FLOOD INSURANCE STUDY

FEMA 37

Guidelines and Specifications for Study Contractors

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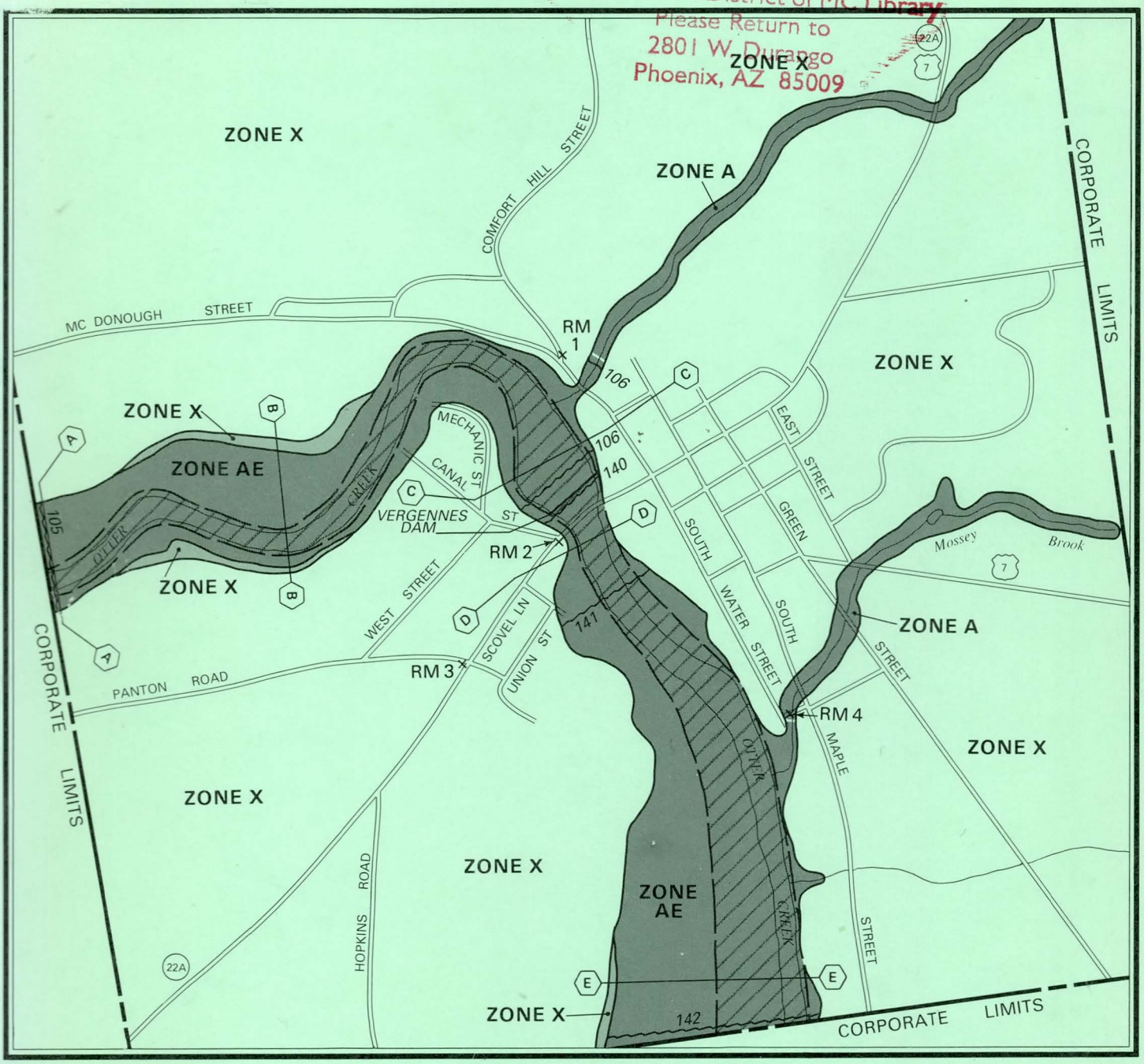

FEDERAL EMERGENCY MANAGEMENT AGENCY
Federal Insurance Administration
March 1991

1304.009

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 Insurance Administration since the Guidelines were last issued in September 1985. In summary, the major changes are as follows:

- An expanded discussion on the requirements for preparation of the draft Flood Insurance Study (FIS) in the Map Initiatives format.
- An expanded discussion on the requirements for restudies and revisions.
- Clarification of the cumulative encroachment issue for restudies and guidance on preventing excessive cumulative encroachment.
- Inclusion of a comprehensive discussion of Study Contractor (SC) responsibilities for evaluating existing approximate floodplain delineations.
- Expansion on modeling and mapping methods for alluvial fans and guidance for flood control structures in these areas.
- Inclusion of the requirement for Regional PO approval of SC-developed discharges prior to the commencement of hydraulic computations.
- Inclusion of specific instructions regarding SC coordination with the community, Regional office, and Technical Evaluation Contractor (TEC), to assure that the most current information is obtained and incorporated into the FIS.
- Incorporation of updated requirements concerning the recognition of levees.
- Minor changes in the format of deliverable items (i.e., standard mylar profile panels, appropriate map scale, etc.) in an effort to reduce TEC costs.
- Inclusion of requirements concerning the submission of digital FIS mapping.
- Inclusion of requirements concerning the submission of materials for the Engineering Study Data Package (ESDP).

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

GLOSSARY OF ACRONYMS

ANI	Area Not Included
BFE	Base (100-year) Flood Elevation
CCO	Community Consultation and Coordination Officer
COE	U.S. Army Corps of Engineers
DLG	Digital Line Graph
ERM	Elevation Reference Mark
ESDP	Engineering Study Data Package
FBFM	Flood Boundary and Floodway Map
FEMA	Federal Emergency Management Agency
FHBM	Flood Hazard Boundary Map
FIA	Federal Insurance Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
HEC	Hydrologic Engineering Center
LMMP	Limited Map Maintenance Program
LOMA	Letter of Map Amendment
LOMR	Letter of Map Revision
NAVD	North American Vertical Datum
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
PO	Project Officer
SC	Study Contractor
SCS	Soil Conservation Service
SFHA	Special Flood Hazard Area
SDTS	Spacial Data Transfer Specifications
SWEL	Stillwater Flood Elevation
TEC	Technical Evaluation Contractor
TSDN	Technical Support Data Notebook
USGS	United States Geological Survey

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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 Insurance Administration (FIA) 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. In addition, certain landmark features in the community may be shown on the FIRM to assist in locating individual properties.

These Guidelines have been restructured 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 and B have been superseded by Zones AE and X, respectively. The SC should determine all appropriate zones as outlined in Chapter 8 of these Guidelines.

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 an FIS restudy or revision unless otherwise specified in the contract.

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. 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.

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, FIA 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 12 months 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.

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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 and 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 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.

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, and topographic information.

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?

- 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?

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, through contact with local, State, and Federal agencies, and contractors conducting studies of adjacent areas; and field reconnaissance of the study area. This information may consist of revisions to a community's FIS, FIRM, and/or FBFM that are not widely published such as Letters of Map Revision (LOMRs). The Regional PO should 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. 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. 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, 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.

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[1] 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 and detailed topographic maps 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.

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

2. Obtain Cross Sections

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 trigonometric or differential leveling using transit-stadia or transit-electronic distance measurements, 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 cross the entire 100-year floodplain. 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. Obtain Physical Dimensions of Hydraulic Structures

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 not be established by aerial photogrammetric methods.

E. Coordination

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.

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 recurrence interval 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. 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 is current before proceeding.

Where large amounts of floodplain storage exist and are capable of significantly attenuating peak flows within the community, but are not reflected by gage records, this attenuation shall be considered by the use of standard flood routing techniques. The use of these procedures shall be cleared with the Regional PO.

Storage capability, below the spillway 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 according to plan will 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.

- A project operating 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 for flood-control purposes. The FEMA 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 operating 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.

At a minimum, the SC should consider gaged versus ungaged streams and the appropriateness of developing a rainfall-runoff model. Each of these approaches are briefly discussed below.

Gaged Streams: 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 the best discharge estimates for the site under consideration. The methodology outlined in the U.S. Army Corps of Engineers "Hydrologic Frequency Analysis" (Reference 2), can also be used to address transfer and changed gage conditions.

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.

Ungaged Streams: 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 Flood Characteristics of Urban Watersheds in the United States (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.

Rainfall-Runoff Modeling: 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. Subbasin drainage area should not be greater than three square miles.

- 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 before determining different discharge frequencies. Computed peak discharges from the hydrologic model should be comparable with the discharges from published 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.

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; (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 hydrologic 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. There will be two phases in performing the hydrologic analysis: preliminary and detailed analyses.

Preliminary Hydrologic Analysis

The preliminary hydrologic analysis would 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 it was calibrated to a known storm. 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 reported to the PO immediately.

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. 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.

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. A significant discontinuity may be determined through a comparison of the 500-year discharge in the effective FIS and the updated 100-year flood discharge. If the two discharges appear to be comparable, then the Regional PO should be consulted.

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) and the U.S. Geological Survey/Federal Highway Administration WSPRO computer model (References 9 and 10) 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.

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 established by the communities in consultation with the Regional office as unobstructed waterways to convey floodwaters. 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.

Normally, the floodway shall be determined using equal loss of conveyance on opposite sides of the stream. If equal loss 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 loss 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.

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 as early as possible. Where the floodplain is entirely contained within one community, the location of the floodway is negotiable and should be coordinated with the State Coordinating Agency, the community, and the CCO. This negotiation 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.

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.

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. 2-D computer models cannot be used for alluvial fan flooding areas.

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).

2. 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.

3. 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.

4. 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.

CHAPTER 6. APPROXIMATE FLOODPLAIN BOUNDARY DELINEATIONS AND SIMPLIFIED METHODS

Approximate study streams being restudied, or unstudied streams to be analyzed by approximate methods, will fall into the following four categories:

1. Flooding sources that will have previously determined 100-year floodplain boundaries adjusted based on updated topographic information.

2. Flooding sources that have new technical information available that can be used in developing approximate 100-year floodplain boundaries.

3. Flooding sources previously unstudied or whose previous 100-year floodplain boundaries are unreasonable from an engineering standpoint; approximate 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 the SC should <u>not</u> question methods used for sources with BFEs and recommend the use of approximate A zones. This category is subject to Regional PO approval.

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, development potential, and existing development should be weighed together when determining the methods to be used. Also, 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).

  - Hand calculated volume/discharge/stage and routing relationships for ponding areas or reservoirs.

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 necessary Manning's "n" values 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 analyze 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 FIA. 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. FIA 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, FIA 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 maintenance 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 an assessment of the degree of confidence associated with the hydrologic and hydraulic analyses.

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. Once again, 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 100-year flood levels on the river side of the levee will be considered to be equal to the top of the levee. The 100-year flood elevations will then be recomputed for the landward side of the unrecognized levee as if the levee did not exist.

If the other frequencies of floods 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.

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.

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. 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 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.

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.

2. Work Maps

The work map is to 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. A sample work map is provided as Figure A. The proper symbology to be used on the work map is illustrated in Figure B. Under certain conditions defined later in this chapter, this map may be submitted in digital form. As indicated in this chapter, the compiled work map (original copy) is 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 (see Figure A).

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'

For panels within unincorporated areas containing flood hazard data determined by approximate methods, a scale of 1"=2,000' may be satisfactory. Please note that when a topographic base map exceeds a 1"=400' map scale (example 1"=200'), the topographic base map should be photo-reduced to a 1"=400' or 1"=500' scale before the floodplain boundaries and flood hazard data are plotted on it.

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).

- 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 county and its 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.

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

The work map may contain, but is not required to show, building outlines, spot elevations, property lines, grid 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 subject community because it is mapped separately on another community's FIRM, or because access to the area is limited due to security reasons such as a military installation or Indian Reservation. 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.

- Flood Boundaries and Floodways

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.

- Cross Sections

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.

Distances between cross sections, as measured along the stream channel or hydraulic base line, must agree 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.

- Base Flood Elevations (BFEs)

BFEs represent 100-year flood elevations and are shown by wavy line contours drawn normal to the direction of the flow of floodwater; 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.

- <u>Elevation Reference Marks (ERMs)</u>

  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.

- <u>Map Index</u>

  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.

- <u>Restudied Areas</u>

  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

Digital work map submissions should be considered by the SC only when their production costs are less than those associated with drafted products (e.g., where the work map base is already available in digital format). Digital work map submissions may only be made with Regional PO approval.

General Guidelines - A digital FIS submittal will be comprised of two categories: base maps and floodplain delineations. Base map and flood hazard data will meet U.S. National Map Accuracy Standards for maps at a publication scale of 1:24,000. SC's will be responsible for assuring that this standard is adhered to. All information will be compiled on the North American Datum (NAD) 1983 and Clarke 1966 spheroid.

- Horizontal Accuracy - Not more than 10 percent of the points shall be in error by more than 1/30 inch, measured in the publication scale of 1:24,000.

- Vertical Accuracy - Not more than 10 percent of the elevations shall be in error more than one-half the contour interval. Map projections and coordinate systems must be compatible with those used by the USGS Publication 1395 (Reference 13).

- Deliverables - USGS DLG files, or format agreed upon in advance with FEMA Regional PO must be submitted on nine track magnetic tape, 1600 BPI format. File size will not exceed 2,500 blocks (a group of bytes treated as one unit of information).

  In addition to the magnetic tapes, the SC will provide hard copy electrostatic plots (minimum of 200 dots per inch) of the combined base map and thematic map data at a scale of 1"=400'.

  Digitizing will be accomplished in such a manner as to collect centerline information for roads and rails. Streams, open water features and other linear features will be digitized in their true positions as line strings.

- Data Format - Base map information requirements are described in Section A 1 of this chapter.

The USGS DLG format and attribute standards specified herein may be deviated from based on FEMA Regional PO approval. These requests should be made well in advance of data submission. This requirement for DLG format data may be superseded in the future by the adoption of a Spatial Data Transfer Specification (SDTS) as a Federal Information Processing Standard.

B. Flood Profiles

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 B and C.

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.

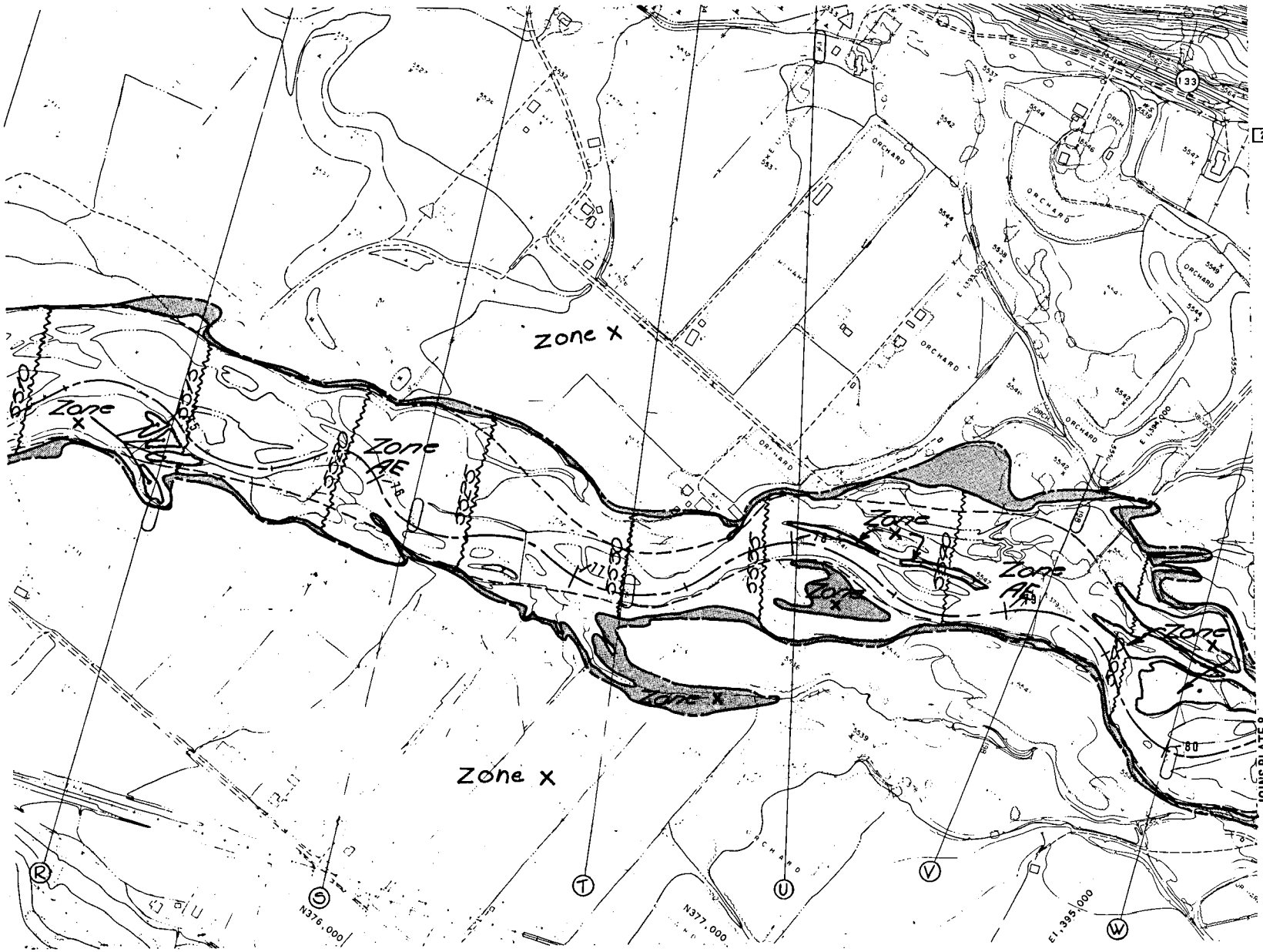
C. Preparation of the Flood Insurance Study Report Data

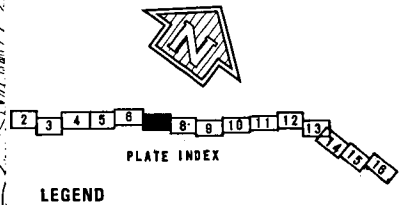
Preface

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 D). 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.





LEGEND

- 100-Year Flood Limits
- 500-Year Flood Limits
- Floodway Limits
- 73 — Distance in thousands of feet upstream from confluence with Gunnison River.
- (P) — Cross Section
- (133) — State Highway

NOTES

Map based on 1" = 200' topographic mapping prepared by Delta Aerial Survey Inc. from photographs taken in June 1975. Minor additions and adjustments made by the Corps of Engineers.

Elevations based on National Geodetic Vertical Datum of 1929.

SCALE IN FEET

250 0 250 500 750

CONTOUR INTERVAL 5 FEET

FLOOD INSURANCE STUDY WORK MAP

DELTA COUNTY, COLORADO

FIGURE A **SAMPLE WORK MAP**

WORK MAP BASE

Corporate Limits or ETJ Boundary	Corporate Limits
County, Parish, State or International Boundary	County Boundary
Excluded Areas	(Name) Area Not Included

WORK MAP

100-Year Floodplain Boundary	
500-Year Floodplain Boundary	
Floodway Boundary	
Approximate (100-Year) Floodplain Boundary	
Hydraulic Base Line	75 76
Cross Section	A A
Elevation Reference Mark	RM7 X
River Mile	• M 1.5
Zone Gutters	
Base Flood Elevations	580
Base Flood Elevation/or Depth (Uniform)	(EL 15)/(DEPTH 2')
Zone Designations	**ZONE AE**

FIGURE B **WORK MAP SYMBOLS**

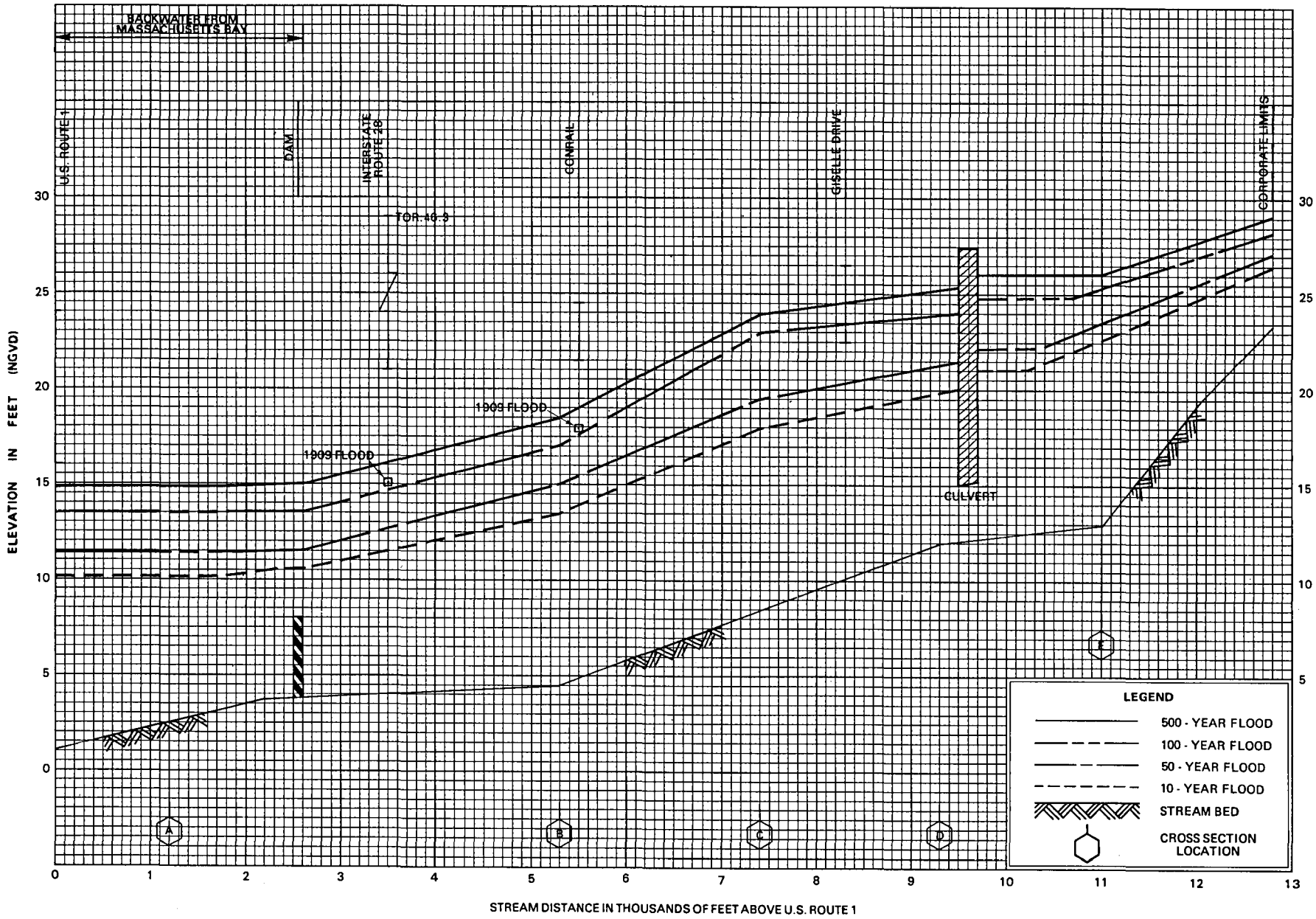


FIGURE C SAMPLE PLOTTED WATER-SURFACE PROFILE

FLOOD PROFILES

MILL RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF FLOODPORT, MA

(FLOOD CO.)

01P

FIGURE D

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): _____

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 ENGINEERING METHODS

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):

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, and d) methodology application 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.

  Document all procedures necessitated by unusual conditions, citing references and presenting calculations and associated area. 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.

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 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

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, tables, and certification statement of work accomplished.

   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 <u>any</u> 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 (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.

A. <u>Technical Support Data Notebook - Engineering Study Data Package</u>

These <u>Guidelines</u> 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, and 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) and associated technical support data (e.g., hydrologic and hydraulic analyses, survey data, general correspondence, documentation, and mapping information).

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. Data Organization

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 four subcategories: Special Problems Reports, Contact (Telephone Conversation) Reports, Meeting Minutes, and General Correspondence.

(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, certified statement of work, 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 shall be listed, organized, and stored under this category.

The SC shall prepare and complete the "Mapping Information Index" sheet(s). 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.

(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 Products - 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 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) <u>FIS Report Data (Draft FIS Report Text)</u> - 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

- date map was prepared and/or published (day, month, year)

- map scale

- name of SC

- name(s) of applicable flooding source(s) covered

- 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) 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. <u>Data Submission</u>

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 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, "Hydrologic Frequency Analysis," April 1975.

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, "National Flood Frequency," M. E. Jennings and E. N. Cookmeyer II.

6. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "Generalized Computer Program, HEC-1," February 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," April 1984.

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

10. U.S. Geological Survey/Federal Highway Administration, "WSPRO Users Manual," in preparation.

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, GPO 050-001-00298-1.

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

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 Flood Insurance Study 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 Flood Insurance Study performed by a FEMA Study Contractor. 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. 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. 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 within the cells of the grid system should be discussed. 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. 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 Study Contractor'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.

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

A1B-2 BEFORE OPERATIONAL STORM SURGE RUNS ARE MADE

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 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 <u>BEFORE WAVE HEIGHT CALCULATIONS ARE MAPPED</u>

a. Copy of all wave height transect computations.

FEMA will provide written comments within 30 days of receipt of each data submission. The Study Contractor 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 Flood Insurance Studies 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 (COE) 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 COE 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.

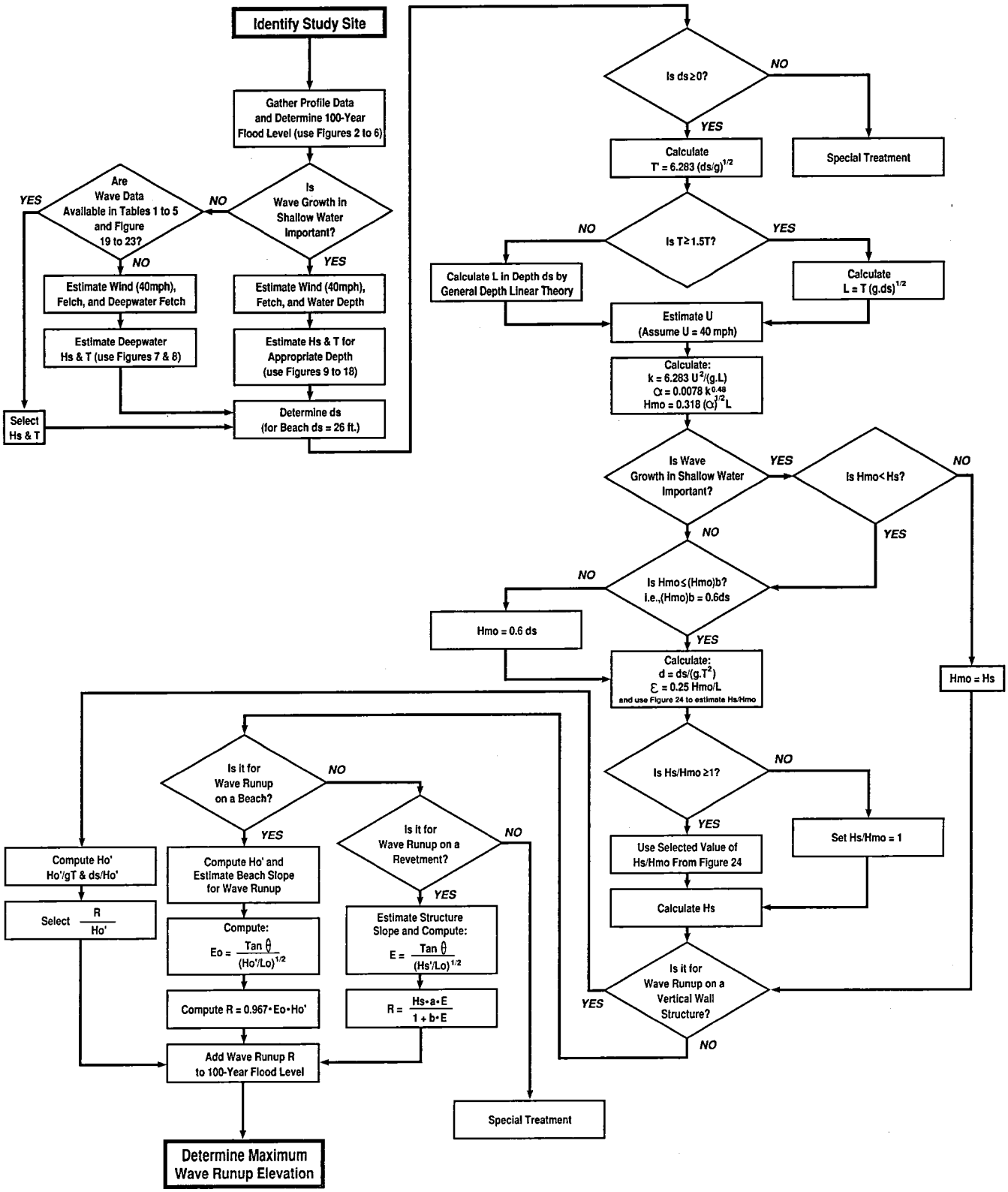
A1C-5 REFERENCES

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.

FIGURE 1

Flow Chart for Great Lakes Wave Runup Elevation Computation



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 X — Zone 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

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 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. 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 AO 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 AO 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 AO 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. Average depths and elevations should be rounded to the nearest whole foot.

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.

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

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 5-foot contour interval topographic map, which meets national map accuracy standards.

Standard photogrammetric methods can provide the information needed to prepare an 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.

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 and the ground is free of snow. Poor weather and difficult terrain conditions can also delay required complimentary (and supplementary) 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 photogrammetry surveys. Should the Study Contractor also perform the photogrammetric work, then any reference herein to Photogrammetric Subcontractor shall be understood to mean Study Contractor.

A4-2 SCOPE

The Study Contractor is responsible for providing the specifications for the aerial photography as well as for the photogrammetric work required. 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 Study Contractor.

In planning for photogrammetry, the Study Contractor 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, U.S. Geological Survey 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 areas (generally a little 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 ERM and bench mark information

A4-3 SPECIFICATIONS

A. Aerial Photography

The floodplain area for which detailed study is required should be outlined by the Study Contractor. The Photogrammetric Subcontractor shall obtain, while the streams are within the main channels, stereoscopic photography of the entire area outlined on the location maps (Figure A4-1) adequate to determine ground point elevations, within limits of accuracy described in Section A4-3C(5)(d).

The Photogrammetric Subcontractor shall store the film negatives for 3 years after completion of the contract, and the film negatives will be available to FIA without cost during that period.

Normally, special photography must be flown for each community being studied. Stereophotographic coverage of the floodplains must be obtained during an optimum time of year, using a first-order 6-inch (153±3 mm) focal length certified aerial camera calibrated within the last 3 years. Any wide-angle aerial camera with a planigon, pleogon, or avigon lens (or their equal) having a radial distribution of less than 20 micrometers 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 photographic flight height for a 6-inch camera lens shall not exceed 7,200 feet, if optic train plotter equipment is to be used. The flight height shall not be over 6,000 feet for analglyphic projection type plotters with a white light source (with no filters), and not over 4,800 feet if a filtered light source is used. The photography must be flown while the sun angle is above 30 degrees and the watercourses are in the main channels, and it must be suitable for use in a stereoplotting instrument to determine spot elevations of ground points within the accuracy requirements described in Section A4-3C(5)(d). The Study Contractor should ascertain the ability of the equipment and personnel used for the project, and then decide on the necessary flight height that will achieve the required accuracies holding the above maximum. Aerial surveys shall be carried out under the direct supervision of a registered civil engineer, registered land surveyor, or certified photogrammetrist. It is recommended that the Study Contractor obtain a signed statement from the Photogrammetric Subcontractor indicating the

personnel and equipment that will be utilized for the project (see Figure A4-2).

B. Control

(1) Vertical Control. The Photogrammetric Subcontractor shall perform necessary field surveys to maintain vertical photogrammetric control, with all elevations referred to NGVD. These surveys shall use third-order leveling procedures and should normally be accomplished by trigonometric or differential leveling using transit-stadia or transit-electronic distance measurements. Vertical control points for stereo-models may be established by other than third-order procedures if elevations are accurate to within ±0.4 foot and are determined from bench marks of third-order or higher accuracy. Primary control will consist of a network of control levels (see Section A4-4, "Glossary"). Enough points shall be included in the primary network so that no stereo-model ground-surveyed control point (picture point) is farther than 1,000 feet from the nearest primary control point in that network. In addition, elevations should be determined at points that represent significant breaks in slope. Elevations of the independent stereo-model or analytical control points shall be determined by tide level logs, except for those points covered under the use of aerial analytical triangulation in the Study Contractor's proposal.

(2) Horizontal Control. Horizontal accuracy must be adequate to provide the vertical accuracy specified. Absolute horizontal position (latitude, longitude, or grid) is not essential. Existing government control may be used, where available, or landmarks on U.S. Geological Survey 7.5-minute series quadrangle sheets may be scaled at the risk of the Photogrammetric Subcontractor that the inherent errors will not affect the vertical accuracy. The horizontal control established by the Photogrammetric Subcontractor must be adequate to provide the specified vertical accuracy and to ensure true horizontal scale (not geographic position) within 100 feet per mile on the map manuscript furnished.

(3) Analytic Control. Aerial analytical triangulation may be used by the Photogrammetric Subcontractor for horizontal and vertical control. The maximum number of stereo-models acceptable in photogrammetric bridging is 4 for vertical control and 5 for horizontal control. Strip adjustment is acceptable for single flight lines, but simultaneous bundle adjustment shall be used on two or more parallel flight lines. The Root Mean Square Error for aerial analytical triangulation is 1:8,000 relative error as a fraction of flight height with horizontal and vertical points. The Study Contractor must recognize these conditions when preparing the proposal. Statements of Work involving aerial analytical triangulation that are submitted to the Regional PO must indicate what firm will do the photogrammetric work; describe the proposed procedures referencing these guidelines; list intended personnel and their credentials; and specify equipment to be used, with dates of last calibration tests. These are all subject to the approval of the Regional PO (see Figure A4-2).

(4) Bridges and Hydraulic Structures. Surveys of all bridges and hydraulic structures and underwater sections will be obtained by the Study Contractor 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. Photogrammetric Compilation

Photogrammetric compilation for an 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 stereoplotting instruments and experienced stereoplotter personnel.

(1) Cross Sections. The Photogrammetric Subcontractor will provide the Study Contractor 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 (120 lines on print) on frosted, 0.004-inch-thick mylar with emulsion on back. All must provide complete single coverage of the flight area. On the 2x photographs, the Study Contractor 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 shall 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 shall be returned to the Photogrammetric Subcontractor.

(2) Plotting and Presentation of Elevation Points. The Photogrammetric Subcontractor, using a stereoplotter, will read an elevation for the top of each designated identifiable ground point designated by the Study Contractor 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 shall be read at each edge of water. Zero station (initial point) for each cross section will be the finally adopted terminus on the left bank (looking downstream). Station shall 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 ETC." subtitle

the low water channel. Where the channel is dry, the "RIGHT BANK ETC." 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" shall be inserted, one for each island, between the left and right bank arrays. The plotting and listing shall 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 shall be viewed looking downstream. A computer card format that includes provision for card sequence and cross-section label and, for each ground point, the station and ground elevation compatible with the Photogrammetric Subcontractor's digitizer (described on Figure A4-2) may be determined by the Study Contractor. The Photogrammetric Subcontractor may use the format to furnish complete data for all cross sections. Elevations of designated identifiable ground points shall be written on the map manuscript sheet only.

(3) Planimetric Map Manuscript. The Photogrammetric Subcontractor shall compile a planimetric manuscript map in pencil on 4-millimeter, mylar-type material at a scale of 1 inch = 400 feet (1:4,800) or smaller. The PO shall approve the final map scale. The map will be used to control transfer of flood boundaries and to update base map information and shall include the areas within the compilation limits of the stereo-models required for cross-section measurement, but need not go beyond the flight 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 ERMs or bench marks specified; and any contours that are specified.

The Photogrammetric Subcontractor will then plot contours of the areas shaded on the location map (see Figure A4-1). 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 Study Contractor 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 Study Contractor 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 Study Contractor should bring the potential use of this approach to the attention of the Regional PO and obtain approval prior to its use.

The Photogrammetric Subcontractor shall prepare a final freehand inked tracing of only the material specified in the subcontract for the compilation manuscript and furnish two copies of the tracing. The copies should be prepared at a scale of 1:4,800 or smaller (as approved by the Regional PO), in a set of sheets each

no larger than 24 inches x 36 inches, screened at about 120 lines per inch, so that line work on the copies furnished is 30 percent black and 70 percent transparent, on 4-mil mylar with emulsion on back and matte finish. Each sheet shall contain a simple legend indicating community name, scale, and north arrow. A diagram indicating placement of each sheet within the set shall be included either on each sheet or on a separate index sheet. The specified format is illustrated in Figure A4-5.

(4) Bench Marks and ERMs. The Photogrammetric Subcontractor shall 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 shall 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 shall be drilled or an "X" that is at least 2 inches by 2 inches shall 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.

(5) Accuracy Requirements.

(a) Contours. The contour interval shall be 4 feet. Ninety percent of the elevations determined from the solid-line contours of the planimetric maps shall have an accuracy with respect to true elevation of one-half the contour interval or better and the remaining 10 percent of such elevations shall not be in error by more than one contour interval.

(b) Coordinate Grid Lines (if used). The plotted positions of each plane coordinate grid line shall not vary by more than 0.01 inch from true grid on each map.

(c) Horizontal Control. Each horizontal control point shall be plotted on the map, within the coordinate grid in which it should lie, to an accuracy of 0.01 inch of its true position as expressed by the plane coordinates computed for the point. Should non-coordinate control procedures be utilized, the same accuracy shall pertain to the plotting of any type of control points.

(d) Spot Elevations. Ninety percent of all spot elevations placed on the maps shall have an accuracy of at least one-fourth the contour interval, and the remaining 10 percent shall not be in error by more than one-half the contour interval.

(e) Planimetric Features. Ninety percent of all planimetric features that are well defined on the photographs shall be plotted so that their position on the maps shall be accurate to within at least 0.025 inch of their true coordinate position. None of the features shall be misplaced on the maps by more than 0.05

inch from their true coordinate position. When map production is accomplished without the benefit of a grid coordinate system, then the accuracy shall be interpreted as the distance between any two well-defined points.

(6) Quality Control Survey

(a) Check Profiles. The map accuracies called for in the specifications are critical, thus, map accuracy checks, by ground survey profile procedure, shall be required. The Study Contractor is responsible for performing the accuracy check. A report of the findings of the quality control checks shall be submitted to the Regional PO upon request.

The minimum amount of ground-surveyed map check profiles shall be equal to one check profile for each three stereo-models whose flight path is basically parallel to the project corridor, or at intervals along the project corridor equal to this distance.

The position of the ground-surveyed map check profile shall be at a point where the contours are of average density of the three-model set being checked and where a minimum of three distinct planimetric features are on or adjacent to such a line.

The length of the ground-surveyed map check profile shall be a minimum of the average width of the corridor within the three-model set being tested or across a minimum of 10 contours, whichever is the lesser horizontal distance. If physical conditions prohibit a profile meeting the above minimum requirements, the requirements may be met by using profiles of lesser length as long as the sum of all profiles meet the minimum requirements, as described above, and at least one of the profiles is one-half of the average corridor width or crosses at least 5 contours.

Each end of a ground-surveyed map check profile must be tied to the plane coordinate grid and vertical control system, used as primary map control, by a horizontal and vertical traverse having a minimum accuracy closure of the third order. As an alternate procedure, the horizontal location of the line may be tied to the map by terminating each end of the ground-surveyed check profile line to a distinct planimetric map feature (road intersection, building corner, or the like) by direct tie or right-angle offset.

(b) Contours. The accuracy of the contours shall be checked by profile methods. The check profiles shall be measured by leveling along a staked traverse that has been surveyed between the above-described profile terminus points by transit traverse. Elevation measurements shall be made at points on the ground where major changes in ground slope exist along the traverse and where each contour elevation is intersected by the traverse. The horizontal distance between elevation measurements shall not exceed 100 feet. Profile elevations measured on the traverse shall be compared with elevations determined from the contours that cross the traverse where it is plotted by coordinates or horizontal position on the map.

(c) Planimetric Features. The accuracy of well-defined planimetric features shall be checked by comparing coordinates, determined for the features by ground

surveys, with the coordinates of the same features as measured from their map position or by their distance from the profile terminus points.

The ground-surveyed check profile information shall be delivered, upon request, to the Regional PO in the form of neatly prepared and maintained field books and a set of paper prints of the project maps on which the check profiles have been plotted from the field book information.

If a profile check line fails to prove the accuracy, then one additional check line parallel to and at least 1,000 feet from the failed line will be permitted. The same methods shall be used in checking the accuracy along this profile as along the first, and the average of the two shall be used in determining the accuracy of the map or maps being tested. If the accuracy meets specification requirements by this averaging process, the map or maps shall be accepted. If any map does not meet the accuracy requirements set forth in the specification, the Photogrammetric Subcontractor shall, at his own expense, make the appropriate corrections and recheck the maps within a period of time specified by the Study Contractor and the Regional PO.

A4-4 GLOSSARY

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

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.

Connecting Levels - A line of differential or trigonometric levels (stadia or electronic distance measurement) run to half-tenths of a foot between a control point and a cross section, with closure that, in the Study Contractor'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 run to hundredths of a foot by differential or trigonometric (electronic distance measurement) leveling methods to third-order accuracy limits (0.05 foot x square root of distance in miles) to serve as starting elevations for connecting levels to determine picture point control elevations.

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

ERM - A permanent monument not included in the National Geodetic Survey or U.S. Geological Survey network but whose elevation has been determined by levels from a BM with copy of field notes or documented summary of levels from BM or ERM furnished.

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

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

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

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.

Quality Control Surveys - The surveys made to verify accuracy of elevations, or cross-section locations, contours, planimetric features, or the distribution of ground points within the cross sections.

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

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

Trigonometric Levels (Stadia) - The levels run with an electronic distance measuring device as an accessory to a theodolite or as an integrated unit.

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

FIGURE A4-1. SAMPLE LOCATION MAP

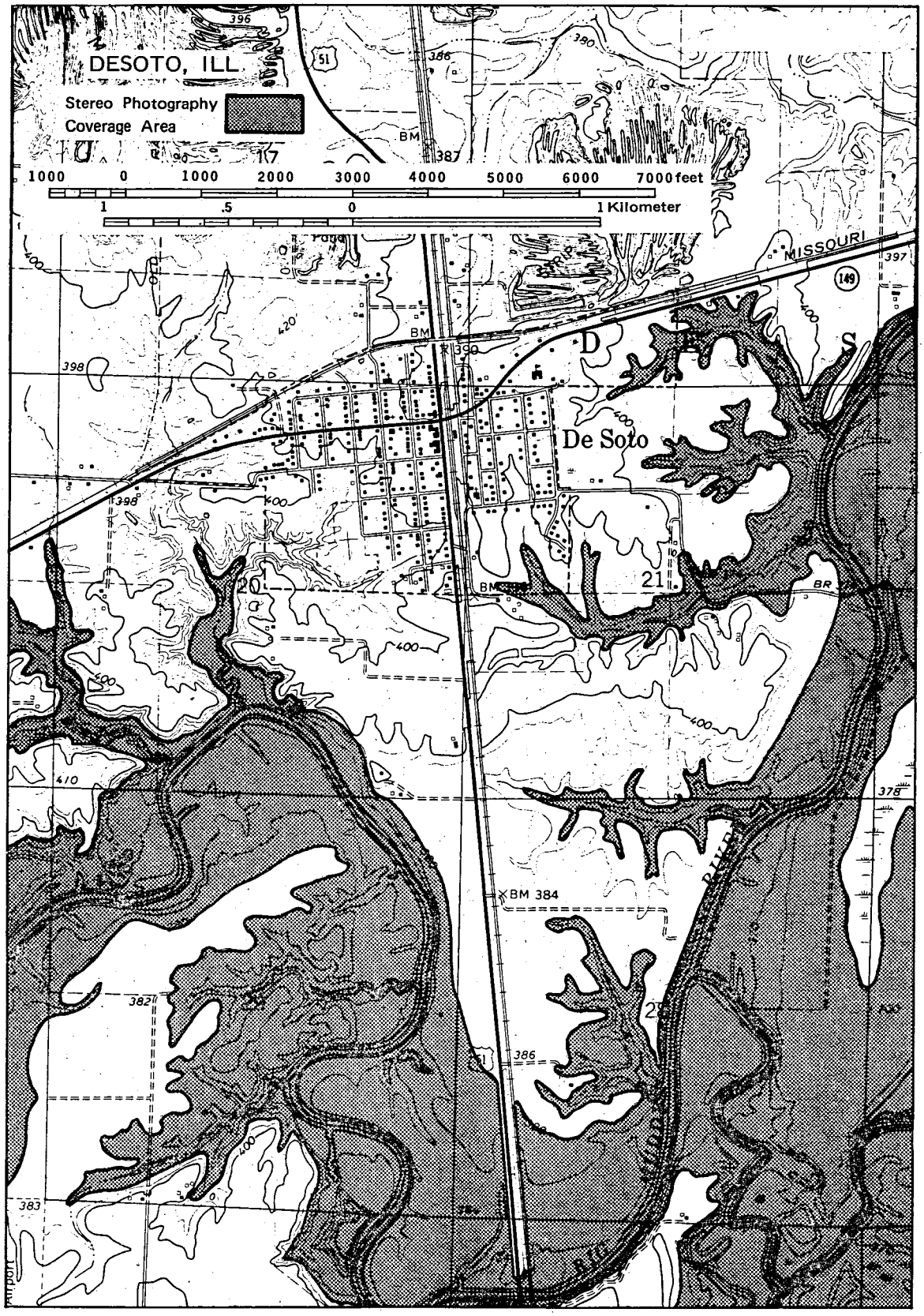


FIGURE A4-2. TABULATION OF PERSONNEL AND EQUIPMENT

List personnel and equipment proposed for use in this project. List only the one camera and the stereoplotter(s) proposed for cross section profiling. Auxiliary equipment for supplemental work such as bridging or mapping may be described elsewhere in the proposal. If photography is to be furnished by the Geological Survey omit the information for Pilot, Photographer, and Camera.

PERSONNEL

Position	★Employed	Name	Experience in This Position
Project Chief	_____	_____	_____Years
Compiler	_____	_____	_____Years
Compiler	_____	_____	_____Years
Compiler	_____	_____	_____Years
Pilot	_____	_____	_____Photo.F1.Hrs.
Photographer	_____	_____	_____Photo.F1.Hrs.
Field Party Chief	_____	_____	_____Years
Field Party Chief	_____	_____	_____Years

CAMERA

★Owned

Make, Model, Ser. No. _____

Certificate for lens, cone, and magazine as one unit

USGS Cert. dated _____ Mfg. Cert. dated _____

Flight Height _____ Distortion correction devices (if any) _____

STEREOPLOTTER(S)

Make	Model	Serial No.	Estimate of "C" Factor	★Owned

DIGITIZER

☐ None proposed, manual listing and plotting planned. ☐ Is part of plotter listed above.

Make, Model, Serial No. _____

Type ☐ XYZ (can read curved cross section). ☐ XZ (straight sections only).
Other (describe)

★1.--By proposing firm. ★2.--By Subcontractor. ★3.--Other (Explain)

Note: Qualifications, education, and experience of administrative personnel should be furnished on other than this form.

_____
Contractor or Authorized Agent

FIGURE A4-3.
EXAMPLES OF CROSS SECTION GROUND POINT SPACING

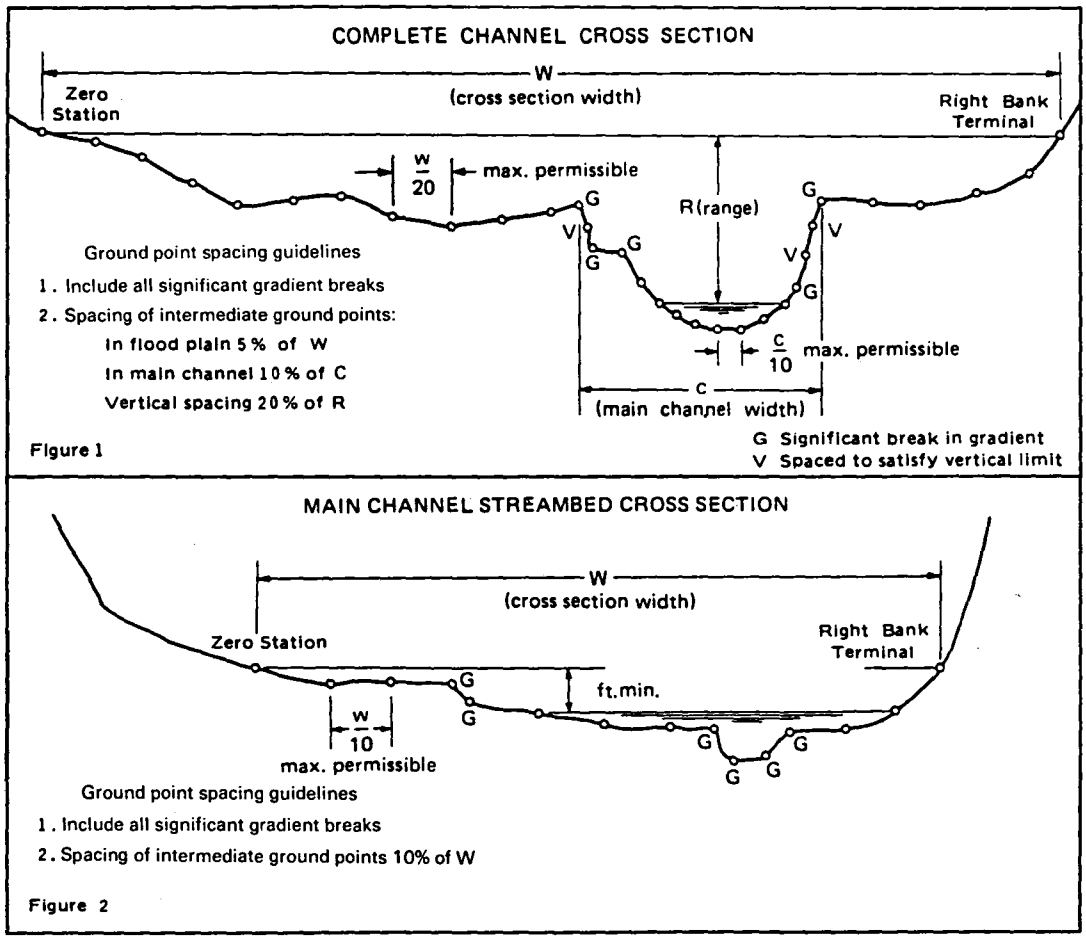


FIGURE A4-4.

EXAMPLE OF AN ACCEPTABLE METHOD OF PRESENTATION OF CROSS SECTION DATA LISTING AND CROSS SECTION PLOTS

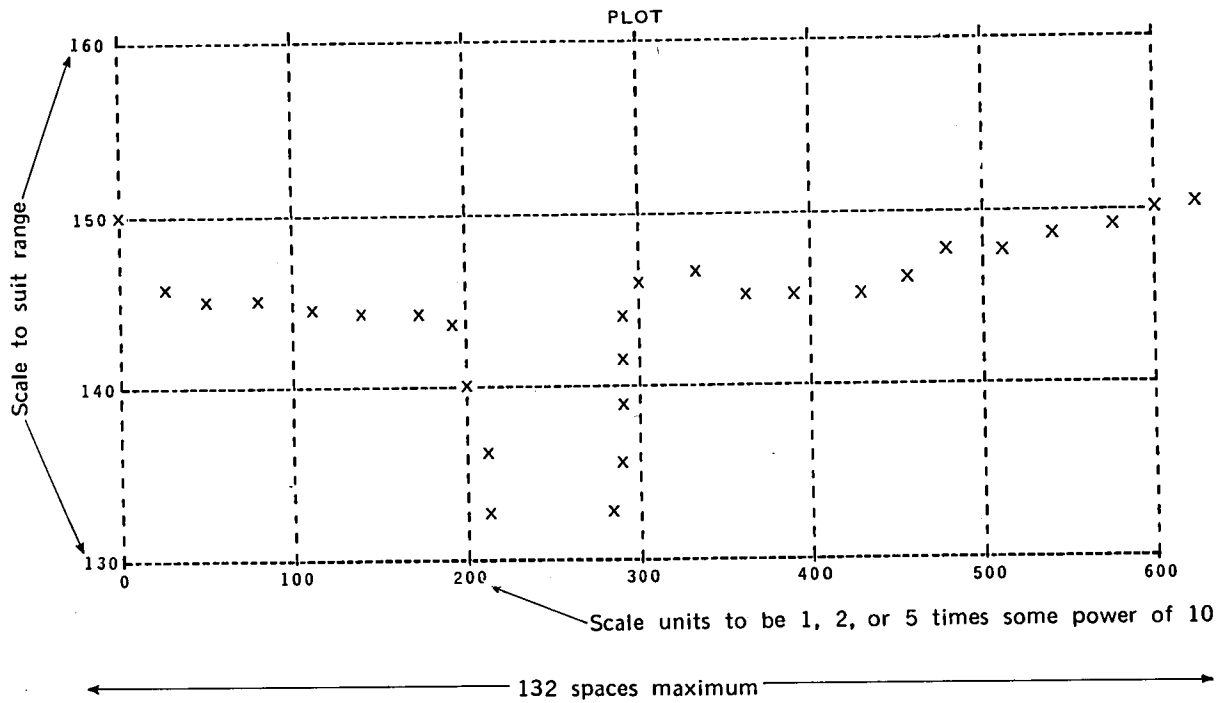
WEST KARNVILLE, WISC.
CROSS SECTION OF

LEFT BANK (STATION—GROUND ELEVATION)

0 150.4	29 146.5	51 145.5	80 145.0	110 144.8	140 144.5	170 144.3	179 143.8
189 142.0	200 140.3	208 137.0	210 133.6				

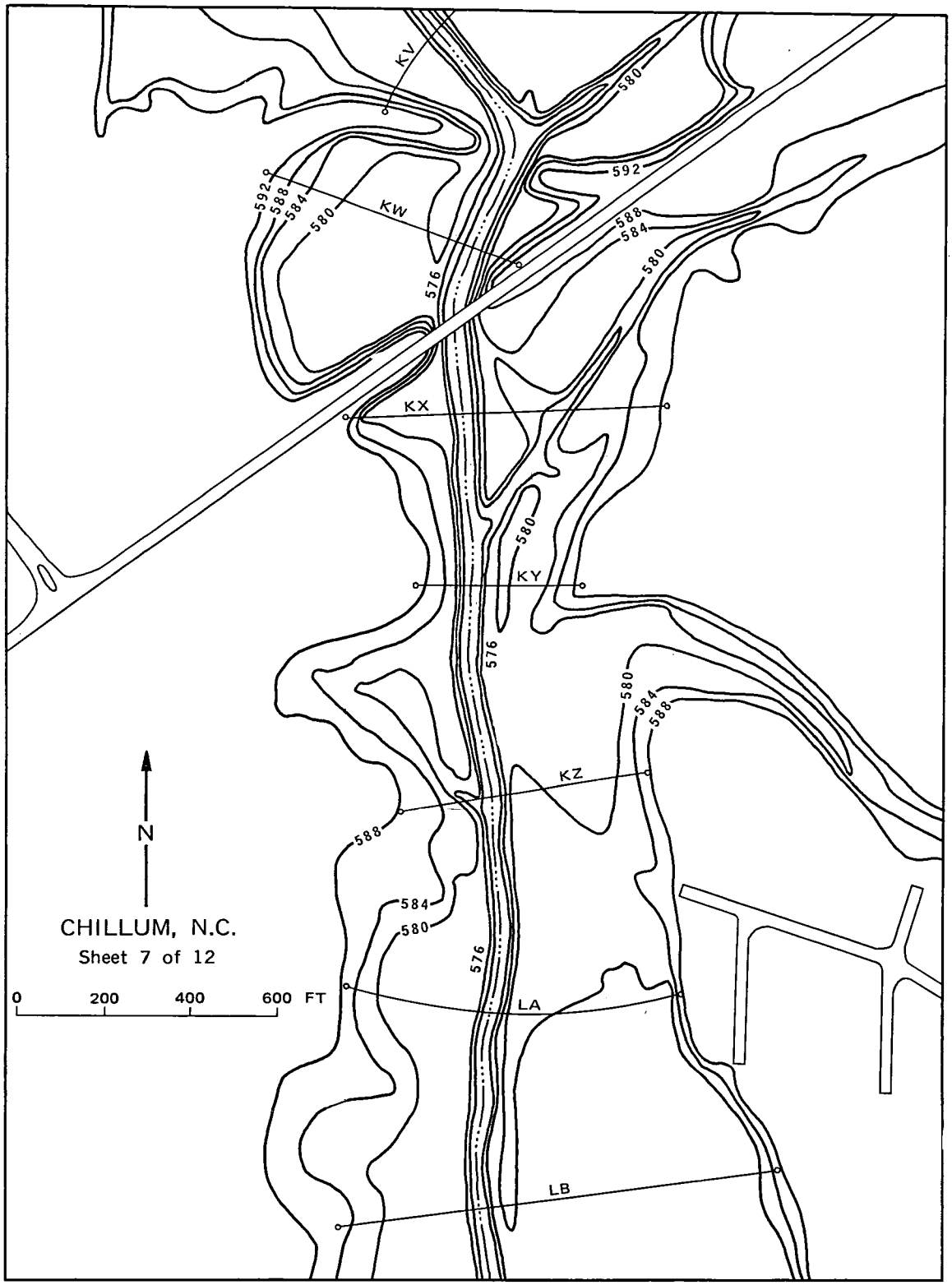
RIGHT BANK (STATION—GROUND ELEVATION)

284 133.6	287 136.4	290 139.4	291 141.8	292 144.0	300 147.1	330 147.5	360 146.5
390 146.0	420 146.5	450 147.0	480 147.5	510 148.0	540 148.6	570 149.2	600 150.0
620 150.5							



Note.--This format is for use where data were originally recorded on computer cards and can be programmed for line printer output. Hand lettered lists and manual plotting in similar format are also satisfactory.

FIGURE A4-5. FLOOD PLAIN CONTOURS



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
Federal Insurance Administration
Office of Risk Assessment
Risk Studies Division
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 STUDIES

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., $P(H|Q=q)$ 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.

Dawdy, D. R., Hill, J. C., and Hanson, K. C., "Implementation of FEMA Guidelines on Alluvial Fans," Hydraulic Engineering, Proceedings of the 1989 National Conference, ASCE, Hydraulics Division, 1989.

Faltas, M. E., "Evaluating Flood Hazards on Alluvial Fans," Hydraulic Engineering, Proceedings of the 1988 National Conference, ASCE, Hydraulics Division, 1988.

Mifflin, E. R., "Design Depths and Velocities on Alluvial Fans," Hydraulic Engineering, Proceedings of the 1988 National Conference, ASCE, Hydraulics Division, 1988.