIX) Design Files
- AutoCAD Drawing Files
- DXF (Drawing Exchange Format)

Digital files must be created to pre-established specifications in order to satisfy follow-on applications. The layer/level or attribute assigned to a graphic element must be consistent and the information accessible to all users. Digital files must be prepared using a pre-defined system or schema that has been consistently used throughout. Base map data must be submitted in separate files from the Flood Insurance Study data.

C. Base Map Files

Information contained in digitally created base map files must meet all the requirements defined in these Guidelines for community base maps. These data must be contained in a separate file or files from the Flood Insurance Study data.

The intent of the base map file is to support the engineering requirements of the hydrologic and hydraulic analyses. New photogrammetric data capture may be required along restudied streams. Existing base map data sources (a community's GIS, USGS files, etc.) may be sufficient for all other areas.

Base map files must meet, at a minimum, U.S. National Map Accuracy Standards for maps at a publication scale of 1:24,000, or better, if better source data is available. SCs will be responsible for assuring that this standard is met. Appendix 4 details the mapping standards for new data collected using photogrammetric and surveying methods.

Base map files may contain road centerlines, edge of pavement, or right-of-ways as a means of depicting the location of road features. Any of these is acceptable for FIS production, however, documentation of the data source(s) and stated accuracy are required.

If base map files are obtained from a community agency, the following criteria must be met in order for them to be used as the base map for newly published digital Flood Insurance Rate Maps:

1. The base map data shall be provided to FEMA at no cost or nominal cost (i.e. the cost of a computer tape).

2. FEMA shall have the right to retain a copy of the digital data.

3. FEMA shall have the right to print and distribute unlimited numbers of hardcopy FIRMs produced using community, county, or state agency supplied digital base map data.

4. It is not FEMA's intent to distribute proprietary digital base map files supplied to them by a community, county, or state agency to the public. FEMA can provide printed mapping, but may only provide community-supplied digital base mapping when the community has explicitly waived any objection to its release by FEMA.

Coordination with FEMA by the SC is required before submitting any files that do not meet these criteria. If the SC submits digital files that do not meet these criteria, they must be clearly marked as such, and the restrictions placed on the data must be noted.

The following features, if contained in the base map file, must be isolated on separate layers/levels or by attributes:

- Primary roads
- Secondary roads
- Unimproved roads
- Railroads
- Abandoned railroads
- Old railroad grades
- Airports
- Cemeteries
- Bridges
- Footbridges
- Park or military reservation boundaries
- Range and township/section lines
- Annotation (road names, etc.)
- Hydrographic features
- Contour lines
- Spot elevations
- Building footprints

For each of the digitizing options, suggested layers/levels or attributes are provided for base map features files. These should be used when new base map data collection is included in the SC scope of work. If preexisting data is used by the SC (USGS DLG files, community-supplied data, etc.), it is not necessary to restructure the files to meet the schema listed with the digitizing options. It is, however, required that the data be separated on documented layers/levels or by attributes.

All features must be digitized in their true positions as line strings or simple linear elements.

If digital orthophotographs or other raster image files are proposed as the digital base map for restudied areas, special coordination with FEMA Headquarters is required.

D. Flood Insurance Study Files

If FIS files are to be provided in DLG format, they must conform to the most current edition of FEMA's Standards for Digital Flood Insurance Rate Maps.

If FIS files are to be supplied in any other format (DXF, DGN, EOO, etc.) they must conform to one of the following layer/level schema options. Coordination between the SC and FEMA is required before choosing one of these options, in order to assure that concurrent and subsequent work is compatible.

No additional elements may be added to any layer/level for any of the options. This assures that data will not be mis-coded in later processing steps or that time will not be spent separating features.

(1) Option 1

In this option, all lines are captured on designated layers/levels. Coincident features are treated separately from features that stand alone and are captured on separate layers/levels. Polygons are not coded in this option. Figure A7-3 outlines the layers/levels and colors for Option 1. Note the following for Option 1:

* Although many software packages allow the use of descriptive layer/level names, it is required that the number shown in the digitizing specifications be used as the layer/level name. This is important because many follow-on processing applications are based on the layer and color numbers assigned to the elements.

** The actual color is not significant. The requirement is that the color NUMBER for each type of feature must be as indicated and retained in each graphic element's header record.

*** SCs are not responsible for collecting information on COBRAs or Otherwise Protected Areas.

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
FLOOD INSURANCE STUDY FILES

LAYER/LEVEL*	COLOR**	LINE CODE	LINE WEIGHT	FEATURES
2	1	0	1	Drainage from FIRM panel
6	0	0	2	Dam/Weir
7	7	0	2	500-Yr Boundary/Zone D Boundary
8	0	0	1	Levee
8	1	0	1	Road on Levee
10	0	2	1	Culvert
12	0	0	0	Pier/Dock/Jetty
12	2	0	1	100-Yr Flood Contained in Channel
12	3	0	1	500-Yr Flood Contained in Channel
12	4	0	1	Floodway Contained in Channel
13	0	0	1	Profile Base Line
14	9	0	3	County Boundary
16	0	0	3	State Boundary
18	2	0	3	Extraterritorial Jurisdictional Boundary
18	5	0	3	Corporate Limits
20	0	0	1	1000 Ft. Marker
21	4	3	2	100-Yr Boundary/Floodway/500-Yr Boundary
22	0	0	0	Quad Neatline
22	2	0	0	Quad Neatline/FIRM Neatline
22	4	0	0	FIRM Neatline
23	10	3	2	100-Yr Boundary/Floodway
23	1	0	1	Drainage from Other Sources (community, study contractor, etc.)
24	4	3	2	Floodway Boundary
24	1	0	1	Drainage from USGS 100 K DLGs
25	2	0	2	500-Yr Boundary
26	3	0	2	100-Yr Boundary
28	0	0	1	Zone Break

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
FLOOD INSURANCE STUDY FILES

LAYER/LEVEL*	COLOR**	LINE CODE	LINE WEIGHT	FEATURES
28	1	0	1	Zone Break/Limit of Detailed Study
28	7	0	1	Zone Break/Floodway
30	0	0	2	Zone D Boundary
31	1	0	1	Drainage from USGS 24 K DLGs
32	13	0	1	Apparent Limit
33	0	0	1	Flowage Easement Line
34	0	0	1	State Encroachment Line
36	12	0	1	Limit of Floodway
38	12	0	1	Limit of Detailed Study
39	13	0	2	Cross Section/Limit of Detailed Study
39	0	0	3	Area Not Included
40	7	0	1	Limit of Study
41	0	0	2	Otherwise Protected Area***
41	3	0	2	100-Yr Boundary/500-Yr Boundary
42	8	0	2	1983 COBRA***
43	8	0	2	1990 COBRA***
44	6	0	2	Cross Section
47	0	0	0	River Mile Marker
48	10	0	2	BFE
49	0	0	2	Intermediate Cross Section
49	14	0	2	Interpolated BFE
50	0	0	0	FIRM Control Point
51	0	0	2	Elevation Reference Mark
54	4	0	2	1983 COBRA*** & 1990 COBRA***
63	0	0	0	Open Level

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
BASE MAP FILES

ELEMENT	**CELL/ PATTERN**			**ELEMENT TYPE**	**GRAPHICS**				**TEXT**							
	AS/PS	PD	PA		LV	WT	LC	CO	LV	WT	LC	CO	TX	TH	TW	FT
International Boundary (CAPS) AP=CTYBDY	1	0	0	Pat LS/Text	1	3	0	0	2	2	0	0	16			76
State Boundary (CAPS) AP=CTYBDY	1	0	0	Pat LS	16	3	0	0	2	2	0	0	16			76
County Boundary (CAPS) AP=CTYBDY	1	0	0	Pat LS	14	3	0	9	2	2	0	0	16			76
Corporate Limits (CAPS) AP=CORPBD	1	0	0	Pat LS	18	3	0	5	2	2	0	0	16			76
Park. Military Res. (U/L) LS=10 Wildlife Refuge				LS/Text	5	3	0	2	6	1	0	2	15			74
City, Borough, Township Name on Map Body LS=20 (U/L)				Text					4	1	0	0	*25			74
City Name Text of ANI (U/L)				Text					4	1	0	0		14	12	74
Area Not Included (CAPS)				Text					4	1	0	0	12.5			76
Range & Township Lines Section Numbers				LS/Text	42	0	0	0	42	1	0	0	15			76
Primary Roads LS=8				LS/Text	23	3	0	7	1	0	0	0	11			76
Secondary Roads LS=8				LS/Text	20	2	0	6	1	0	0	0	11			76

*May change depending on size of community
**Refer to fill memo for various shapes/holes/etc.

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
BASE MAP FILES

ELEMENT	**CELL/ PATTERN**			**ELEMENT TYPE**	**GRAPHICS**				**TEXT**							
	AS/PS	PD	PA		LV	WT	LC	CO	LV	WT	LC	CO	TX	TH	TW	FT
Unimproved Roads LS=8				LS/Text	19	1	2	0	1	0	0	0	11			76
Roads that are Coincident Corporate Limits				LS	61											76
Interstate Route Symbol AC=INTRST	1	0	0	Cell/Text	8	1	0	3	8	1	0	3	11			76
U.S. Route Symbol AC=USRTE	1	0	0	Cell/Text	8	1	0	3	8	1	0	3	11			76
State Route Symbol AC=STATE	1	0	0	Cell/Text	8	1	0	3	8	1	0	3	11			76
RR Pattern (CAPS) AP=RR	15	0	0	Pat LS/Text	9	1	0	3	10	1	0	3	12			23
Abandoned Railroad AP=ABDNRR	15	0	0	Pat LS/Text	9	1	0	3	10	1	0	3	12.5			75
Old Railroad Grade				Pat LS/Text	9	1	3	3	10	1	0	3	12.5			75
Airport/Landing Strip (U/L) Proper Names in CAPS				LS/Text	20	1	0	9	21	1	0	9	15			75
Bridge/Foot Bridge (U/L) Proper Names in CAPS	1		0	LS/Text	19	1	0	8	21	1	0	8	12.5			75
Footbridge				Cell	19	2	0	8								

*May change depending on size of community
**Refer to fill memo for various shapes/holes/etc.

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
BASE MAP FILES

ELEMENT	CELL/ PATTERN			ELEMENT TYPE	GRAPHICS				TEXT							
	AS/PS	PD	PA		LV	WT	LC	CO	LV	WT	LC	CO	TX	TH	TW	FT
AC=BRIDGE																
Dam/Weir (U/L) Proper Names in CAPS				Text					21	1	0	6	12.5			75
Pier/Dock/Jetty (U/L)				Text					21	1	0	6	12.5			75
Cemetery (U/L) Proper Names in CAPS				LS/Text	12	0	0	0	21	1	0	6	12			76
Levee Pattern & Text (U/L) AP=LEVEE	1	0	0	Pat LS/Text					50	2	0	8	12.5			75
Culvert (U/L) Headwalls				Text	3	1	0	5	21	1	0	6	12.5			75
Landforms or Islands with Proper Names (CAPS)				Text					56	2	0	9	15			76
Drainage Text LS=8 (U/L) for Single Line (CAPS) for Double Line				Text					12	2	0	1	16.5			73
Floodway Fill				Shape**	39	0	0	4								
100-Year Flooding Fill				Shape**	38	0	0	3								
500-Year Flooding Fill] AP=ZONEX				Shape**	41	0	0	2								

*May change depending on size of community
**Refer to fill memo for various shapes/holes/etc.

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
BASE MAP FILES

ELEMENT	CELL/ PATTERN			ELEMENT TYPE	GRAPHICS				TEXT							
	AS/PS	PD	PA		LV	WT	LC	CO	LV	WT	LC	CO	TX	TH	TW	FT
Coastal Barrier Fill (1983)		12.5	135	Hatch	46	2	0	8								
Coastal Barrier Fill (1990) AP=COBA90	15	0	135	Pattern	47	1	0	9								
Otherwise Protected Fill (1991) AP=OPA	1.5	0	135	Pattern	48	1	0	6								
Zone Labels (CAPS) LS=10				Text					56	2	0	2	16			70
Limit of Detailed Study (CAPS) Limit of Study Notes LS=8				Text					56	1	0	2	11			76
Profile Base Line Pattern AP=PROFIL	15	0	0	Pat LS/Text	13	1	0	0	13	1	0	0		14	12	76
Zone Break Pattern AP=GUTTER	1	0	0	Pat LS	28	1	0	0								
BFE Pattern & Text AP=BFE	1	0	0	Pat LS/Text	48	2	0	7	50	2	0	8	16.5			75
Cross-Section Hexagon AC=hex1 AC=hex2	1			Cell	52	0	0	4								
ERM Text AC=RMTEXT	1	0	0	Cell	16	1	0	7	16	1	0	7	18			1

*May change depending on size of community
**Refer to fill memo for various shapes/holes/etc.

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
BASE MAP FILES

ELEMENT	CELL/ PATTERN			ELEMENT TYPE	GRAPHICS				TEXT							
	AS/PS	PD	PA		LV	WT	LC	CO	LV	WT	LC	CO	TX	TH	TW	FT
River Mile Text AC=RVMITX	1			Cell	17	1	0	1								
Leader Lines				LS	57	1	0	5								
Dots for Leader Lines AC=MTBALL	1			Cell	57	3	0	3								
Arrow Heads for Leader Lines AC=ARRWHD	1			Cell	57	1	0	5								
Coastal BFE Note AC=NOTE1	1		0	Cell	56	1	0	2						10.5	13.5	43
100-Year Contained in Culvert AC=NOTE2	1		0	Cell	56	1	0	2						10.5	13.5	43
1983 Coastal Barrier Note AC=NOTE3	1		0	Cell	56	1	0	2						10.5	13.5	43
1990 Coastal Barrier Note AC=NOTE4	1		0	Cell	56	1	0	2						10.5	13.5	43
Otherwise Protected Areas Note AC=NOTE5	1		0	Cell	56	1	0	2						10.5	13.5	43
Joins Inset_On Panel_ _ _ _ Note (CAPS)				Cell					62	1	0	0	10			43

*May change depending on size of community
**Refer to fill memo for various shapes/holes/etc.

FIGURE A7-3

DIGITIZING SPECIFICATIONS OPTION 1
BASE MAP FILES

ELEMENT	CELL/ PATTERN			ELEMENT TYPE	GRAPHICS				TEXT							
	AS/PS	PD	PA		LV	WT	LC	CO	LV	WT	LC	CO	TX	TH	TW	FT
Inset Label (CAPS)				Text					62	3	0	0		22.8	14	32
ERM Description AC=ERMTBL				Cell					60							
Neatline				LS	22	0	0	4								
North Arrow AC=NORTH	15			Cell	63											
D-Frame Border AC=DFRAME	1			Cell	62											
Joins Panel Note AC=JOINS	1			Cell	62	1	0	0								
Community Listing for Index AC=COMLIS	1		0	Cell	62											

*May change depending on size of community
**Refer to fill memo for various shapes/holes/etc.

(2) Option 2

In this option, fewer layers/levels are used for linear features, and each type of linear feature is continuous on its own layer/level. However, all polygons formed by crossing lines are coded with their flood insurance zone and elevation.

Figure A7-4 outlines the layers/levels and colors required for Option 2.

Note the following for Option 2:

Flowage easement areas are indicated by changing the feature line color to 3.

* The actual color is not significant. The requirement is that the color NUMBER for each type of feature must be as indicated and retained in each graphic element's header record.

** Line code and line weight are optional. Features are fully segregated by layer/level, and color. These may be included for plotting purposes.

*** SCs are not responsible for collecting information on COBRAs or Otherwise Protected Areas.

**** Annotation for areas should be attached to area centroid.

FIGURE A7-4

DIGITIZING SPECIFICATIONS OPTION 2
FLOOD INSURANCE STUDY FILES

LAYER/ LEVEL	COLOR*	LINE CODE**	LINE WEIGHT**	FEATURE	ANNOTATION LAYER/LEVEL	ANNOTATION
2	1	6	0	Drainage from FIRM	3	Stream name
2	2	6	0	Drainage from 100K USGS DLG	3	Stream name
2	3	6	0	Drainage from 24K USGS DLG	3	Stream name
2	4	6	0	Drainage from other source	3	Stream name
5	1	4	2	Profile Base Line	0	Profile Base Line
6	1	0	3	Dam or Weir	7	Dam Weir
7	2	0	3	Culvert	0	Culvert
8	3	0	3	Levee crown or floodwall	0	Levee Floodwall
8	238	0	3	Road on Levee	0	Road on Levee
9	4	0	3	Coastal hard point (pier, jetty)	0	Pier Jetty
12	2	7	0	Corporate boundary		
12	33	7	0	Extraterritorial Limits		
13	5	4	1	Floodplain boundary/Panel neatline/Corporate Boundary		
14	3	7	2	County boundary	15	County names
16	4	7	4	State boundary	17	State names
18	5	7	1	Corporate boundary/ Floodplain boundary	19	

FIGURE A7-4

DIGITIZING SPECIFICATIONS OPTION 2
FLOOD INSURANCE STUDY FILES

LAYER/ LEVEL	COLOR*	LINE CODE**	LINE WEIGHT**	FEATURE	ANNOTATION LAYER/LEVEL	ANNOTATION
				Political area labels	19****	State, County, Community FIPS Code
20	10	0	0	FIRM panel neatline-community based, printed	21****	11-digit FIRM panel number
20	10	0	0	FIRM panel neatline-community based, not printed	21****	11-digit FIRM panel number
20	10	0	0	FIRM panel neatline-county-wide, printed	21****	11-digit FIRM panel number
20	10	0	0	FIRM panel neatline-county-wide, not printed	21****	11-digit FIRM panel number
22	9	0	0	USGS quad neatline	23	
24	11			FIRM panel neatline/USGS neatline		
26	12	2	0	Floodplain boundary		
	0	0	0	Flood area labels-Zone A	25****	A
				Zone AE	25****	AE
				Zone AH	25****	AH
				Zone AO	25****	AO
				Zone A99	25****	A99
				Zone AE(EL__)	25****	AE_EL

FIGURE A7-4

DIGITIZING SPECIFICATIONS OPTION 2
FLOOD INSURANCE STUDY FILES

LAYER/ LEVEL	COLOR*	LINE CODE**	LINE WEIGHT**	FEATURE	ANNOTATION LAYER/LEVEL	ANNOTATION
				Zone D	25****	D
				Zone V	25****	V
				Zone VE	25****	VE
				Zone VE (EL__)	25****	VE_EL
				Zone X or Zone B	25****	X5
				Zone X or Zone C	25****	X
				Floodway	25****	FW
				*** 1983 COBRA area	25****	UCB
				*** 1990 COBRA area	25****	UCB9
				Area Not Included	25****	NI
				Open water area	25****	OPW
				Area outside study limits	25****	OUT
				100-year Flood Contained in Channel	25****	AEC
				500-year Flood Contained in Channel	25****	X5C
				Floodway Contained in Channel	25****	FWC
				***Otherwise	25****	OTH

FIGURE A7-4

DIGITIZING SPECIFICATIONS OPTION 2
FLOOD INSURANCE STUDY FILES

LAYER/ LEVEL	COLOR*	LINE CODE**	LINE WEIGHT**	FEATURE	ANNOTATION LAYER/LEVEL	ANNOTATION
				Protected Area		
32	7	0	0	Apparent limit		
36	8	4	1	Limit of Floodway	37	Limit of Floodway
37	5	4	1	Limit of floodway/Corporate boundary		
38	8	4	1	Limit of Detailed Study	39	Limit of Detailed Study
39	5	4	1	Limit of Detailed Study/Corporate boundary		
40	8	4	3	Limit of Study	41	Limit of Study
41	5	4	3	Limit of Study/Corporate boundary		
42	8	4	5	Coastal barrier area boundary***	43	
44	0	7	1	Cross section	45	Cross section letter
	0	0	0	River mile marker	47	Marker number
48	5	0	1	Base Flood Elevation line	49	Elevation
	7	0	1	Elevation Reference Mark	51	RM_number_EL.DEC
63				Error Indicators		

FIGURE A7-4

DIGITIZING SPECIFICATIONS OPTION 2
BASE MAP FILES

BASE MAP FEATURES	LEVEL	COLOR	LINE CODE	LINE WEIGHT
Primary Roads	1	0	0	0
Secondary Roads	4	2	0	0
Unimproved Roads	5	3	0	0
Railroads	8	0	0	0
Abandoned Railroads	8	2	0	0
Old Railroad Grades	8	3	0	0
Airports	12	2	0	0
Cemeteries	30	2	0	0
Bridges	40	1	0	0
Footbridges	23	1	1	0
Park or Military Reservation Boundaries	45	6	1	0
Range and Township/Section Lines	50	136	0	0
Annotation (Road Names, etc.)	21	0	0	0
Hydrographic Features	22	1	0	6
Contour Lines	55	4	0	0
Spot Elevations	60	0	0	0
Range and Township Labels	51	0	0	0

(3) Option 3

In this option, all lines and areas are coded with attribute codes. Layers/levels and colors are not a concern. The FIS data is structured into 4 separate files (political features, map panel features, hydrographic and miscellaneous line features, and flood hazard zone features). If a feature requires more than one attribute to describe it, the attributes must all be attached to the feature at a single node or label point. This file structure will allow for the ready conversion of digital data to DLG format. However, DLG-3 files are not required for this option. Header files, projection files, etc. which are necessary to convert files to DLG format are not required.

Note the following for Option 3:

* Refer to FEMA's separately published Standards for Digital Flood Insurance Rate Maps for attribute definitions.

** SCs are not responsible for collecting information on COBRAs or Otherwise Protected Areas.

Figure A7-5 outlines the features and attributes required for Option 3.

FIGURE A7-5

DIGITIZING SPECIFICATIONS OPTION 3
FLOOD INSURANCE STUDY FILES

FILE	FEATURE TYPE	FEATURES	ATTRIBUTES*
Political	Area	Community Area	410 0101 410 State# 411 County# 412 Comm#
	Area	Undefined political area	410 0150
	Line	Corporate boundary	410 0200
	Line	County boundary	410 0210
	Line	State boundary	410 0220
	Line	Area not Included boundary	410 0230
	Line	Extraterritorial Jurisdictional Boundary	410 0240
	Line	USGS quad neatline	410 0270
Map	Area	Community based FIRM panel	420 0150 421 FIRM# 422 Suffix 423 State# 424 County#
	Area	Area outside FIRM panels	420 0151
	Area	Community based FIRM panel not printed	420 0152 421 FIRM# 422 Suffix 423 State# 424 County#
	Area	County-wide FIRM panel	420 0153 421 FIRM# 422 Suffix 423 State# 424 County#
	Area	County-wide FIRM panel not printed	420 0154 421 FIRM# 422 Suffix 423 State# 424 County#
	Area	Unmapped Community	420 0155
	Line	FIRM panel neatline	420 0250

FIGURE A7-5

DIGITIZING SPECIFICATIONS OPTION 3
FLOOD INSURANCE STUDY FILES

FILE	FEATURE TYPE	FEATURES	ATTRIBUTES*
	Line	USGS quad neatline	420 0270
Hydrography	Line	USGS quad neatline	430 0250
	Line	Cross section	430 0260 433 Letter
	Line	Drainage from FIRM	430 0270 (Add 430 0044 if drainage is coincident with zone break)
	Line	Drainage from 100K USGS DLGs	430 0271 (Add 430 0044 if drainage is coincident with zone break)
	Line	Drainage from 24K USGS DLGs	430 0272 (Add 430 0044 if drainage is coincident with zone break)
	Line	Drainage from other source	430 0273 (Add 430 0044 if drainage is coincident with zone break)
	Line	Profile base line	430 0281
	Line	Dam or weir	430 0406
	Line	Culvert	430 0418
	Line	Levee or floodwall	430 0435
	Line	Road on Levee	430 0436
	Line	Coastal hard point (pier or jetty)	430 0466
	Point	Elevation Reference Mark	430 0350 435 ERM# 431 Elev. 434 Decimal 430 Units 430 Datum
	Point	River mile marker	430 0351 437 RMM#

FIGURE A7-5

DIGITIZING SPECIFICATIONS OPTION 3
FLOOD INSURANCE STUDY FILES

FILE	FEATURE TYPE	FEATURES	ATTRIBUTES*
Flood	Area	Zone V	440 0150
	Area	Zone VE	440 0151 441 Elev 440 Units 440 Datum
Flood (Continued)	Area	Zone A	440 0152
	Area	Zone AE	440 0153 441 Elev 440 Units 440 Datum
	Area	Zone AO	440 0154 445 Depth 440 Units 440 Datum
	Area	Zone AO Alluvial fan	440 0155 445 Depth 449 Velocity 440 Units 440 Datum
	Area	Zone AH	440 0156 441 Elev. 440 Units 440 Datum
	Area	Zone A99	440 0157
	Area	Zone D	440 0158
	Area	Zone X (500)	440 0160
	Area	Zone X	440 0161
	Area	1983 COBRA**	440 0162
	Area	1990 COBRA**	440 0163
	Area	Otherwise Protected Area**	440 0164
	Area	100-year flood discharge contained in channel	440 0170

FIGURE A7-5

DIGITIZING SPECIFICATIONS OPTION 3
FLOOD INSURANCE STUDY FILES

FILE	FEATURE TYPE	FEATURES	ATTRIBUTES*
	Area	500-year flood discharge contained in channel	440 0171
	Area	Floodway contained in channel	440 0172
Flood (Continued)	Area	Area outside study limits	440 0180
	Area	Area of undesignated flood hazard	440 0191
	Area	Area Not Included	440 0181
	Area	Floodway	440 0710
	Area	Flow easement area	440 0712
	Area	State encroachment area	440 0713
	Line	Apparent Limit	440 0204
	Line	100-year Boundary	440 0245
	Line	500-year Boundary	440 0246
	Line	Zone Break	440 0247
	Line	Zone D Boundary	440 0248
	Line	Floodway Boundary	440 0249
	Line	Flow Easement Boundary	440 0250
	Line	Limit of Detailed Study	440 0251
	Line	Limit of Floodway	440 0252
	Line	Limit of Study	440 0253

FIGURE A7-5

DIGITIZING SPECIFICATIONS OPTION 3
FLOOD INSURANCE STUDY FILES

FILE	FEATURE TYPE	FEATURES	ATTRIBUTES*
	Line	State Encroachment Line	440 0254
	Line	1983 COBRA Boundary**	440 0256
	Line	1990 COBRA Boundary**	440 0257
	Line	Otherwise Protected Area Boundary**	440 0258
	Line	Base Flood Elevation	440 0261 441 Elev. 440 Units 440 Datum
	Line	USGS quad neatline	440 0270

FIGURE A7-5

DIGITIZING SPECIFICATIONS OPTION 3
BASE MAP FILES

FILE	FEATURE TYPE	FEATURE	ATTRIBUTES
Transportation	Line	Primary Road Secondary Road Unimproved Road Railroad Abandoned Railroad Dismantled Railroad	170 0200 170 0205 170 0210 180 0201 180 0201 180 0603 180 0201 180 0604
	General	Bridge Footbridge Parking Area Airport	170 0602 170 0213 170 0215 190 0403
Structures	General	Building Cemetery Levee Dock, Pier, Jetty Tailings	200 0400 200 0420 200 0435 200 0466 200 0163
PLSS	Line	Section Line Range, Township Line Military Reservation Indian Reservation Land Grant	300 0210 300 0211 300 0107 300 0100 300 0103
	Area	Section Number Range, Township Number	301 _ _ _ _ 302 _ _ _ _ (N) 303 _ _ _ _ (S) 304 _ _ _ _ (E) 305 _ _ _ _ (W)
Hydrography	Line	Shoreline Stream Ditch/Canal Wash	050 0200 050 0412 050 0414 050 0420
	General	Falls Gaging Station Dam Lock Spillway	050 0401 050 0403 050 0406 050 0407 050 0408
Topography	Line	Contour Approximate Contour Depression Contour	020 0200 022 _ _ _ _ (elev.) 020 0200 020 0610 022 _ _ _ _ (elev.) 020 0200 020 0611 022 _ _ _ _ (elev.)
	Point	Spot Elevation	020 0300 022 _ _ _ _ (elev.)

E. Digitizing

If the digital graphics FIS file is generated using digital photogrammetric methods, or other automated techniques, data conversion is normally minimal. Data must be collected within the schema (specifications) guidelines (Figures A7-3, A7-4, A7-5). If however, the map compilation is completed manually, digitizing operations will have to be performed to create the digital file. Digitizing should be performed from stable base materials.

During this conversion process, the layer/level, color, or attributes will be established for each feature. While this is a relatively straightforward in-process procedure, there will be many coincident features that must superimpose, vertex (shape point) for vertex within the files. One of several methods that can be used to achieve this condition involves digitizing the feature and then copying it to all other layers where it is coincident. However, for digitizing Options 1 and 3, the preferred symbology for coincident features is a single linear element that represents multiple features. Separate layers/levels have been designated for these coincident features in the digitizing specifications. For high volume work it may be beneficial to use specially written commands to perform repetitive operations with minimal operator interaction.

F. Data Structure

Another essential characteristic of digital graphics files is the data structure itself. The SC must meet the following conditions. Public domain software may be available from FEMA to assist in topologically structuring the digital files.

- Vectors may not cross other vectors within the same theme; all intersecting vectors must meet at single point intersections. This applies to thematic flood hazard data only, not to base map files.

- Files must be free of discontinuities such as overlapping lines, gaps, "turnbacks," dangling lines and duplicate elements. This also applies only to thematic flood hazard data, not to base map files.

- Digitized linework must be collected at a reasonably fine line weight. ONLY SIMPLE LINESTRINGS OR SIMPLE LINEAR ELEMENTS MAY BE USED FOR ALL LINEWORK. NO ARCS, CIRCLES, SPLINES or elements complexed with any of these types of elements may be included.

- Graphics files should not contain any linear or area patterns.

G. Edge Matching

Files may be delivered as seamless units or may be divided into areas that coincide with USGS 7.5' topographic quadrangles or quarters thereof. If the data is structured to 7.5' cells, all detail must tie exactly at the cell area neatlines. Vectors that cross a cell neatline must be divided at the neatline and contain a vertex coincident with the neatline for each vector segment.

H. Horizontal Datum

All digitized data must reside in a file which was created on and contains either the approved State Plane grid or the Universal Transverse Mercator grid. The plotted spacing of the grid lines should be sufficient to clearly define the grid (200 feet, 500 feet, etc.), and each line must be correctly labeled. The horizontal production datum may be either NAD 27 or NAD 83, but not mixed within a single study.

I. Vertical Datum

The vertical datum may be either NGVD 29 or NAVD 88, but not mixed within a single study. It is recommended that all new studies be referenced to NAVD 88. The SC must coordinate with FEMA prior to beginning any survey work to determine whether to use NAVD 88. See Appendix 6 of this document for further guidance on the use of NAVD 88.

A7-5 QUALITY CONTROL

As specified in the previous sections, it is important that the digital files are structured to one of the pre-established schemas. This allows future work on the files to be done using automated procedures. It is also important that the files are clean of unnecessarily duplicated elements and contain no complex linestrings. The data must be horizontally controlled and referenced to the appropriate vertical datum. All digitizing must be done carefully and in conformance with accuracy standards. A thorough quality control review should be performed by the SC prior to submitting data to FEMA. FEMA will review the data provided by the SC using both automated and interactive techniques.

The following items should be reviewed on a mylar verification plot to ensure that all deliverables meet minimum quality standards.

- All required features have been included.
- An acceptable and correct control grid exists and is labeled.
- The correct datum has been used and is clearly indicated.
- All digitized linework is within .005" of its compiled location if digitizing is performed from a hard copy manuscript. Plotted linework should not show gaps between plotted lines and compiled lines when plots and compilation manuscripts are overlaid.

- Character of features has been maintained. (Straight lines are straight; curves are curved, etc.)
- No obvious discontinuities exist. (gaps, overshoots, etc).
- Required labels (text) have been placed.
- All plotted data agree with engineering analyses (floodway widths, etc) and cross section labeling agrees with HEC 2 or other appropriate computer model.
- Deliverable plots meet requirements specified in paragraph A7-6.
- Feature attributes are correct.

✐ Pseudo-nodes or shape points have been kept to the minimum required to maintain the correct character of the features.

A7-6 DELIVERABLES

After completion of an internal quality review process, the SC materials will be submitted to FEMA in Technical Study Data Notebook (TSDN) format. All deliverables required by these Guidelines apply to digital submissions. Hard copies are required for profiles and work maps, and checkplots are also required if digitizing was performed from hardcopy source maps. Digital Elevation Models (DEMs) or Digital Terrain Models (DTMs), if used by the SC, should be submitted as part of the TSDN.

Deliverable work maps should include all base map and contour data. They may show floodplain boundaries plotted manually or digitally. If the boundaries were plotted manually, it is assumed that this manuscript was used for digitizing. In this case, digitally generated checkplots must also be supplied. These checkplots will at a minimum depict the road network and the FIS data. Contours may be plotted if available digitally and if they will not render the other data illegible.

If the work maps are digitally produced (i.e. if the data are generated using a photogrammetric stereo plotter interfaced to a digital system or by other automated methods) the work maps will be the checkplots. In this case, only one set of plots is required. These plots should show the road network, topography, and FIS data.

Graphic symbolization must be compatible with the scale at which the FIRMs will be published. Text size should be approximately 10 pt or its equivalent at plotted scale. FEMA's DFIRM specifications must be followed for all graphic elements such as route shields, cross-section hexagons, etc. Digital libraries, sometimes called "cell libraries" may be available from FEMA to assist the SC in this effort.

A. Digital Files

1. Data Format

There is a wide variety of media and format selections that can be used to transfer digital map data from the SC to FEMA. Since digital map files are usually quite large in size, transmittal of data on tape is preferred over floppy disks.

The following formats are acceptable for data submission:

(a) Transfer Medium

9 track tape rated at 6250 BPI, written at 1600 BPI
*8mm tape written at 2.7 gigabytes or 5.0 gigabytes
4mm DAT tape
1/4" cartridge tape 150 Mb
1/4" cartridge tape 60 Mb
3 1/2" diskette, DOS or UNIX
5 1/4" diskette, DOS or UNIX

(b) Tape writing format

*Tar

CPIO
SCPIO
VMS Backup
VMS Copy
Ansitape

(c) Format for Diskettes

CPIO
Tar
to_flop
dd
DOS backup

Please provide the utility to uncompress the files, if a file compression utility was used.

Specify single or double sided, high or low density

*(Preferred Transfer Format)

2. File Naming Recommendations

A maximum of 8 characters is recommended for all file names. In addition, the file name should reflect the contents of the file.

3. Data Identification Requirements

All tapes or diskettes submitted must be labeled with at least the following information:

- SC name
- Community name and state for which the FIS was prepared
- Date tape was made
- Tape writing format and command syntax used
- Density
- Tape contents (a brief description of contents)

A listing of all file names and file sizes on the tape or diskettes must also accompany the submission, as part of the Digital Data Submission Checklist (Figure A7-1). A comprehensive list of the level or attribute structure of all base map files must also be submitted.

B. Hard Copy Plots

Hard copy plots generated from the digital files, must be submitted by the SC. Because of the substantial number of features that could be plotted, it is not reasonable to specify a unique plotting color for each feature. However, in order to establish some uniformity, certain basic categories of features should be plotted in specific colors as follows:

- Political boundaries-Black
- Cross sections-Black
- BFEs-Green
- Floodplain and floodway boundary information-Red
- Hydrography-Blue

Sound judgement must be used when assigning colors to other features to eliminate the possibility of any confusion. If color plots cannot be produced, sample black and white plots must be submitted for prior approval.

The plotting device itself may be a vector pen plotter, an electrostatic plotter, a laser plotter, or an ink jet plotter. Color plots are preferred, but black and white plots may be accepted with prior coordination. The resolution of the plotting device must be at least 400 dots per inch (or equivalent). All linework must be reasonably fine. Lines shall have line codes assigned to further distinguish features, (such as 100-year floodplain boundary vs. the 500-year floodplain boundary). These line codes shall correspond to those specified in Chapter 9 of these Guidelines. Most standard graphics packages contain universal symbols and dashing patterns for linework that allow for distinctions to be made between different features. A legend should be developed and included in the bottom margin of the hardcopy checkplot to explain the symbology. In addition, the plot must contain the control grid, clearly labeled at all four corners.

Information required in the bottom margin area of each plot includes the following:

- Six-digit Community Identification number.
- Community Name (Include State/territory)
- Date of compilation (month and year)
- Horizontal datum
- Vertical datum
- Control grid (UTM or State Plane)
- North arrow
- Scale
- FIRM panels affected
- Study Contractor's name

C. Index

One supplemental requirement to be prepared and provided by the SC is an index, keyed to a small scale map (normally the Community Index) which identifies the locations of the studies themselves. This product may be a blueline copy highlighted using colored pencils.

D. Metadata File

In order to meet the requirements of the Federally mandated Spatial Data Transfer Standard (SDTS) for the transfer of data files between users, a Metadata File shall accompany all digital submissions.

This file shall include a description of the source material from which the data were derived and the methods of derivation, including all transformations involved in producing the final digital files. The description shall include the dates of the source material and the dates of ancillary information used for update. The date assigned to a source shall reflect the date that the information corresponds to the ground; however, if this date is not known, then a date of publication may be used, if declared as such.

Any data base created by merging information obtained from distinct sources shall be described in sufficient detail to identify the actual source for each element in the file.

The file shall describe the mathematical transformations of coordinates used in each step from the source material to the final product. The locations of any registrations points for coordinate transformations shall be given. The methods used to make coordinate transformations shall be documented. To fulfill this standard, it is acceptable to make reference to separate documentation for the coordinate transformation algorithm used, but the specific parameters applied shall be described for the particular case. Documentation of a transformation algorithm shall include the nature of computational steps taken to avoid loss of digits through roundoff and shall include a set of sample computations including numerical values of coefficients to confirm equivalence of transformations. The documentation of a transformation algorithm shall be available on request by a user obtaining digital data even if that user is not licensed to use the particular software.

The Metadata File should be submitted as a read.me file. Figure A7-2 outlines the format the file should take.

References

Federal Emergency Management Agency,
Standards for Digital Flood Insurance Rate Maps, October 1993.

Federal Emergency Management Agency,
Converting the National Flood Insurance Program to the North American Vertical Datum of 1988, June 1992.

U.S. Department of the Interior, Geological Survey,
Spatial Data Transfer Standard, December 1990.

Federal Geographic Data Committee,
Content Standards for Digital Geospatial Metadata, June 8, 1994.

U.S. Department of the Interior, U.S. Geological Survey,
Standards for Digital Line Graphs, May 1994.

GLOSSARY OF TERMS
FOR
DIGITAL FLOOD MAPPING

Accuracy - In mapping, conforming with real measurement. Degree of correctness attained in a measurement.

Alphanumeric - Consisting of both letters and numbers, and possibly symbols such as punctuation marks.

ASCII - American Standard Code for Information Interchange - A popular standard for the exchange of alphanumeric data.

ARC/INFO - An Environmental Systems Research Institute (ESRI) software package that provides a menu and key-in operator interface with commands for generating, editing, and analyzing graphics and data. It is vector geo-relational software.

Area - A level of spatial measurement referring to a two-dimensional defined space.

Area Not Included (ANI) - A political entity, such as an incorporated community, that is excluded from a given Flood Insurance Study (FIS). Major roads and drainage may be shown if the feature continues through the ANI back into the mapped community, but generally the ANI is unmapped.

Artwork - The various layers prepared by cartographic staff which are the components of the FIRM and/or Flood Boundary and Floodway Map (FBFM).

Attribute - Descriptive characteristic or quality of a feature. An attribute value is a measurement assigned to an attribute for a feature instance.

Batch Processing - System by which the computer processes, without operator intervention, all input for an application at one time to produce the desired output, even though input data might have been collected periodically.

Base Map - Map of the community that depicts cultural features (roads, railroad, bridges, dams, and culverts, etc.), drainage features and the corporate limits.

Bit - Abbreviation for binary digit; number that can take only values of 0 or 1.

Block - A group of bytes treated as one unit of information, sometimes called a physical record.

Buffer Zone - An area of specified distance (radius) around a map item or items.
Byte - A group of bits that can be stored and retrieved as a unit.

CAD/CAM - Computer aided design/computer aided manufacturing. Differs from a Geographic Information System in that the system can only create displays. It cannot analyze or process the base data.

Cell - A defined geometric shape that stores data or defines an area that is labeled. The most common mapping cell is a square. Also the basic element of spatial information in raster data structures.

Central Processing Unit - The portion of the computer that controls the hardware (screen, printer, disks, etc.) and completes tasks assigned by a program.

Centroid - A point interior to a polygon whose coordinates are the averages of the corresponding coordinates for all points included in the polygon.

Choropleth map - Map with shaded or hatched areas.
Choro = place and pleth = value.

Computer-Aided Drafting and Design (CADD) - Software with the capability of assisting the operator to perform standard engineering and architecture design functions.

Control Point - Any station in a horizontal or vertical control network that is identified in a data set of photograph and used for correlating the data shown in the data set or photograph.

Coordinate Geometry (COGO) - Use of bearings and distances, azimuths and coordinate locations to enter and describe graphic data. Usually used for civil engineering and survey applications.

Coordinate Pair - Set of cartesian coordinates describing the location of a point, line or area (polygon) feature in relation to the common coordinate system of the data base.

Coordinate System - A particular kind of reference frame or system, such as plane rectangular coordinates or spherical coordinates, which use linear or angular quantities to designate the position of points within that particular reference frame or system, i.e. State Plane, UTM.

Data Base - A collection of information related by a common fact or purpose.

Data Base Management System (DBMS) - A systematic approach to maintaining, accessing, and manipulating data base files. A DBMS may consist of a single program or a collection of task-specific programs.

Data Capture - Series of operations required to encode data in a computer-readable form (digitizing).

Data Layer - Refers to data having similar characteristics being contained in the same plane or overlay (e.g., roads, rivers). Usually information contained in a data layer is related and is designed to be used with other layers.

Data Set or Data File - A named collection of logically related data records arranged in a prescribed manner. The physical set of data of one data type being referred to or being used in the context of a data processing operation.

Digital data - Data displayed, recorded, or stored in binary notation.

Digital Elevation Model (DEM) - A file with terrain elevations recorded for the intersection of a fine-grained grid and organized by quadrangle as the digital equivalent of the elevation data on a topographic base map.

Digital Flood Insurance Rate Map - (DFIRM) - The Digital Flood Insurance Rate Map (DFIRM) is comprised of all digital data required to create the hardcopy FIRM. This includes base map information, graphics, text, shading, and other geographic and graphic data required to create the final hardcopy FIRM product to FEMA standards and specifications. This product will normally be held by the TEC in the format of the TEC GIS or CAD system. These data serve the purposes of map design and provide the database from which the Digital Line Graph thematic product of the flood risks can be extracted to create the DFIRM-DLG. These products are generally produced in a county-wide format. DFIRMs are subjected to community review and approval and are, therefore, the official basis for implementing the regulations and requirements of the NFIP within the community.

Digital Flood Insurance Rate Map -DLG (DFIRM - DLG) - This product is created by extracting the flood risk thematic data from the DFIRM. The format of this product is the U.S. Geological Survey Digital Line Graph Level 3 Optional format, as described in the FEMA specifications for digital FIRMs. The DFIRM-DLG does not include base map information, nor does it include graphic data required to create a hardcopy FIRM. This product is intended to be the primary means of transferring flood risk data depicted by FIRMs to GISs through a public domain data exchange format. The DFIRM-DLG's are tiled the to U.S. Geological Survey 1:24,000 scale topographic map series.

Digital Line Graph (DLG) - A computer file format for mapping data that provides a topological structure to describe points, lines and polygons. The U.S. Geological Survey Digital Line Graph Level 3 Optional format has been adopted by FEMA for the purposes of the National Flood Insurance Program mapping and engineer requirements. A DLG may contain lists of point coordinates describing boundaries, drainage lines, transportation routes and other linear features, which are organized by USGS quadrangle areas. These data are the digital equivalent of the linear hydrographic and cultural data on a topographic base map. The flood risk thematic layers developed by FEMA layers will fit the quadrangle as an overlay.

Digitizing - A process of converting an analog image or map into a digital format usable by a computer.

Digital Line Graph Level 3 (DLG3) - Level 3 data files are fully topologically structured and are designed to be integrated into GISs.

Digital Terrain Model (DTM) - A land surface represented in digital form by an elevation grid or lists of three-dimensional coordinates.

Drawing exchange file (DXF) - A commonly used format for the exchange of graphic data.

Edge Matching - The comparison and graphic adjustment of features to obtain agreement along the edges of adjoining map sheets.

Export - Process of transferring digital data or software from one system to another system.

FIRM-DLG - The FIRM-DLG is a product developed by digitizing and/or scanning the existing hardcopy FIRM to create a thematic overlay of flood risks. These products differ from the DFIRM as they are not tied to a base map, not used to produce a new version of the hardcopy FIRM, and are not subjected to community review. FIRM-DLGs are intended to faithfully duplicate the existing hardcopy FIRM and provide users with automated flood risk data that is comparable to that they would derive from the hardcopy FIRM. To this end, edge-matching errors, overlaps and underlaps in coverage, and similar problems are not corrected during digitizing or scanning as they are during the DFIRM-DLG production.

Flood Risk Directory (FRID) - Tabular data base product that identifies flood risks by street address ranges within a community.

FloodView - Software developed by Terralogics, Inc. to display the flood zones of the NFIP communities. FloodView is the software used on the NFIP prototype CD-ROM.

Frame - Refers to the size of a FIRM or FBFM panel as follows: "A" (28"x21"); "B" (28"x24"); "C" (28"x28"); "D" (28"x32"); "E" (28"x40").

Geographic Information System (GIS) - System of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems.

Geocoding - Associating either geographic coordinates or grid cell identifiers to data, points, lines, and shapes.

Georeference System - An X,Y or X,Y,Z coordinate system that locates points on the surface of the earth as a reference to points on a map.

Geo-relational - Geometry of the spatial data. Housed separately from its attributes.

GRASS - Geographic Resources Analysis and Support System, GIS software developed by U.S. Army Corps of Engineers, used by several federal agencies.

Grid - 1) A network of uniformly spaced horizontal and perpendicular lines that enclose an area with an associated value assigned. 2) A defined aggregate spatial object.

Horizontal Control - Network of stations of known geographic or grid positions referred to a common horizontal datum, which control the horizontal positions of mapped features with respect to parallels and meridians, or northing and easting grid lines shown on the map.

Import - Process of bringing data or software into a dissimilar system.

Initialize - To set program variables to their starting values, commonly zero, at the beginning of a program.

Island - A closed two-dimensional figure. In a GIS, an island is a unit of land cover lying completely within another land-cover unit.

Kilobyte - A unit of memory representing 1,024 bytes and often designated with the symbol K, as 4Kb or 4 kilobytes. The symbol K is also used to refer to 1,024 words of any specified size.

Layer - Refers to the various "overlays" of data, each of which normally deals with one thematic topic. These overlays are registered to each other by the common coordinate system of the database. In GIS, a layer or a theme represent a specific kind of data.

Line - A level of spatial measurement referring to a one-dimensional defined object having a length, direction, and connecting at least two points.

Macro - A series of instructions combined to be executed with a single command.

Menu- A list of options on a screen display or pallet allowing an operator to select the next operations by indicating one or more choices with a pointing device.

Merge - To combine items from two or more similarly ordered sets into one set that is arranged in the same order. In a GIS, to splice separate but adjacent mapped areas into a single data set.

Microstation - An Intergraph software package that provides a menu and key-in operator interface with commands for generating and editing graphics and data.

Modem (MOdulator DEModulator) - A translating device that links a terminal to a telecommunication network. An acoustic coupler is a modem that permits a terminal to communicate through the handset of a standard telephone instrument.

Network Analysis - Analytical technique concerned with the relationships between locations on a network such as the calculation of optimal routes through road networks, capacities of network systems, best location for facilities along networks, etc.

Node - A point at which two or more lines meet; called an edge or vertex in graph theory.

Operating System - The master control program that governs the operation of a computer system, running job entry, input/output services, data management, and supervision or housekeeping.

Planimetric Map - Map representing only horizontal positions from features represented; distinguished from a topographic map by the omission of relief in measurable form. A planimetrically accurate map shows accurate horizontal distances between features.

Pixel - Short for "picture element". The smallest discrete element which makes up an image.

Point - A level of spatial measurement referring to an object that has no dimension.

Point Data - In a vector structure, data consisting of single, distinct X,Y coordinate. In a raster structure, point data is represented by single cells.
Polygon - A two-dimensional figure with three or more sides intersecting at a like number of points. In Geographic Information Systems, an area.

Pre-digital preparation - Includes latitude/longitude horizontal control points on mylars, tied with USGS quads.

Quad (also USGS Quad) - A U.S. Geological Survey (USGS) topographic map; Quad stands for "Quadrangle."

Quality Assurance/Quality Control, (QA/QC) - Intermediate and final review of the FIS and FIRM performed to ensure compliance with FEMA standards.

Raster - The pattern of horizontal, parallel scan lines comprising the image on a CRT screen, on which each scan line consists of segments varying in intensity.

Raster Data - Raster data thus refers to data in the form of parallel scan line segments, grid cells, or pixels.

Read Only Memory (ROM) - A microcircuit containing programs or data that cannot be erased. When new data or programs can replace old ones, the microcircuit is called an EROM, for erasable read only memory, or PROM, for programmable read only memory.

Record - A groups of items in a file treated as a unit. For example, all data items for a census tract can be grouped as a record and assigned to a single segment of a magnetic tape, or other media file for convenient storage and retrieval.

Scale - A representative fraction of a paper map distance to ground distance. Example: 1:12,000 is the representative fraction in which one unit of measure on the map is equal to 12,000 of the same units of measure on the ground. FEMA map scales are expressed in a ratio of 1" of map distance equal to a given number of feet on the ground.

Scanner - Any device that systematically decomposes a sensed image or scene into pixels and then records some attribute of each pixel.

Scanning - Process of using an electronic input device to convert analog information such as maps, photographs, overlays, etc., into a digital format usable by a computer.

Standard Interchange Format (SIF) - A commonly used format for the exchange of alphanumeric data.

State Plane Coordinates - A system of X,Y coordinated defined by the USGS for each state. Locations are based on the distance from an origin within each state.

TIF - Technical exchange format for raster or image files.

TIGER --Topologically Integrated Geographic Encoding and Referencing File- The nationwide digital data base of planimetric base map features developed by the U.S. Bureau of the Census for the 1990 Census.

Topology - A branch of geometric mathematics that is concerned with order, continuity, and relative position, rather than actual linear dimensions.

Transformation - Conversion of coordinates between alternative referencing systems.

Triangulated Irregular Network (TIN) - A set of non-overlapping triangles developed from irregularly spaced points. Used to represent the facets of a surface.

UTM Grid - The Universal Transverse Mercator grid, a system of plane coordinates based upon 60 north-south trending zones, each 16 degrees of longitude wide, that circle the globe.

Vector - A directed line segment, with magnitude commonly represented by the coordinates for the pair of end points.

Vector Data - Vector data refers to data in the form of an array with one dimension.

FIGURE C

FLOOD INSURANCE STUDY REPORT DATA CHECKLIST

FLOOD INSURANCE STUDY
NAME OF COMMUNITY, STATE

1.0 INTRODUCTION

1.1 Purpose of Study

Community Name: ___________________
County: __________________
State: __________________

1.2 Authority and Acknowledgments

Study Contractor: _____________
Subcontractor (if applicable): ____________
Inter-Agency Agreement No.: _______________
or Contract No.: ______________
Completion Date (month and year): _______________

Provider/Agency of Base Map & Address: ___________________________
____
Base Map Compilation Source: _____________________________________
Base Map Compilation Scale: _____________________
Base Map Compilation Date: _____________________

Coordinate System: ________________________
Projection: _______________________________
Datum: ____________________________________

Has base map source been modified? ________
If so, how and where? ____

Any restrictions on release of base map data? ____________________
If yes, what restrictions apply? _________________________________

1.3 Coordination

Initial Consultation and Coordination Officer's (CCO) meeting date:

____

List attendees and agencies represented at the initial CCO meeting:

Intermediate CCO meeting data and attendees (if applicable):

List contacts made for purposes of acquiring information:

2.0 AREA STUDIED

2.1 Scope of Study

Note areas excluded from study, as well as areas of extraterritorial jurisdiction:

List the flooding sources studied in detail (detailed study streams should be listed in the same order as they appear in the profiles). If they are also partially studied by approximate methods, provide the limits of detailed study:

List the flooding sources studied by approximate methods:

If applicable, discuss streams on which study was terminated where the 100-year floodplain permanently narrowed to less than 200 feet wide or for which detailed study was ended where the drainage area was less than 1 square mile:

2.2 Community Description

Provide a general description of the community's location within the county and state:

List surrounding communities and their locations with respect to the subject community:

List other nearby large cities and their locations:

Briefly describe the community. This description may include patterns of residential and commercial development; the extent and nature of floodplain development; natural features that affect flood hazards in the community; and sufficient description of climatic, physiographic, and land use factors to support the discussion of flood problems that follows (Section 2.3).

2.3 Principal Flood Problems

Include the discharges and recurrence intervals of major floods:

Give the locations (city and state) of all stream gages for studied streams:

Note any factors that aggravate flood problems:

Provide photos of flooding, flood control structures, etc. (with location of photo noted):

2.4 Flood Protection Measures

Describe all flood protection structures and floodplain management measures used to reduce potential flood damage:

Mention all dams, including those affecting the community that lie outside the community:

Mention dams within the community used for purposes other than flood control:

If levees are mentioned, state whether the levees meet or fail to meet the FEMA 3-foot freeboard requirement.

3.0 <u>ENGINEERING METHODS</u> (Note any digital methodologies used)

3.1 Hydrologic Analyses

Describe the hydrologic analyses for all flooding sources studied in detail:

In a Summary of Discharges table, provide a summary of drainage area-peak discharge relationships for the streams studied by detailed methods. Discharges and drainage areas for each stream should be listed in descending order. Streams should be listed in the same order as flood profiles:

If applicable, discuss methods used to determine stillwater elevations and reference the Summary of Stillwater Elevations table:

3.2 Hydraulic Analyses

State how cross sections were developed for all streams studied by detailed methods:

Describe how the dimensions of hydraulic structures were determined:

Explain how channel roughness factors (Manning's "n") were assigned. The "n" values for ALL streams studied by detailed methods (channel and overbank areas) should be given:

State how water-surface elevations were obtained for all streams studied by detailed methods:

State how starting water-surface elevations were obtained for all streams studied by detailed methods:

Describe the methodology for wave height/runup, lacustrine, ice jam, alluvial fan flooding, and shallow flooding areas (where applicable):

If applicable, reference the Transect Descriptions which should include: transect number, location, 100-year stillwater elevation, and maximum 100-year wave elevation.

If performed, describe the hydraulic analyses for the approximate flooding sources:

If applicable, reference the Transect Data Table which should include: Flooding Source (with the affected transects), 10-, 50-, 100-, and 500-year stillwater elevation, zone designation and Base Flood Elevation.

If applicable, reference the Transect Location Map.

Standard paragraphs in this section include paragraphs for cross sections, NGVD, and unobstructed flow.

Specify whether elevations are referenced to NGVD or NAVD or other datum, and give releveling dates, if any.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

4.1 Floodplain Boundaries

Identify all maps used. Include the scale, contour interval, and type of map (topographic, compiled from aerial photographs, etc.):

Identify and reference all maps or methods used to delineate floodplain boundaries for approximate flooding sources:

4.2 Floodways

List streams, if any, for which floodway widths extend beyond the corporate limits:

List streams affected by backwater:

Provide method used for floodway computations:

Give reason or reasons why no floodway was delineated for streams or portions of streams:

Identify any abnormal procedures (such as state-imposed surcharges of less than 1.0 foot) for floodway delineations:

7.0 OTHER STUDIES

Identify and reference all other FISs for contiguous communities and any other published reports or available data dealing with related flooding sources. All disagreements and discrepancies must be noted and resolved:

9.0 BIBLIOGRAPHY AND REFERENCES

List references with complete information, including date, place of publication, and scale (as applicable):

GLOSSARY OF ACRONYMS

AML	ARC Macro Language
ANI	Area Not Included
ASCII	American Standard Code of Information Interchange
BFE	Base (100-year) Flood Elevation
BM	Bench Mark
CAD	Computer-Assisted Design (or drafting, or drawing)
CADD	Computer-Aided Drafting and Design

CAM	Computer-Assisted Manufacturing
CDROM	Compact Disk Read Only Memory
CCO	Community Consultation and Coordination Officer
COGO	Coordinate Geometry
CPU	Central Processing Unit
DBMS	Data Base Management System
DFIRM	Digital Flood Insurance Rate Map
DGPS	Differential Global Positioning System
DLG	Digital Line Graph
DMRS	Data Management and Retrieval System
DTM	Digital Terrain Model
DXF	Drawing Exchange File
ERM	Elevation Reference Mark
ERP	Elevation Reference Point
ESDP	Engineering Study Data Package
FAAT	Fully Analytical Aerial Triangulation
FBFM	Flood Boundary and Floodway Map
FEMA	Federal Emergency Management Agency
FGCC	Federal Geodetic Coordinating Committee
FGDC	Federal Geographic Data Committee
FHBM	Flood Hazard Boundary Map
FIA	Federal Insurance Administration
FIPS	Federal Information Processing Standards
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FRID	Flood Risk Directory
GIS	Geographic Information System
GPS	Global Positioning System
HEC	Hydrologic Engineering Center
LMMP	Limited Map Maintenance Program
LOMA	Letter of Map Amendment
LOMR	Letter of Map Revision
Mb	Megabyte (10^6)
MODEM	Modular Demulator
NAVD	North American Vertical Datum of 1988
NCSSA	National Cartographic Standards for Spatial Accuracy
NFIP	National Flood Insurance Program
NGRS	National Geodetic Reference System
NGVD	National Geodetic Vertical Datum of 1929
NMAS	National Map Accuracy Standards
PO	Project Officer
QA/QC	Quality Assurance/Quality Control
RAM	Random Access Memory
RDMS	Relational Data Base Management System
RMS	Root Mean Square
SC	Study Contractor
SCS	Soil Conservation Service
SFHA	Special Flood Hazard Area
SDTS	Spacial Data Transfer Specifications
SIF	Standard Interchange Format
SWEL	Stillwater Flood Elevation
TEC	Technical Evaluation Contractor
TIGER	Topologically Integrated Geographic Encoding and Referencing
TSDN	Technical Support Data Notebook
USACE	U.S. Army Corps of Engineers

USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VAX	Virtual Address Extension
VMS	Virtual Memory System
WORM	Write Once Read Many (CD ROM drive)