Modernizing FEMA's Flood Hazard Mapping Program: Recommendations for Using Future-Conditions Hydrology for the National Flood Insurance Program

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Introduction

The Federal Emergency Management Agency (FEMA) has designed a plan to modernize the Flood Hazard Mapping Program that will reduce the burden on taxpayers for disaster relief and maintain the maps as valuable resources for flood hazard mitigation. One of the most exciting and revolutionary aspects of the Map Modernization Plan is that it will facilitate ownership of the flood maps by State and local entities through greatly increased involvement in the flood mapping process. This will be achieved through cooperative agreements with State or local partners whereby FEMA will provide flood mapping funds, technical assistance, and mentoring to the State or local partner, which will then develop and maintain all or a component of its flood map. The proposed community agreements recognize that hazard identification and mapping must go hand-in-hand with the responsibility of managing floodplains at the local level. By creating a strong local program that maintains the connection between mapping and managing flood hazard areas, the National Flood Insurance Program (NFIP) is likewise strengthened in its ability to reduce the loss of property and life.

Many communities have promoted the use of future land-use conditions in defining hydrology and floodplains that represent stricter land-use regulations than the minimum requirements of the NFIP. The use of future-conditions hydrology is consistent with cooperative agreements, modernizing the Flood Hazard Mapping Program, and FEMA's desire to be flexible and supportive of those communities that would like to implement stricter land-use regulations.

Role of State and Local Partners

FEMA's goals are best accomplished through partnerships with State, regional, and local community agencies under the NFIP and within other hazard mitigation programs and activities. With over 19,000 communities participating in the NFIP, FEMA faces a challenge in trying to monitor floodplain development activities and conduct the necessary flood data updates in a timely manner. Thus, FEMA must rely on local entities, with their unique knowledge of flooding conditions and control over permitting processes, to enhance the process of flood hazard identification. However, State and local involvement in the flood mapping process has been somewhat limited. FEMA has, in many cases, produced the NFIP flood maps with little community input. The responsibility to administer the NFIP regulations based on those same maps, however, is left entirely up to the community. The result is that the flood maps are often viewed as "FEMA maps" that often do not meet community needs. Therefore, many communities have no sense of ownership in the maps, and they are reluctant to assume responsibility for them.

In developing the Map Modernization Plan, FEMA recognized this limitation was recognized and devised a strategy designed to increase community involvement. Specifically, the Map Modernization Plan will proactively pursue strong Federal-State-Local partnerships through a variety of cooperative programs. Many States, communities, and other local entities, at their own expense, have furthered the partnership in recent years by investing considerable resources in identifying and updating flood hazard information. The intent of the Map Modernization Plan is to facilitate and capitalize on these efforts and coordinate them with FEMA's flood mapping efforts rather than on an ad-hoc basis. This will result in strengthened mapping and floodplain management programs and, thus, should reduce flood losses and disaster assistance.

Emphasis on Local Mapping Needs

The identification of local mapping needs beyond what is currently being done will also be an important aspect of the cooperative agreements. By mapping locally pertinent information, local ownership of the maps will be increased. Because flood conditions and hazards vary locally and regionally, inclusion of those unique local conditions on the flood map may be warranted. For example, a community may find it useful to identify areas on the flood hazard maps with high erosion hazards or floodplains based on developed/future hydrologic conditions in addition to the standard features already depicted on the flood map.

In effect, the cooperative agreements will help FEMA maintain national standards while at the same time providing a useful tool to the community. When communities enter into cooperative agreements with FEMA, it will be the beginning of their acceptance of responsibility for maintenance of the maps in the future.

Historical Perspective on Future Conditions

Historically, flood hazard information presented on NFIP maps has been based on the existing conditions of the floodplain and watershed. When the mapping of flood hazards was initiated under the NFIP, the intent of the Program was to reassess each community's flood hazards periodically and, if needed, revise the NFIP maps. Flood hazards may change significantly in areas experiencing urban growth or changes in physical conditions caused by such geologic processes as subsidence and erosion. Budgetary constraints prevent initiating actions to update NFIP maps with sufficient frequency to reflect the changing flood hazards brought about by natural and man-made changes (approximately 45 percent of the NFIP maps are at least 10 years old, and 70 percent are 5 years or older).

As discussed in *Flood Insurance Study Guidelines and Specifications for Study Contractors*" (FEMA 37, January 1995), flood hazard determinations should be based on conditions that are planned to exist in the community within 12 months following completion of the draft Flood Insurance Study (FIS) report. Examples of future conditions to be considered in the context of FEMA 37 are public works projects in progress, including channel modifications, hydraulic control structures, storm-drainage systems, and other flood protection projects. These are changes that will be completed in the near future for which completion can be predicted with a reasonable degree of certainty and their completion can be confirmed prior to the NFIP map becoming effective. By contrast, future land-use development, such as urban growth, is uncertain and difficult to predict, and is not to be considered in the context of the FEMA 37 guidelines.

Communities experiencing urban growth and other changes have expressed a desire to use future-conditions hydrology in regulating watershed development. While some communities do regulate based on future development, others are hesitant to enforce more restrictive standards without Federal support. In order to assist officials in such progressive communities, FEMA could place future-conditions flood risk data on the NFIP maps for informational purposes.

FEMA completed a study in 1989 (FEMA, 1989) to examine the use of future floodplain conditions on flood hazard maps. For this study, the advantages and disadvantages of several options were explored. The recommended option was for FEMA to incorporate future-conditions data prepared by the communities into NFIP maps for regulatory and insurance purposes with reduced insurance rates within the future-conditions floodplain. The choice of using future-conditions floodplains was up to the community that would be expected to use the future-conditions data for floodplain management and to defend their data in case of legal challenges. This option was never initiated possibly due to administrative and legal problems associated with insurance rates within future-conditions floodplains. The recommendations described later in this report avoid this problem.

Defining Future Conditions

In considering watershed development, the term "future" itself can be defined in several different ways: 10 or 20 years projected into the future, for example, or the maximum development planned for a given watershed. For the purposes of this discussion, we will consider future conditions to be those land-use conditions shown on the current zoning maps or comprehensive land-use plans. Future-conditions hydrology is then defined as the flood discharges that would occur if the land-use conditions shown on the current zoning maps or comprehensive land-use plans were realized. There are two instances where existing conditions are equivalent to future conditions (1) no significant development is planned for an area, and (2) areas currently developed to the extent shown on the current zoning maps or comprehensive land-use plans of local governments within the watershed. Under these conditions, no additional hydrologic analyses are needed.

Watershed development can include hydrologic as well as hydraulic modifications. The changes in the watershed that can influence the hydrology and flood discharges are the increase in impervious area and the improvements in the drainage network that accompany urbanization. For example, as buildings and parking lots are constructed, the amount of impervious land within the watershed increases, which increases the amount or volume of direct runoff. The construction of storm sewers and curb and gutter streets usually cause an increase in the peak rate of direct runoff. These modifications can have dramatic effects on the flood frequency characteristics of a watershed, resulting in significantly increased base flood discharges and elevations. For example, Sauer and others (1983) indicate that if a watershed is fully developed, the 1-percent-annual-chance (base) flood discharge is about 2.5 times the base flood discharge under rural or undeveloped conditions.

The construction of flood detention structures can also significantly effect the flood frequency characteristics of a watershed. Because the hydrologic effects of flood detention structures are very site specific and difficult to evaluate, future conditions as defined herein do not include the construction of flood detention structures.

Hydraulic modifications are changes that are within a stream or other waterway, such as bridge and culvert construction, fill, and excavation. Similar to flood detention structures, the effects of projected future hydraulic modifications on flood frequency are site specific and difficult to predict and are considered beyond the scope of this discussion. Therefore, the future hydrology conditions discussed herein are based on future land-use conditions of the watershed, and do not include future construction of flood detention structures or hydraulic structures.

Future land-use conditions will be based on current zoning maps or comprehensive land-use plans and it will be the responsibility of the community to determine the level of future development. These zoning maps or comprehensive land-use plans should go through the normal review process and be adopted as part of the ordinances of the community. The community will be responsible for defending the determination of the future land use and future-conditions hydrology.

Once the future land-use conditions are determined, the future-conditions hydrology based on these projections will be determined by the community as part of their stormwater-management programs. There are several hydrologic procedures for making these calculations including the use of gaging station data, regional regression equations and rainfall-runoff models. These hydrologic procedures are briefly discussed in Appendix 1.

For those communities using future-conditions hydrology, a regulatory floodway could be developed and adopted for floodplain management. The use of a future-conditions floodway should be described and backed by local ordinances. The future-conditions floodway would also exceed the minimum NFIP criteria of the floodway based on existing conditions. This is similar to the use of an “administrative floodway” that FEMA currently map choose to map based on the desire of the local community. The use of a future-conditions floodway will not impact insurance ratings since the floodway is specifically a floodplain management tool to be adopted by the community.

Uses of Flood Hazard Maps

The different uses of FEMA’s flood hazard maps should be considered if floodplains based on future-conditions hydrology are to be used in the NFIP. Currently, two of the primary uses of the flood hazard maps are floodplain management and flood insurance rating. If future-conditions hydrology is shown on the NFIP maps, we must determine how these and other purposes will be impacted.

Floodplain Management

From a floodplain management standpoint, future-conditions floodplains can be used by communities to enforce a more stringent floodplain management policy than required by FEMA. By displaying future-conditions floodplains on FEMA maps, the community and FEMA are alerting the public that flood hazards may increase in the future due to urban development. Currently, many communities throughout the country develop future-conditions hydrology and create their own maps to regulate floodplain development. This has resulted in two sets of maps being produced for a community: future-conditions maps for local floodplain management and FIRMs for flood insurance determinations. As a result, these progressive communities do not have a sense of ownership for the FIRMs and their resources are directed toward the future-conditions maps. Generally, the communities are in areas that are experiencing rapid urban growth and development, including Tucson, Arizona; Denver, Colorado; Las Vegas, Nevada; Charlotte, North Carolina; Tulsa, Oklahoma; Dallas/Fort Worth, Texas; and the Washington, DC metropolitan area. Details on the use of future-conditions hydrology are provided for three communities in Appendix 2.

From the community perspective, the future-conditions data would be used for mandatory floodplain management regulations. The display of future-conditions data on FEMA maps should provide additional support for the local community in adopting more stringent floodplain management guidelines. The enforcement of more stringent floodplain ordinances is just one of the ways that communities can earn credit through the Community Rating System. Details of the Community Rating System are given in Appendix 3.

From FEMA's perspective, the future-conditions data would be shown for informational purposes only; FEMA's floodplain management compliance requirements would still be based on existing-conditions data as described in 44CFR 60.3. In addition, 44CFR 65.6(a)(3) of the NFIP regulations states, "Revisions cannot be made based on the effects of proposed projects or future conditions." However, 44CFR 60.1 provides encouragement to communities to adopt more stringent floodplain ordinances through the statement "Therefore, any flood plain management regulations adopted by a State or a community which are more restrictive than the criteria set forth in this part are encouraged and shall take precedence." The decision to show future conditions on the FIRM would be based on the request of the community and not by FEMA.

Flood Insurance Rating

The current procedure for flood insurance rating is that structures shown within the existing-conditions 1-percent-annual-chance (100-year) floodplain are subject to a mandatory purchase requirement. Due to statutory constraints at this time, FEMA can not use future-conditions data for flood insurance purposes. Therefore, there will be no change in the use of existing-conditions data for establishing flood insurance rates. Through community participation in the CRS, reduced flood insurance rates are available for those communities that enforce more stringent regulatory standards than required by the NFIP.

Other Uses

In addition to the two primary uses discussed above, several other uses of the FEMA flood hazard maps exist, as discussed below.

- Real estate professionals and property owners use the maps to determine the flood risk status of properties.
- Flood map determination firms use the maps to specify the location of properties relative to the SFHA.
- The land development industry use the maps to aid in designing developments that will be safe from flood hazards.
- Surveyors use the maps to prepare elevation certificates for structures.
- Engineers use the maps to consider the flood risk when designing flood mitigation projects, such as structure elevation and relocation, buyouts, and culvert and bridge replacements.
- Disaster and emergency response officials use the maps to prepare for flood-related disasters; to issue warnings to those in danger of flooding; and, after a flood has occurred, to implement emergency response activities and to aid in the rebuild and reconstruction phase.

Federal agencies use the FEMA flood maps to meet the requirements of Executive Order No. 11988 to evaluate the potential effects of any actions they may take in a floodplain. As stated in Executive Order No. 11988, "Each agency shall provide leadership and shall take actions to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for (1) acquiring, managing, and disposing of Federal lands and facilities; (2) providing Federally undertaken, financed, or assisted construction and improvements; and (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities."

Federal agencies typically use the existing-conditions 0.2-percent-annual-chance (500-year) flood to plan activities in the floodplain. The proposal to include future-conditions floodplains on FIRMs is consistent with the intent of Executive Order No. 11988, because the existing-conditions 0.2-percent-annual-chance (500-year) flood profile and/or floodplain boundaries will still be published by FEMA.

Constraints and Benefits of Using Future-Conditions Data

Many constraints and benefits of mapping floodplains based on future-conditions hydrology must be considered in evaluating present mapping policies. Some of the principal constraints and benefits of using future-conditions data are briefly listed below.

Constraints

The following are constraints of using future-conditions data on FEMA flood maps:

- A rational and reasonable link between the public health and safety and the resultant land-use regulations and flood insurance rates may not exist; as a result, property owners may object to land-use regulations and flood insurance rates based on a condition that does not currently exist.

- Greater uncertainty in predicting future land-use conditions and the associated 1-percent-annual-chance (100-year) flood elevation, floodplain, and floodway may make the regulatory data based on future conditions more subject to challenge.

- An increase in appeals of future-conditions 1-percent annual chance (100-year) flood elevations is likely and they will be more difficult to address because of the uncertainty in determining future land-use conditions and the associated hydrology.

- Greater effort and expense will be needed in gathering data, calibrating, and using statistical and watershed models for future conditions.

- Methodologies used to determine future-conditions flood discharges will likely differ between communities, resulting in a less consistent and uniform nationwide program.

- Projections for land-use development may change over time, making the future-conditions floodplain data on NFIP maps inaccurate.

- NFIP regulations may need to be updated to describe the use of future-conditions data.

- More resistance to the NFIP may result because of the perception that the Federal government is seeking more restrictions on land-use regulations and infringing on land development.

Benefits

The following are benefits of using future-conditions data on FEMA flood maps:

- Future damage to structures and loss of life may be reduced because flood hazard areas would be increased and less development would likely occur in the floodplain.

- Communities would be supported by FEMA in their use of stricter floodplain management regulations.

- More informed decisions could be made on where to locate structures near the floodplain; for example, placing structures in an area that may eventually be in the 1-percent-annual- chance (100-year) floodplain may be discouraged.

- Subsidies for structures constructed on risk conditions that are out of date may be reduced.

- Fewer revisions to NFIP maps would be needed, thereby reducing FEMA costs in the long term.

- The Community Rating System could be used to reduce flood insurance rates in communities that use future-conditions data.

- Greater opportunities exist for increasing the partnership between FEMA and communities through the FEMA Cooperating Technical Partners (formerly Cooperating Technical Communities) initiative, given that future land-use conditions will be determined by the communities.

Conclusions

An evaluation of the constraints and benefits for mapping floodplains based on future-conditions hydrology suggests the best approach is to display the future-conditions floodplains on the NFIP maps for informational purposes. The future-conditions land use and hydrology should be determined by the local community. This option uses the benefits of displaying future-conditions data while minimizing many of the constraints. If a community chooses to adopt a regulatory floodway based on future-conditions hydrology, the use of this floodway must be supported by local ordinances.

Specifically, the future-conditions 1-percent-annual-chance (100-year) floodplain can be shown on the FIRM in lieu of the existing-conditions 0.2-percent-annual-chance (500-year) floodplain and labeled as Zone X (Future Base Flood) if the community desires, with no Base Flood Elevations (BFEs) shown. BFEs would only be shown for the existing-conditions 1-percent-annual-chance (100-year) floodplain, or the Special Flood Hazard Area (i.e., the area inundated by the base flood and labeled Zone AE on the flood map). The future-conditions 1-percent-annual-chance (100-year) flood elevations would be included in the FIS report on the Flood

Profiles and in the Floodway Data Table, thus providing necessary information to the community to meet their local floodplain management needs. The existing-conditions 0.2-percent-annual-chance (500-year) profile would also be shown in the FIS report to meet the requirements of Executive Order No. 11988 and provide Federal agencies information to evaluate the potential effects of any actions they may take in a floodplain. Conversely, the community may choose to show the existing-conditions 0.2-percent-annual-chance (500-year) floodplain on the map and include the future-conditions 1-percent-annual-chance (100-year) flood profile in the FIS report. Various other combinations to display the flood hazard data are also possible. The main point is that FEMA and the community work together to produce the most useful maps for the community.

An example FIS report with Flood Profile and associated FIRM is included in Appendix 4. In this example, the future-conditions 1-percent-annual-chance (100-year) floodplain is shown on the FIRM and the future-conditions 1-percent-annual-chance (100-year) flood profile and existing-conditions 0.2-percent-annual-chance (500-year) flood profile are included in the FIS report. In general, it will not be feasible to show both the future-conditions 1-percent-annual-chance (100-year) floodplain and the existing-conditions 0.2-percent-annual-chance (500-year) floodplain on the FIRM because these boundaries are usually very close and could not be adequately distinguished on the same map.

From a floodplain management standpoint, FEMA will continue to require regulation of floodplain development based on the existing-conditions data, while local floodplain managers can regulate development based on the future-conditions data. From a flood insurance standpoint, FEMA will continue to require flood insurance for structures shown in the existing-conditions floodplain. By labeling the future-conditions floodplain as "Zone X (Future Base Flood)," FEMA should avoid any confusion regarding the mandatory flood insurance requirement, and will allow insurance policies to be purchased at the reduced rate currently available for structures in the existing-conditions 0.2-percent-annual-chance (500-year) floodplain.

The FEMA Map Modernization Plan includes state-of-the-art engineering, mapping, information management, and communication technologies. Given the substantial benefits of using future-conditions data, FEMA should begin to display floodplains based on future-conditions hydrology on its flood maps. The user-community developed data, such as future-conditions data, will further enhance stronger FEMA, State, and local partnerships. Clearly, mapping floodplains based on future-conditions hydrology is an important option for participating CTPs, and it can easily be implemented as the inventory of FIRMs are converted to digital format as new DFIRM products. Mapping floodplains based on future-conditions hydrology is an important step to take for FEMA to successfully modernize its mapping program.

Implementation

Map Specifications

As part of the FEMA Map Modernization Plan, a new digital FIRM product is being developed. The new digital FIRM product will include options that can be exercised depending on the available data. This new digital FIRM product will include certain basic features and meet certain minimum mapping requirements. Additional options will be included depending on the community needs and available funding. A review of needs and available data will lead to a time and cost estimate and a recommendation on which options to exercise. Procedures for displaying future-conditions floodplains on this digital product should be included in these new mapping specifications, such as the appropriate layer/level to store the data, line code and weight and other specifications described in FEMA 37.

Cooperating Technical Partners

CTP agreements provide an opportunity for communities to get involved with the development, review, and update of the flood hazard information shown on NFIP maps. These agreements will allow for varied levels of community involvement, depending on the level of responsibility the community is capable of and wishes to undertake. Several options that FEMA plans to present to communities include: digital base map sharing; digital FIRM preparation and maintenance; hydrologic and hydraulic data development, mapping and review; and risk assessment. As a part of these agreements, an option could be for communities to show the future-conditions 1-percent-annual-chance (100-year) floodplain on the NFIP flood map in addition to the existing-conditions 1-percent-annual-chance (100-year) floodplain. The communities would develop and map the data, provide it to FEMA; in turn, they would receive a useful tool for risk assessment and flood hazard mitigation. FEMA is supports the use of future-conditions floodplains for floodplain management within the community.

Revisions

Because mapping future-conditions floodplains would be implemented on a community level, the maps will maintain consistency within community boundaries, regardless of how many map panels the community encompasses. When FEMA receives future-conditions data from communities, the data could be easily incorporated at the time of the digital conversion to the new digital FIRM product. Alternatively, communities that require flood hazard updates can submit future-conditions data to be incorporated with the existing-conditions data updates for the digital FIRM conversion. Displaying future-conditions data will increase community involvement in the NFIP and help FEMA build stronger partnerships with communities. If these communities are involved at the beginning of the digital conversion process, they will have a stronger sense of ownership of the maps, since they will have input to what kind of data are shown on their maps.

Once the future-conditions floodplains have been included on a community's flood hazard maps, all flood insurance studies, restudies, and revisions will incorporate the future-conditions hydrology that the community has determined. FEMA will minimally review these locally developed data and will include the data in all map updates. FEMA will continue to issue Letters of Map Amendment and Letters of Map Revisions Based on Fill for structures and parcels of land to determine whether they are in or out of the existing-conditions floodplain. This procedure can be expanded to determine if they are in or out of the future-conditions floodplain when that data are shown on the NFIP maps.

Rule Making

Before future-conditions data and floodplains may be displayed on FIRMs and in FIS reports, FEMA must modify pertinent sections of the NFIP regulations to incorporate several new definitions. To begin with, Section 59.1, entitled, "Definitions" must be modified to include "future-conditions hydrology," which would be defined as

> …the flood discharges associated with projected land-use conditions based on a community's zoning maps and/or comprehensive land-use plans and without consideration of projected future construction of flood detention structures or projected future hydraulic modifications within a stream or other waterway, such as bridge and culvert construction, fill, and excavation.

In Section 59.1, "future-conditions flood hazard area," or "future-conditions floodplain," would be defined as "the land area that would be inundated by the 1-percent-annual-chance (100-year) flood based on future-conditions hydrology."

Finally, Paragraph 64.3(a)(1) of the NFIP regulations, entitled "Flood Insurance Maps," includes a list of flood insurance zone designations shown on FIRMs. FEMA must modify the list to expand the definition of Zone X to include "areas of future-conditions flood hazard."

All of these changes to the regulations are necessary in the implementation of displaying the future-conditions floodplains on the FIRMs.

Outreach

An initial draft of this report was sent for review to approximately to FEMA Headquarters and Regional Office staff, the Technical Mapping Advisory Council, and the Association of State Floodplain Managers. We incorporated the comments received from these reviewers in a revised version of the draft report, which was posted on the FEMA Flood Hazard Mapping website and referenced in the Proposed Rule published in the *Federal Register* on June 14, 2001, at 66 FR 32293. On that date, FEMA invited interested parties to submit written comments to the Rules Docket Clerk, Office of General Counsel, on or before August 13, 2001. All comments submitted during that comment period were considered in preparing this final version.

References

Akan, A. O. 1993. Urban Stormwater Hydrology: A Guide to Engineering Calculations. Pennsylvania: Technomic Publishing Company, Inc.

Anderson, D. G. 1970. Effects of Urban Development on Floods in Northern Virginia. U.S. Geological Survey Water Supply Paper 2001-C. Washington, DC: U. S. Government Printing Office.

Federal Emergency Management Agency. 1989. Examination of the Use of Future Floodplain Conditions on NFIP Maps.

Federal Emergency Management Agency. 1995. Flood Insurance Study Guidelines and Specifications for Study Contractors: FEMA 37.

Federal Emergency Management Agency. 1997. Modernizing FEMA's Flood Hazard Mapping Program, A Progress Report.

Interagency Advisory Committee on Water Data. 1982. Guidelines For Determining Flood Flow Frequency: Bulletin 17B of the Hydrology Subcommittee, Office of Water Data Coordination, U.S. Geological Survey. Reston, Virginia.

Jennings, M. E., Thomas, W. O., Jr., and Riggs, H. C. 1994. Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Streams: U.S. Geological Survey Water-Resources Investigations Report 94-4002.

McCuen, R. H. 1989. Hydrologic Analysis and Design: Prentice Hall, Englewood Cliffs, New Jersey.

McCuen, R. H. 1993. Microcomputer Applications in Statistical Hydrology: Prentice Hall, Engelwood Cliffs, New Jersey.

Montgomery, D.C., and Peck, E.A. 1982. Introduction to Linear Regression Analysis: John Wiley & Sons.

Sauer, V. B., Thomas, W. O., Jr., Stricker, V. A., and Wilson, K. V. 1983. Flood characteristics of urban watersheds in the United States: U.S. Geological Survey Water-Supply Paper 2207.

Urbonas, B. and Yoon. 1982. Hydrologic Modeling for Flood Hazards: Colorado Urban Hydrograph Procedure: need to add where published.

U.S. Department of the Army, Corps of Engineers. 1990. Hydrologic Engineering Center. HEC-1 Flood Hydrograph Package, User's Manual: Davis, California.

U.S. Department of the Army, Corps of Engineers. 1996. Risk-Based Analysis for Flood Damage Reduction Studies: Davis, California.

Appendix 1
Procedures for Determining Future-Conditions Hydrology

Although it is our recommendation to use future-conditions data developed by communities, FEMA should provide guidelines and specifications for the development of future-conditions hydrology to be used by communities and/or study contractors that are not currently using such data. General guidelines are described below; in addition, appropriate appendices will be developed for FEMA 37 to document these procedures.

To begin with, engineers should work with planners and local officials and use local zoning maps and comprehensive land-use plans to estimate the amount and types of future development within a given watershed. The most significant factors that will affect hydrologic calculations is the amount of impervious area and the improvements in the drainage network that are expected to eventually exist within the watershed. These two factors generally increase flood discharges. After carefully determining the projected development factors, engineers should generally follow the guidelines currently provided in FEMA 37.

FEMA 37 outlines procedures for determining flood discharges for gaged and ungaged watersheds. For ungaged watersheds, both regional regression equations and rainfall-runoff models are considered reasonable methods.

Ungaged Streams

Regional Regression Equations

For ungaged streams, study contractors and revision requestors can use published regional regression equations, such as those developed by USGS, to determine base flood discharges where the equations are applicable. Regression equations have been developed by USGS for urban areas in about a dozen states. The most frequently-used measure of urbanization in these regression equations is the percentage of impervious area in the watershed. The current USGS regional regression equations, for rural and urban areas, are given in the USGS National Flood Frequency (NFF) Program (Jennings and others, 1994).

For those areas of the country that do not have locally-developed urban regression equations, engineers may use methods described in Sauer and others (1983) to adjust for the effects of urbanization. These urban regression equations, which are applicable nationwide, are included in the NFF program and are based on seven watershed parameters. These parameters are contributing drainage area, channel slope, 2-year 2-hour rainfall, basin storage, basin development factor, percentage impervious area, and peak discharge for an equivalent rural drainage area in the same hydrologic area. The urbanization factors are the basin development factor, a measure of improvements in the drainage system, and impervious area measured as the percentage of the watershed that is impervious to infiltration. The equivalent rural peak discharge is estimated from the applicable rural regression equations described by Jennings and others (1994). The percentage of impervious area and the basin development factor for future conditions can be estimated and input to equations developed by Sauer and others (1983) to obtain flood discharges for future land-use conditions.

Rainfall-Runoff Models

Several different rainfall-runoff modeling techniques can also be used to determine future-conditions hydrology. For example, HEC-1 and TR-20 are two frequently-used computer programs that are used to develop flood frequency estimates for the NFIP. These models consist of many hydrologic and hydraulic components, most importantly, the percentage of impervious area and the loss rate. The percentage impervious area in a watershed is the amount of land that is covered by rooftops, parking lots, and sidewalks, for example, where rainfall loss is the amount of rainfall that does not produce runoff. In urban watersheds, for instance, losses occur as a result of several processes, including interception, depression storage, and infiltration. Interception is the part of the rainfall that is blocked by such things as trees, vegetation, and buildings. Depression storage occurs as rainfall is trapped in small puddles by surface depressions; it eventually evaporates into the atmosphere. Infiltration occurs as water passes through the ground surface and fills the pores of the underlying soils. Impervious areas and runoff losses are important factors in hydrologic calculations.

The HEC-1 hydrologic computer model simulates a rainfall event for a given watershed and determines the amount of rainfall runoff produced. To calculate losses, the model has four methods to choose from: uniform loss rate, the Holtan formula, the Green and Ampt model, and the Soil Conservation Service (SCS) curve number technique. The TR-20 computer model uses the SCS curve number technique to calculate runoff. This technique is an empirical method that separates total losses from rainfall, based on soil types, hydrologic conditions, and land-use practices, such as commercial, industrial, and residential areas. HEC-1 and TR-20 are both single event models that compute direct runoff hydrographs resulting from any synthetic or actual rainstorm. Runoff hydrographs are routed through stream channels, reservoirs, and combined at sub-watershed confluences to determine the discharge for a watershed. By varying the input data based on projected development, engineers can use any of these rainfall-runoff models to determine future-conditions discharges.

McCuen (1989) describes a procedure for adjusting peak discharges for given future conditions based on changes in runoff curve number, percentage of impervious area and percentage of hydraulic channel length modified. This procedure is part of the chart method described in the 1975 version of Technical Release 55 (TR-55) of the Natural Resources Conservation Service (formerly the Soil Conservation Service).

Gaged Streams

Bulletin 17B, Guidelines for Determining Flood Flow Frequency (IACWD, 1982) can be used to determine flood discharges for existing conditions (both rural and urban conditions). For watersheds subject to urbanization, one must determine that the annual peak discharges were collected during reasonably constant land-use conditions before applying Bulletin 17B techniques. McCuen (1993) describes several statistical tests for determining whether flood data are homogeneous and suitable for frequency analysis. Various approaches for adjusting flood discharges for gaged streams are discussed below.

Rural flood discharges estimated using Bulletin 17B can be adjusted to future conditions by using the regression equations developed by Sauer and others (1983) that were described earlier. If the annual peak discharges were collected prior to any urbanization, then the flood discharges estimated from Bulletin 17B can be input to the equations developed by Sauer and others (1983) as the equivalent rural discharge.

McCuen (1989) describes a procedure for adjusting a flood record where the data were collected during changing land-use conditions. This procedure consists of first adjusting each annual peak discharge to rural conditions and then adjusting each discharge to current urban conditions based on the percentage of the watershed urbanized. This procedure could be used to adjust each annual peak discharge to some future urbanization condition. Bulletin 17B procedures could then be applied to the peak discharges that were adjusted to future conditions to get the flood frequency estimates.

Use of Confidence and Prediction Limits

There is uncertainty associated with flood discharges for a given frequency from any hydrologic procedure and confidence and prediction limits are used to quantify this uncertainty. Different approaches are used in defining these limits depending on whether the frequency estimates are made using gaging station data, rainfall-runoff models or regional regression equations. Confidence limits are used with gaging station data and rainfall-runoff models and prediction limits are used in regression analysis. Confidence and prediction limits define an interval that will enclose the true flood discharge a given percent of the time. For example, there is a 50 percent chance that the true flood discharge will lie between the upper and lower 50-percent confidence or prediction limits.

Because some communities prefer to use future-conditions hydrology to regulate development in the floodplain, confidence and prediction limits can be used to determine if there are significant differences between existing- and future-conditions flood discharges. If there are no significant differences, then use of future-conditions hydrology can be justified within the existing regulatory constraints of the NFIP. Guidelines on determining what constitutes a significant difference need to be defined.

Procedures for defining confidence limits for flood discharges from analyses of gaging station data are given in Appendix 9 of Bulletin 17B. Confidence coefficients defining the confidence limits for flood discharges are approximated by the non-central t distribution based on the exceedance probability, confidence level, weighted skew coefficient, systematic record length and the standard normal deviate. The confidence coefficients define the number of standard deviations that the upper and lower confidence limits are above the mean of the logarithms of the annual peak discharges.

Procedures for defining confidence limits for rainfall-runoff models, such as HEC-1 and TR-20, are given in the U.S. Army Corps of Engineers EM 1110-2-1619 dated August1, 1996. For these models, Bulletin 17B procedures are used for defining confidence limits with the systematic record length estimated on the basis of engineering judgement. For example, rainfall-runoff models calibrated to several events recorded at gaging stations in the watershed are assumed to have an equivalent record length of 20 to 30 years. Given the equivalent record length, the procedures described above for gaging station data can be applied to flood discharges estimated from rainfall-runoff models.

Procedures for defining both confidence and prediction limits for regression equations are described in several textbooks, such as Montgomery and Peck (1982). Confidence limits as defined in regression analysis pertain to an interval about the mean response from the regression equation for an observation used to calibrate the equation. Prediction limits pertain to an interval about a prediction for a future observation. Therefore, prediction limits are more appropriate for measuring the uncertainty when estimating flood discharges for an ungaged site.

Appendix 2
Selected Communities Using Future-Conditions Hydrology

Three communities in particular that are regulating floodplain development based on future-conditions hydrology are Fairfax County, Virginia; Plano, Texas; and the Denver Urban Drainage and Flood Control District, Colorado. These communities have proven to be proactive in managing their floodplains and are regulating to several other higher standards than the NFIP requires, in addition to future-conditions hydrology. They are all participants in the CRS and are receiving credit for their activities by reduced flood insurance premiums. A detailed discussion of the actions of these communities follows.

Fairfax County, Virginia

Fairfax County is an example of a metropolitan area that has experienced significant urban development due to its proximity to Washington, D.C. The population of Fairfax County has grown tremendously over the years: 41,000 in 1940; 360,000 in 1966, and is estimated at approximately 800,000 today. In the late 1960s, the foreseen urban growth of the county led officials to be concerned with carefully planning future development to ensure optimum land use. The County also recognized the significance of flooding risks in developing land-use plans. They were specifically concerned with the increased flooding risks associated with rapid land development. In an effort to establish guidelines to develop optimum land-use plans, Fairfax County, in cooperation with the City of Alexandria, Virginia, supported a study by the U.S. Geological Survey (USGS) entitled, "Effects of Urban Development on Floods in Northern Virginia", USGS Water-Supply Paper 2001. This study provided an engineering methodology for estimating the increase in flood probabilities as watersheds change from natural conditions to fully developed areas. This tool gave the community a reasonable technological basis for controlling land development in the floodplain.

USGS Water-Supply Paper 2001, written by Daniel G. Anderson, explains the methodologies used to develop 1-percent-annual-chance (100-year) flood discharges for future watershed conditions. The "Anderson Method," as it has been coined, explains that there are five independent variables required to perform the calculations: the size, length, and slope of the watershed, which can be measured from maps; and the percentage of impervious area and type of drainage system, which is estimated for future conditions. This method provides the procedure that can be used to calculate 1-percent-annual-chance (100-year) flood discharges based on future watershed conditions. In fact, the USGS used this methodology in Fairfax County's initial Flood Insurance Studies to produce flood maps in the 1970s.

Since the late 1970s, when floodplain management ordinances were adopted, Fairfax County has been regulating development based on future-conditions hydrology. The maps that were produced by the Anderson Method take future watershed development into account; today, developers are given their choice of methodologies to calculate 1-percent-annual-chance (100-year) flood discharges and delineate the associated floodplains. The Anderson Method, the SCS method, and the Rational formula (for small watersheds) are the different methods that the County allows. The "future" development is based on the County's Comprehensive Plan

Density, the master land-use plan for the County that was developed in accordance with Virginia law.

For floodplain management purposes, Fairfax County uses the maps that were produced by the USGS and others, rather than the NFIP maps; they only consult the FIRM for insurance rating purposes. Additionally, the County maps provide a much better level of detail than the FIRMs do—with 2-foot contour interval and 1” = 100’ horizontal scale, floodplain management is much more efficient.

In addition to future-conditions hydrology, many of Fairfax County’s other floodplain management regulations exceed the minimum standards set forth by the National Flood Insurance Program. For example, a minimum vertical elevation of 18” above the BFE, and a 15’ horizontal setback from the floodplain is required for new construction. In addition, the County is a Level C community (no defined floodway or V Zone) in their floodplain management ordinances; however, they have a more restrictive 0.1’ allowable rise in BFE for fill placed anywhere in the floodplain, rather than the 1.0’ allowable rise criteria for a floodway delineation (Level D). Finally, FEMA guidelines currently direct that floodplains be developed for watersheds that are one square mile (640 acres) in area or larger; Fairfax County, on the other hand, regulates watershed development and establishes floodplains for watersheds 70 acres in area or larger. All of these factors illustrate the County’s commitment to sound floodplain management and land-use practices.

An example of increased flooding hazards as a result of watershed development is Four Mile Run in the adjoining Arlington County. Contributing drainage areas that discharge into Four Mile Run fall within the corporate limits of Fairfax and Arlington Counties, as well as the Cities of Falls Church and Alexandria, Virginia. Recognizing the increasing flooding risks associated with the rapid development of the metropolitan area, the Army Corps of Engineers designed a flood control project, consisting mainly of concrete channels. The project was federally funded, in exchange for a regional flood control plan that prohibited any new construction within the contributing watersheds that would increase the base flood elevations at all.

Fairfax County, within the Washington, DC metropolitan area, is a community that has developed rapidly and continues to do so. The County has proven to be proactive in floodplain management, recognizing that urbanization greatly influences flooding conditions. By regulating to higher standards than the NFIP requires, including future-conditions hydrology, they have proven to establish a successful floodplain management program with the goal of protecting its citizens from the disaster of flooding. By participating in the CRS, they are additionally benefiting the citizens by qualifying for reduced flood insurance rates to reflect their floodplain management activities.

City of Plano, Texas

The City of Plano is a rapidly developing suburb of Dallas, Texas: in 1990, the population was 100,000 and it is approximately 210,000 today. The City began regulating floodplain development based on higher standards than the NFIP requires in the late 1970s. During the 1980s, Flood Insurance Studies were performed for many of the City's large streams. Following that, the consultant that performed those studies provided calculations for future-conditions hydrology based on master land-use plans to the City, and those discharges were used to regulate floodplain development by the City. Today, developers are required to use the future-conditions discharges in the analysis of their projects, and must provide the associated floodplain to the City.

Using the maps that developers provide, the City regulates floodplain development based on future-conditions hydrology. Remarkably, they do not allow any new construction in the floodplain at all. For new construction, the City requires a minimum of 2 feet of freeboard between the future-conditions flood elevation and the first floor of a structure, located outside the floodplain. For new subdivisions, for example, the City requires all of the lots that are in or partially in the floodplain to be dedicated to the City as part of an open-space agreement, or it can be dedicated to the Homeowners' Association. There is no private ownership of the floodplains in the City of Plano.

The City of Plano is a Level C community in floodplain management ordinances. However, the City regulates floodplain development with a no-rise requirement: any new development in the floodplain must not cause any rise in flood elevation. An exception to this requirement is containment on the property of the developer. The new construction can cause a rise in flood elevation, but only if it is mitigated within the developers' property boundaries.

Interestingly, the City places a restriction on channel construction as well. For the major streams, including White Rock Creek, Rowlett Creek, and Spring Creek, any project must preserve flood storage at any given cross section. Therefore, the cross sectional area can not be decreased at all for any project. For the smaller tributaries within the City, a 15% reduction in storage is allowed. Additionally, channels can not be constructed with complete concrete lining; however, concrete bottom lining with earthen sides is permitted.

The City of Plano is another example of a community that is regulating floodplain development to higher standards than the NFIP requires. Future-conditions hydrology, no-rise in flood elevations for new construction, additional freeboard requirements, and restrictions on channel designs are several examples of activities that the City has undertaken to protect its citizens from flood losses, while benefiting them financially through the CRS.

Urban Drainage and Flood Control District, Denver, Colorado

The Denver, Colorado metropolitan area is another example of a region that has experienced significant urban growth throughout the past several decades. Since 1969, the population has grown by about 800,000 people, and the total population today is estimated to be 2.2 million.

The Urban Drainage and Flood Control District (UDFCD) was established by the Colorado State Lgislature in 1969, for the purpose of assisting local governments in the Denver, Colorado metropolitan area in assessing their drainage and flood control problems. UDFCD has jurisdiction over a 1,600 square mile area, which includes the City of Denver, as well as parts of 5 surrounding counties and all or parts of 33 incorporated cities and towns.

UDFCD has been developing flood hazard information based on future-conditions hydrology since the early 1970s, as a response to the rapid growth of the area. Future conditions of the watersheds are determined by the master land-use plans for the areas. In its Master Planning Program, UDFCD develops hydrology for both existing and future conditions, but maps only the future-conditions 1-percent-annual-chance (100-year) floodplain. In its Flood Hazard Area Delineation Program, UDFCD develops and maps future-conditions hydrology only. The maps produced by the UDFCD have considerable detail: 1" = 100' horizontal scale, with two-foot contour intervals, allowing communities to manage their floodplains effectively.

For recent and future studies, UDFCD requires that the Colorado Unit Hydrograph Procedure (CHUP) be used in determining the existing-conditions 1-percent-annual-chance (100-year) flood discharges and the future-conditions 1-percent-annual-chance (100-year) flood discharges for individual subbasin analyses. The CUHP is a hydrologic method that that was developed based on data collected in Colorado. For subbasin combination and flow routing, the SWMM model is used.

UDFCD has the authority to regulate floodplain development through its Floodplain Management Program; however it has chosen not to do so. Instead, it encourages communities in its jurisdiction to adopt their own floodplain management ordinances, with assistance provided by UDFCD. UDFCD provides model ordinances to the communities and encourages floodplain management to higher standards than the NFIP requires, including future-conditions hydrology.

Most communities served by UDFCD have adopted floodplain management ordinances based on future-conditions hydrology. Furthermore, UDFCD encourages new construction to be elevated 12 to 18 inches above the future-conditions base flood elevation. Some communities have additionally implemented stricter floodway standards, for example, a 0.5-foot allowable increase in water surface elevation.

UDFCD has allowed each community to successfully use future-conditions hydrology for floodplain management purposes. By providing technical assistance to local governments, UDFCD has proven to be a great benefit to this urbanizing area.

Appendix 3
Description of the Community Rating System.

The NFIP provides federally backed flood insurance to property owners in communities that participate in the Program. Upon entering the Program, communities are required to adopt and enforce floodplain management ordinances with minimum standards for construction in flood hazard areas. The standards were established to provide guidance to community officials to ensure that any new construction will not cause flooding hazards to increase. Throughout the history of the NFIP, we have found that most communities follow these minimum standards to regulate floodplain development; however, many place higher restrictions on development in the floodplain, and exceed the minimum requirements set forth by the NFIP.

The Community Rating System (CRS) was established to recognize these communities that are regulating to stricter standards than the NFIP requires. In addition, the CRS provides an incentive for communities to do more than fulfill the minimum requirements because it reducing flood insurance premium rates based upon ratings for different activities. It is a voluntary program and was established to support communities by accounting for activities that: (1) reduce flood damage to existing structures, (2) manage areas of flood hazard that are not mapped in the NFIP, (3) protect new buildings to standards that exceed minimum NFIP requirements, (4) help insurance agents obtain flood data, and (5) help people obtain flood insurance.

By reducing the communities' insurance premium rates, the CRS rewards communities that are doing more than meeting the minimum NFIP requirements to help their citizens prevent or reduce losses from floods. Additionally, the CRS provides financial incentives for communities to initiate new flood protection activities. The goals of the CRS are to prevent or reduce flood losses, facilitate accurate insurance rating, and promote the awareness of flood hazards.

The CRS Schedule is broken down into four categories of floodplain management activities for which communities can receive credit. These categories include: (1) Public Information, (2) Mapping and Regulations, (3) Flood Damage Reduction, and (4) Flood Preparedness.

Under Category 2, Mapping and Regulations, activities are credited that provide increased flood hazard protection against new development. Such activities include providing additional flood hazard data than what is shown on FIRMs, preserving open space, enforcing higher regulatory standards, and managing stormwater. These activities all work toward the CRS goals of reducing flood damages and facilitating accurate flood insurance rating.

In providing additional flood data, there are many activities for which a community can receive credit. These include: providing a floodplain for streams that are unstudied by FEMA, providing base flood elevations for areas that are shown on the FIRM as unnumbered A or V zones, or mapping floodplains based on techniques that exceed FEMA's guidelines, such as by future-conditions hydrology, among others.

Appendix 4
Example Flood Insurance Study Report and Map Materials

The following example materials are included in this Appendix:

- FIS Report Narrative – Only those sections of narrative and tables that change due to inclusion of future-conditions 1-percent-annual chance (100-year) flood information is shown. The parts of sections of narrative that change as a result of including future-conditions information are shown in bold and underlined.

- Table 2 – Summary of Discharges

- Table 7 – Floodway Data

- Flood Profiles

- Flood Insurance Rate Map

3.0 ENGINEERING METHODS

For the flooding source studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 1-percent-annual-chance (100-year) flood in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analysis reported herein reflects flooding potentials for the flood events stated above based on conditions existing in the community at the time of completion of this study**. In addition, the future-conditions 1-percent-annual-chance (100-year) flood is reflected in this study. The future-conditions floodplain is based on land use described in community zoning ordinances and delineated on community zoning maps.** Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analysis

Hydrologic analysis for existing conditions were carried out to establish the peak discharge-frequency relationships for each flooding source studied in detail affecting the county. **In addition, hydrologic analysis was carried out for the future-conditions 1-percent-annual-chance (100-year) flood.**

The hydrologic model for the Perkeonin Creek and its tributaries in Sample County was developed using the NRCS Technical Release 20 (TR-20) (Reference 2). An existing condition TR-20 model was first developed using the current landuse/land cover conditions in the watershed. The existing-condition database was obtained by digitizing data supplied by local planning agencies into a Geographic Information System (GIS). In addition, a future condition database for land use was developed for the watershed based on community zoning maps supplied by the local planning agencies. Aerial photography and field investigations were also used to verify the database.

The TR-20 existing-condition model was calibrated by reproducing flood hydrographs for four historical events at the stream gage. Peak rate of discharge, runoff volume, and hydrograph shape were the parameters used for calibration and verification. In addition, TR-20 simulated flows compared

within 10% to discharge from the frequency analysis based on procedures in the Interagency Advisory Committee for Water Data Bulletin 17B (Reference 3).

After calibration, The TR-20 existing-condition model was run for the 2-, 10-, 50-, 100-, and 500-year events using 24 hour rainfall values from the National Weather Bureau Technical Paper No. 40 (Reference 4). In addition the future-conditions 1-percent-annual-chance (100-year) flood event was run through TR-20. The future watershed condition was based on land-use conditions in the watershed reflected in the community zoning maps. Land cover was determined from field investigations. The resulting flood discharges were then used in USACE HEC-RAS (Reference 30) to generate water-surface profiles.

A summary of the drainage area-peak discharge relationships for the streams studied by detailed methods are shown in Table 2, “Summary of Discharges.”

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. Therefore, for each study, FEMA generally provides existing-conditions 1-percent-annual-chance (100-year) flood elevations and delineations of the existing-conditions 1-percent-annual-chance (100-year) and 0.2-percent-annual-chance (500-year) floodplain boundaries and regulatory floodway to assist in developing floodplain management measures. **For this study, in response to request by the community, the future-conditions 100-year floodplain boundary was delineated on the FIRM (Exhibit 2) instead of the existing-conditions 0.2-percent-annual-chance (500-year) floodplain boundary. However, in order to comply with Executive Order No. 11988, the existing-conditions 0.2-percent-annual-chance (500-year) flood elevations are available from the Flood Profiles (Exhibit 1).**

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the existing-conditions 1-percent-annual-chance (100-year) flood has been adopted by FEMA as the base flood for floodplain management purposes. **For this study, the future-conditions 1-percent-annual-chance (100-year) flood was employed instead of the existing-conditions 0.2-percent-annual-chance (500-year) flood** to indicate additional areas of flood risk in the community. For the streams studied by detailed methods, **the existing- and future-conditions 1-percent-annual-chance (100-year)** floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic maps, photogrammetric methods and previously printed FISs (References 41, 116,117 and 130).

For the flooding sources studied by approximate methods, the boundaries of the existing-conditions 1-percent-annual-chance (100-year) floodplain were delineated using the previously printed FISs (References 28 and 29).

The existing- and future-conditions 1-percent-annual-chance (100-year) floodplain boundaries are shown on the FIRM (Exhibit 2). On this map, the **existing-conditions 1-percent-annual-chance)** (100-year) floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A and AE) and the **future-conditions 1-percent-annual-chance (100-year)** floodplain boundary corresponds to the boundary of areas of **projected special flood hazards (Zone X)**. In cases where the **existing- and future-conditions 1-percent-annual-chance** (100-year) floodplain boundaries are close together, only the **existing-conditions 1-percent-annual-chance** (100-year) floodplain boundary has been shown on the FIRM (Exhibit 2). Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

For the streams studied by approximate methods, only the **existing-conditions 1-percent-annual-chance** (100-year) floodplain boundary is shown on the FIRM (Exhibit 2).

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the **existing-conditions 1-percent-annual-chance** (100-year) floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent-annual-chance (100-year) flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodway in this study is presented to local agencies as a minimum standard that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodway presented in this study was computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections (Table 7). The computed floodway is shown on the FIRM (Exhibit 2). In cases where the floodway and existing-conditions 1-percent-annual-chance (100-year) floodplain boundaries are either close together or collinear, only the floodway boundary is shown. **In addition to the existing-conditions 1-percent-annual-chance (100-year) flood elevations and floodway, the future-conditions 1-percent-annual-chance (100-year) elevations without the floodway is shown in Table 7.**

5.0 INSURANCE APPLICATIONS

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the existing-conditions 0.2-percent-annual-chance (500-year floodplain), **areas between the existing-conditions and future-conditions 1-percent-annual-chance (100-year) floodplain boundaries,** and to areas of 1-percent-annual-chance (100-year) flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance (100-year) flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent-annual-chance (100-year) flood by levees. No base flood elevations or depths are shown within this zone.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the **existing-conditions 1-percent-annual-chance (100-year)** floodplains that were studied by detailed methods, shows selected whole-foot base flood elevations or average depths. Insurance agents use the zones and base flood elevations **for existing conditions** in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by **cross-hatching** and symbols, the **existing- and future-conditions 1-percent-annual-chance (100-year)** floodplains. Floodways for the **existing-conditions 1-percent-annual-chance (100-year)** flood event and the locations of selected cross sections used in the hydraulic analysis and floodway computations are shown where applicable.

The current FIRM presents flooding information for the entire geographic area of Sample County. Previously, separate Flood Hazard Boundary Maps and/or FIRMs were prepared for each identified flood-prone incorporated community and the unincorporated areas of the county. This countywide FIRM also includes flood hazard information that was presented separately on Flood Boundary and Floodway Maps, where applicable. Historical data relating to the maps prepared for each community are presented in Table 8, "Community Map History."

TABLE 2. SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)				
		10-YEAR	50-YEAR	100-YEAR		500-YEAR
				EXISTING	**FUTURE**	

PERKIOMEN CREEK						
At confluence with The Schuylkill River						
At a point approximately 0.63 mile upstream of con fluence of Norma Run	362.0	29,350	41,600	47,000	54,000	59,700
At confluence of Tributary A to Perkiomen Creek	293.9	27,550	38,250	42,700	48,200	52,500
At USGS gage No. 01473000 at Graterford	291.2	27,550	38,250	42,700	48,200	52,500
Downstream of confluence of Swamp Creek	279.0	25,500	38,000	41,000	47,200	52,500
Upstream of confluence of Swamp Creek	206.0	17,500	29,000	35,850	44,200	52,500
At a point approximately 350 feet upstream of Kratz Road	150.6	13,000	21,300	26,800	36,000	45,750
Upstream of confluence of Unami Creek	142.8	13,000	21,300	26,000	35,500	45,000
Upstream of confluence of Deep Creek	95.0	7,000	12,150	15,650	22,000	29,100
Upstream of confluence of Macoby Creek	89.0	6,200	10,850	14,100	19,200	24,700
Upstream of Church Road	71.0	5,000	8,800	11,450	15,600	20,100
Upstream of confluence of Hosensack Creek	37.8	4,250	8,000	10,150	13,400	16,800
	17.0	2,220	4,350	5,600	7,500	9,50

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NGVD)				
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE	FUTURE CONDITIONS
Perkiomen Creek									
A	430	452	7,956	5.91	96.9	96.9	97.9	1.0	99.7
B	1,000	489	8,649	5.43	97.0	97.0	98.0	1.0	99.8
C	1,615	410	7,372	6.38	97.2	97.2	98.2	1.0	100.0
D	2,535	369	6,185	7.60	97.8	97.8	98.7	0.9	100.6
E	2,960	412	6,864	6.85	97.9	97.9	98.9	1.0	100.7
F	3,925	537	8,740	5.38	98.0	98.0	99.0	1.0	100.8
G	5,360	736	11,375	4.13	99.0	99.0	100.0	1.0	101.9
H	5,800	680	11,105	4.23	99.1	99.1	100.0	0.9	102.0
I	6,825	630	10,033	4.68	99.2	99.2	100.2	1.0	102.1
J	7,805	528	8,810	5.30	99.4	99.4	100.3	0.9	102.3
K	8,850	505	8,760	5.33	99.5	99.5	100.4	0.9	102.4
L	9,495	406	7,936	5.88	100.0	100.0	101.0	1.0	102.9
M	10,315	366	7,281	6.41	100.3	100.3	101.2	0.9	103.3
N	11,255	378	7,350	6.35	100.8	100.8	101.8	1.0	103.8
O	12,255	387	7,227	6.46	101.3	101.3	102.3	1.0	104.3
P	13,130	378	6,409	7.29	101.8	101.8	102.8	1.0	104.7
Q	14,360	330	6,907	6.76	103.4	103.4	104.4	1.0	106.3
R	14,670	314	6,704	6.97	103.7	103.7	104.6	0.9	106.6
S	15,275	349	6,628	6.53	104.2	104.2	105.0	0.8	107.2
T	15,800	398	6,959	6.22	104.5	104.5	105.5	1.0	107.5
U	16,715	484	8,104	5.34	105.2	105.2	106.2	1.0	108.2
V	17,625	530	8,869	4.88	106.0	106.0	107.0	1.0	108.9
W	18,545	470	9,415	4.60	107.8	107.8	108.8	1.0	110.8
X	19,085	437	8,837	4.90	108.0	108.0	109.0	1.0	111.0
Y	20,130	388	8,360	5.18	108.5	108.5	109.5	1.0	111.4
Z	20,665	368	7,212	6.00	108.6	108.6	109.6	1.0	111.5
AA	21,120	317	6,729	6.43	108.9	108.9	109.9	1.0	111.9
AB	21,980	235	4,678	9.26	109.5	109.5	110.3	0.8	112.4

[1]Feet above confluence with the Schuylkill River

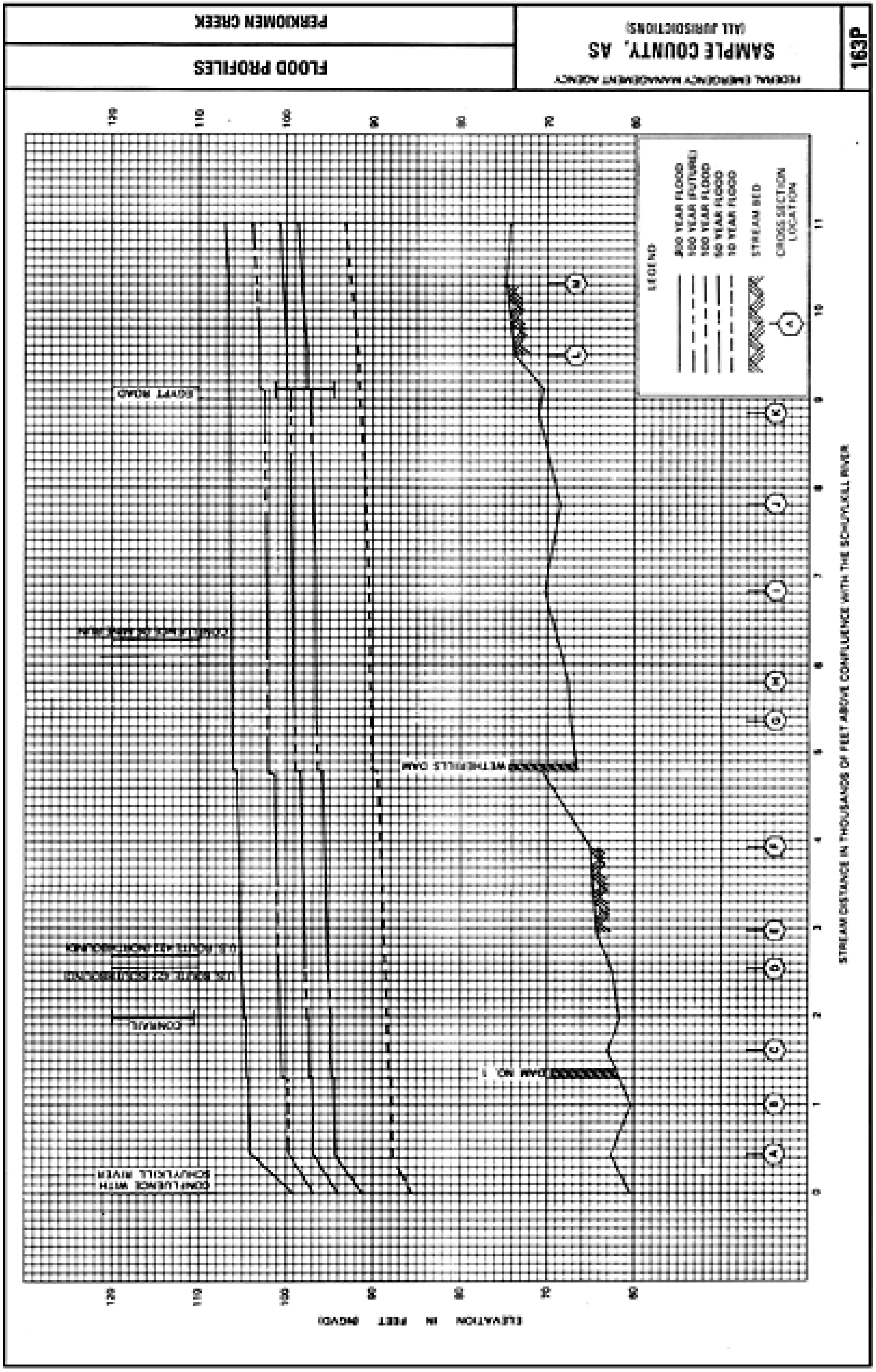
TABLE 7

FEDERAL EMERGENCY MANAGEMENT AGENCY

SAMPLE COUNTY, AS
(ALL JURISDICTIONS)

FLOODWAY DATA

PERKIOMEN CREEK


PERKIOMEN CREEK
FLOOD PROFILES
FEDERAL EMERGENCY MANAGEMENT AGENCY
SAMPLE COUNTY, AS
(ALL JURISDICTIONS)
163P
LEGEND
500 YEAR FLOOD
100 YEAR (FUTURE)
100 YEAR FLOOD
50 YEAR FLOOD
10 YEAR FLOOD
STREAM BED
CROSS SECTION LOCATION
STREAM DISTANCE IN THOUSANDS OF FEET ABOVE CONFLUENCE WITH THE SCHUYLKILL RIVER
ELEVATION IN FEET (NGVD)
WETHERILLS DAM
DAM NO. 1
CONFLUENCE WITH SCHUYLKILL RIVER
EGYPT ROAD
CONRAIL