

MANAGING FLOODPLAIN DEVELOPMENT

IN

APPROXIMATE ZONE A AREAS

**A GUIDE FOR OBTAINING AND DEVELOPING
BASE (100-YEAR) FLOOD ELEVATIONS**

APRIL 1995

FOREWORD

This guide was developed for use by community officials, property owners, developers, surveyors, and engineers who may need to determine Base (100-year) Flood Elevations (BFEs) in special flood hazard areas designated as approximate Zone A on the Federal Emergency Management Agency's Flood Insurance Rate Maps published as part of the National Flood Insurance Program. One of the primary goals of this document is to provide a means of determining BFEs at a minimal cost.

The guidance provided herein is primarily intended for use in riverine and lake areas where flow conditions are fairly uniform, and do not involve unusual flow regimes (rapidly varying flow, two-dimensional flow, supercritical flow, hydraulic jumps, etc.).

This guide is not to be used for areas that experience alluvial fan flooding or areas that contain characteristics of alluvial fan flooding. In addition, this guide is not to be used in Zone V (velocity) areas or coastal Zone A areas that are subject to flooding due to storm surge from hurricanes and other coastal storms. Furthermore, guidance on determining regulatory floodways is not provided in this guide.

Notes on the .PDF version of the Zone A Manual

Appendices 8 and 9 (hand calculations) were not included in the .PDF (Internet) version of this Manual. The information was not in a text format. The scanned images of Appendices 8 & 9 would have made the file size of this document much larger. To keep the file size down they were omitted.

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I. INTRODUCTION

This guide is primarily intended to assist local community officials in administering and enforcing the floodplain management requirements of the National Flood Insurance Program (NFIP). This document provides guidance for determining Base (100-year) Flood Elevations (BFEs) in special flood hazard areas that have been identified and designated as approximate Zone A on a community's NFIP maps. Zone A identifies an approximately studied special flood hazard area for which no BFEs have been provided. Although BFEs are not provided, the community is still responsible for ensuring that new development within approximate Zone A areas is constructed using methods that will minimize flood damages. This often requires obtaining or calculating BFEs at a development site.

Developers, property owners, engineers, surveyors, and others at the local level who may be required to develop BFEs for use in approximate Zone A areas should also find this guide useful. Included in this guide are methodologies that can be used to develop BFEs, which can be used to determine the elevation or floodproofing requirements for buildings. The detailed methodologies described in this guide can also be used to develop the BFE information necessary to obtain a Letter of Map Amendment or a Letter of Map Revision Based on Fill from the Federal Emergency Management Agency (FEMA) to remove a legally defined property or structure from a special flood hazard area. In addition, Letter of Map Revision requestors may use the detailed methods in this document to develop the BFE information that must be submitted to FEMA to demonstrate that an area will not be flooded during the 100-year flood.

II. NATIONAL FLOOD INSURANCE PROGRAM BACKGROUND

In 1968, the United States Congress passed the National Flood Insurance Act, which created the NFIP. Congress recognized that the success of this program required that community participation be widespread, that studies be conducted to accurately assess the flood risk within each participating flood-prone community, and that insurance premium rates be established based on the risks involved and accepted actuarial principles. To meet these objectives, the 1968 Act called for: 1) the identification and publication of information within five years for all floodplain areas that have special flood hazards; and 2) the establishment of flood-risk zones in all such areas to be completed over a 15-year period following the passage of the act.

Within the first year of NFIP operation, it became evident that the time required to complete the detailed flood insurance studies would markedly delay implementation in many flood-prone communities. As a result, an interim means for more rapid community participation in the NFIP had to be provided. The Housing and Urban Development Act of 1969 expanded participation by authorizing an Emergency Program under which insurance coverage could be provided at non-actuarial, federally-subsidized rates in limited amounts during the period prior to completion of a community's flood insurance study.

Until engineering studies could be conducted for these communities, Flood Hazard Boundary Maps, such as the one shown in Figure 1, "Flood Hazard Boundary Map," which delineated the boundaries of the community's special flood hazard areas, were prepared using available data or approximate methods. The Flood Hazard Boundary Maps identified, on an approximate basis, the areas within a community subject to inundation by the 100-year flood (i.e., Zone A). The 100-year flood has a one-percent chance of being equalled or exceeded in any given year. The Flood Hazard Boundary Map was intended to assist communities in managing floodplain development, and insurance agents and property owners in identifying those areas where the purchase of flood insurance was advisable.

The Flood Disaster Protection Act of 1973, which also amended the 1968 Act, required that flood-prone communities be notified of their flood hazards to encourage program participation. This notification was accomplished through the publication of Flood Hazard Boundary Maps for all communities that were identified as containing flood hazard areas. In addition, the 1973 Act required the purchase of flood insurance by property owners who were being assisted by

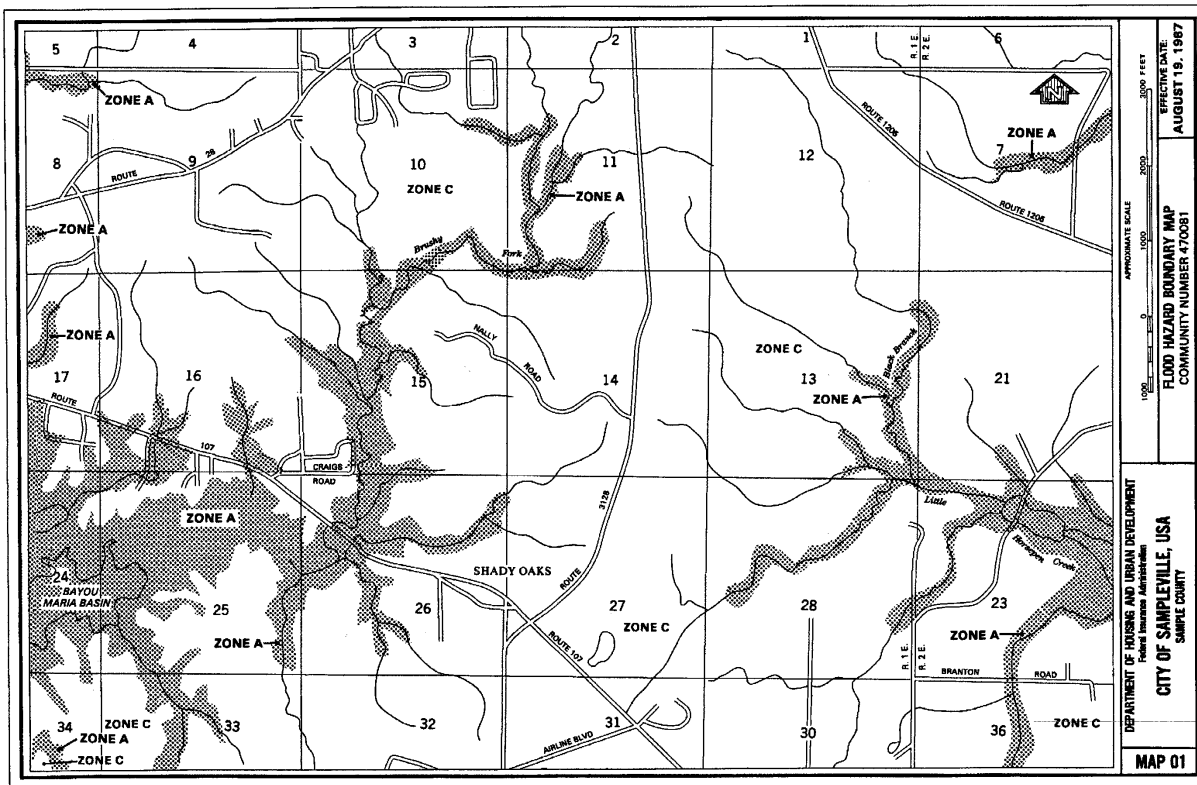


Figure 1 - Flood Hazard Boundary Map

Federal programs, or by Federally supervised, regulated, or insured agencies or institutions, in the acquisition or improvement of land or facilities located, or to be located, in special flood hazard areas. This act also severely limited Federal financial assistance in the flood hazard areas of communities which did not join the NFIP.

The initial Flood Hazard Boundary Maps for communities identified as having flood hazards were prepared using available floodplain data contained in reports developed by a variety of Federal, State, and local sources. For those communities that had no available flood information, approximate hydrologic and hydraulic methods or historical flood data were used to determine the extent of the special flood hazard areas.

Flood Insurance Studies that used detailed hydrologic and hydraulic analyses to develop BFEs and designate floodways and risk zones were subsequently developed for most NFIP communities. The results of a Flood Insurance Study were

issued to the community in the form of a Flood Insurance Rate Map (FIRM), such as the one shown in Figure 2, "Flood Insurance Rate Map," and, in most cases, a Flood Boundary and Floodway Map and a Flood Insurance Study report. Once more detailed risk data were provided, the community could enter the Regular Program whereby more comprehensive floodplain management requirements were imposed and higher amounts of insurance could be purchased by owners of structures.

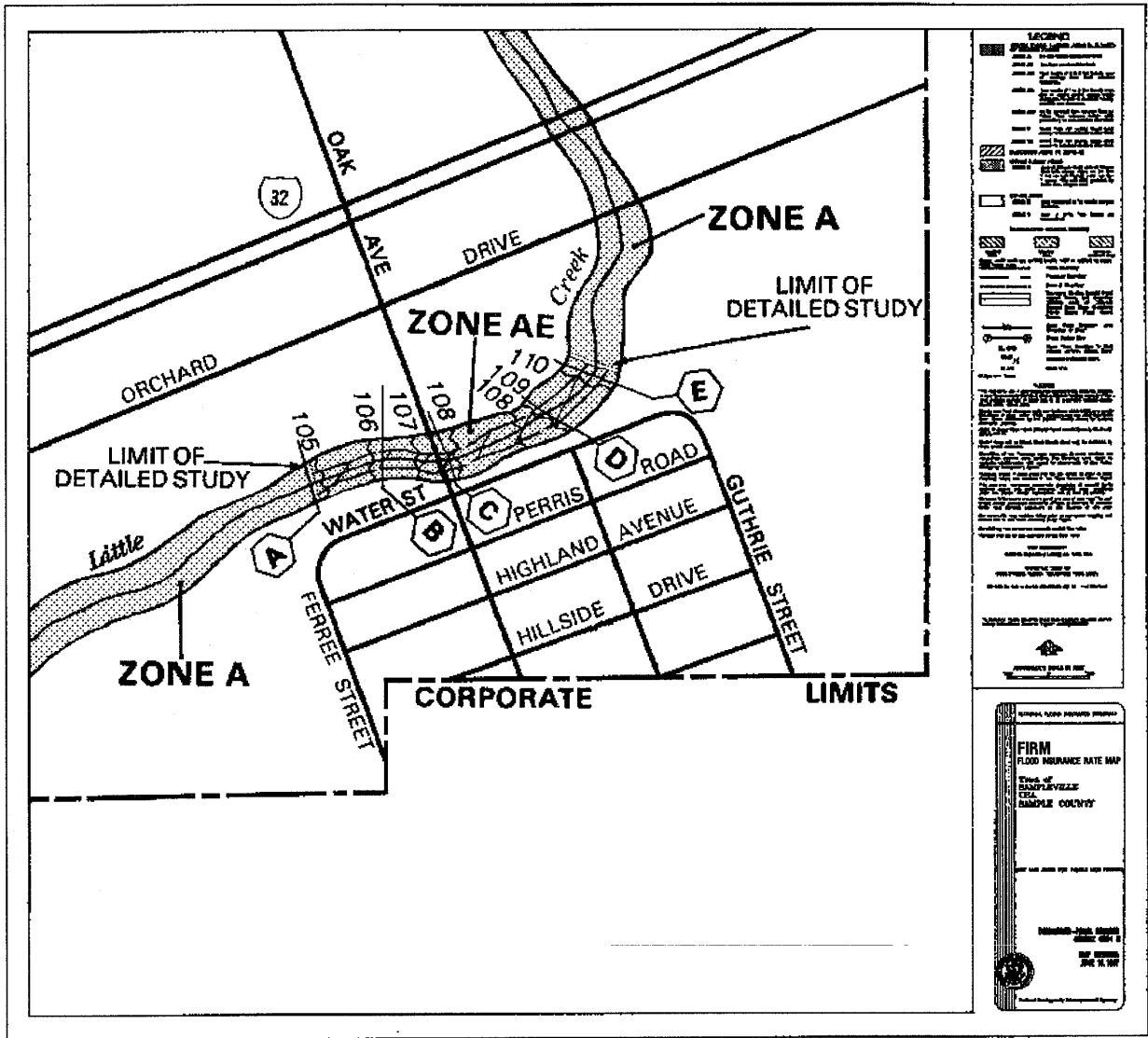


Figure 2 - Flood Insurance Rate Map

As early as 1976, FEMA recognized that some communities did not require a detailed Flood Insurance Study because there were few existing buildings in the floodplain and minimal development pressure. Shortly thereafter, FEMA began utilizing a special conversion process whereby communities

were converted to the Regular Program without a Flood Insurance Study. Consequently, these communities were converted using FIRMs in which all of the special flood hazard areas were designated as approximate Zone A, without BFEs.

Although over 10,000 communities have now been provided detailed Flood Insurance Studies and issued FIRMs that include BFEs, many floodplains are still designated as approximate Zone A without BFEs. Due to the costs of developing detailed risk data, areas not subject to development pressure are studied using approximate methodologies and continue to be shown on the FIRM as approximate Zone A areas. FEMA only provides BFEs for the floodplains of those flooding sources that are currently subject to development pressure or are projected at the initiation of a Flood Insurance Study or Flood Insurance Study restudy to be subject to development pressure during the immediate future. Generally, a planning period of approximately five years is used. Even in these cases, BFEs are provided on a priority basis due to funding constraints. The community plays a major part in the determination of the level of detail required in the study of selected streams. As a result, most communities will have FIRMs that include special flood hazard areas for flooding sources that have been studied in detail with BFEs and special flood hazard areas for flooding sources that have been studied using approximate methods, and have been designated as approximate Zone A.

III. APPLICABLE NATIONAL FLOOD INSURANCE PROGRAM FLOODPLAIN MANAGEMENT REQUIREMENTS IN APPROXIMATE ZONE A AREAS

The primary requirement for community participation in the NFIP is the adoption and enforcement of floodplain management regulations that meet the minimum standards of the NFIP regulations in Title 44 of the Code of Federal Regulations (CFR) Section 60.3. These minimum standards vary depending on the type of flood risk data provided to the community by FEMA. The intent of floodplain management regulations is to minimize the potential for flood damages to new construction and to avoid aggravating existing flood hazard conditions that could increase potential flood damages to existing structures. To protect structures in riverine and lacustrine areas, the NFIP regulations require that the lowest floor (including basement) of all new construction and substantial improvements of residential structures be elevated to or above the BFE. New or substantially improved non-residential structures in riverine areas must either be elevated or floodproofed (made watertight) to or above the BFE.

Requirements for Obtaining BFE Data

In areas designated as approximate Zone A, where BFEs have not been provided by FEMA, communities must apply the provisions of Paragraph 60.3(b) of the NFIP regulations. Subparagraph 60.3(b)(4) requires that communities:

Obtain, review and reasonably utilize any base flood elevation and floodway data available from a Federal, State, or other source... [44 CFR 60.3 (b)(4)]

Section IV describes the sources from which BFE data may be obtained. These data are to be used as criteria for requiring that new construction, substantial improvements, and other development within all approximate Zone A areas meet the applicable requirements in Paragraphs 60.3(c) and (d) of the NFIP regulations, including the requirement that structures have their lowest floors elevated to or above the BFE (or floodproofed to or above the BFE for non-residential structures). These data should be used as long as they reasonably reflect flooding conditions expected during the base (100-year) flood, are not known to be scientifically or technically incorrect, and represent the best data available. Communities should consider formally adopting these data by reference as part of their floodplain management regulations.

Requirements for Developing BFE Data

Under Subparagraph 60.3(b)(3) of the NFIP regulations, communities must also:

Require that all new subdivision proposals and other proposed development (including proposals for manufactured home parks and subdivisions) greater than 50 lots or 5 acres, whichever is the lesser, include within such proposals base flood elevation data; [44 CFR 60.3 (b)(3)]

This means that any subdivision which meets this threshold must be evaluated to determine if the subdivision proposal is affected by an approximate Zone A area and whether BFE data are required. BFE data are required for the affected lots in the subdivisions shown in Figure 3, "Proposed 76-Lot Subdivision," and Figure 4, "Proposed 6.7-Acre Subdivision." Figure 3 clearly shows a 76-lot subdivision with several lots affected by an approximate Zone A area. The subdivision depicted in Figure 4 is only 12 lots, but because the subdivision is greater than 5 acres and clearly shows buildable sites affected by an approximate Zone A area, BFE data are required.

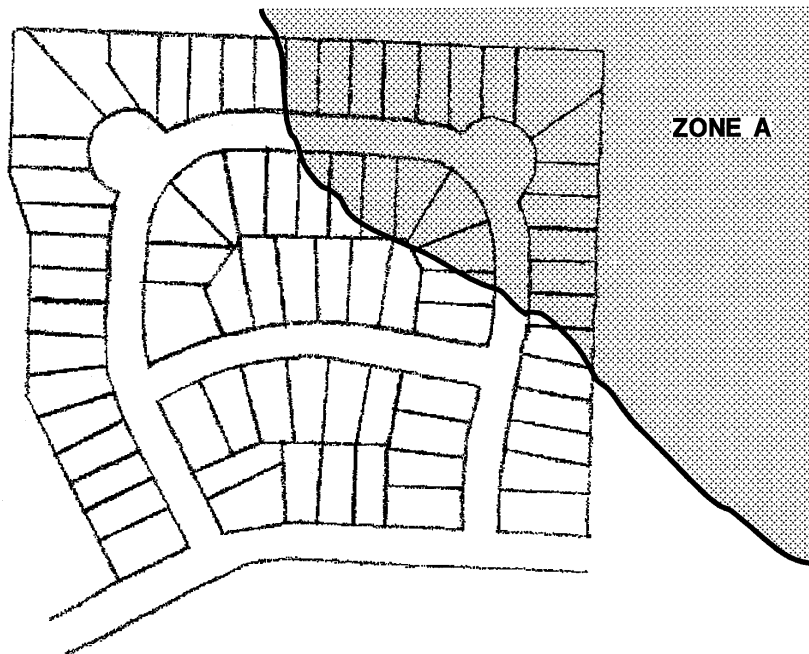


Figure 3 - Proposed 76-Lot Subdivision

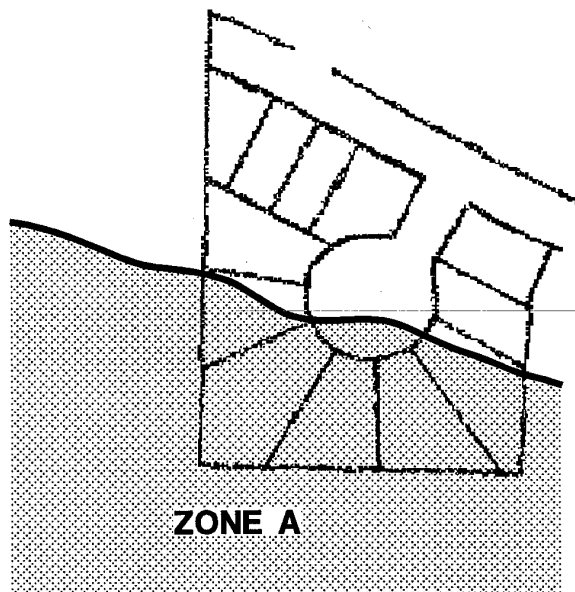


Figure 4 - Proposed 6.7-Acre Subdivision

Communities are encouraged to address the flood hazards at the earliest stages of subdivision planning rather than at the actual placement of individual structures. If a community can work with the developer and others when land is being subdivided, many long-term floodplain management benefits can be achieved, particularly if the floodplain is avoided altogether.

In Figure 5, "Proposed 76-Lot Subdivision," the entire approximate Zone A area is to be dedicated as open space. If the planned subdivision shows the floodplain is contained entirely within an open space lot, it may not be necessary to conduct a detailed engineering analysis to develop BFE data.

Also, it may not be necessary to develop detailed BFE data in large-lot subdivisions or single-lot subdivisions that are within the thresholds under Subparagraph 60.3(b)(3) of the NFIP regulations when the actual building sites are clearly outside of the Zone A area. In Figure 6, "Proposed 5.6-Acre Subdivision," it is evident from the topographic features of this 5.6-acre subdivision that the building sites would be clearly out of the floodplain since the proposal indicates a steep grade between the approximate Zone A area and the building sites which are located on natural high ground.

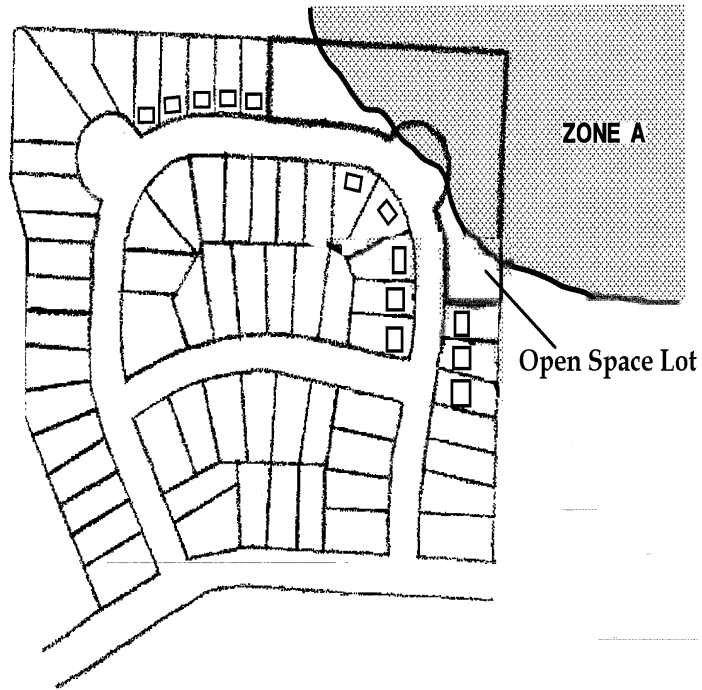


Figure 5 - Proposed 76-Lot Subdivision

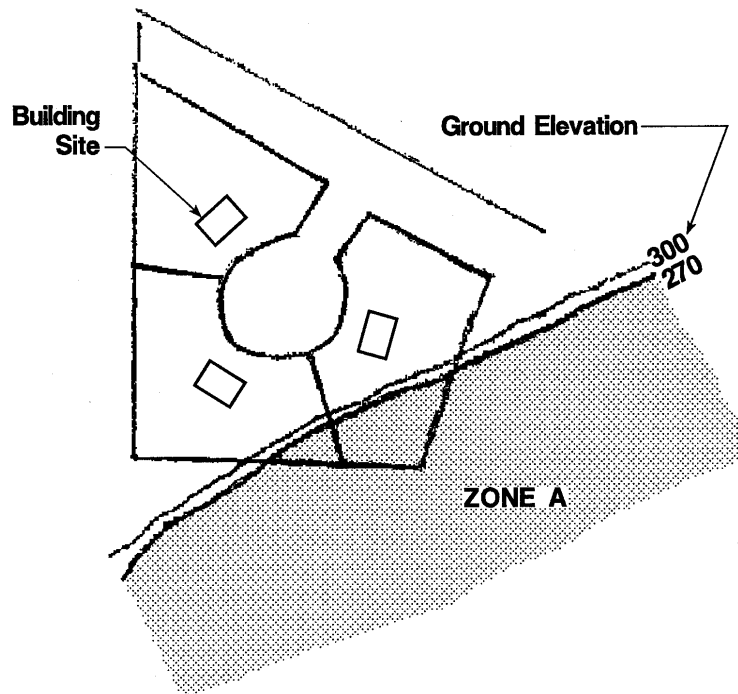


Figure 6 - Proposed 5.6-Acre Subdivision

If the grade between the actual building sites and the approximate Zone A area of the proposed subdivision is relatively gradual, as shown in Figure 7, "Proposed 6.7-Acre Subdivision," the floodplain could extend beyond what is shown on the Flood Insurance Rate Map. It is very likely that flooding could affect the building sites. In this case, an analysis should be conducted to determine the location of the 100-year floodplain and the BFE.

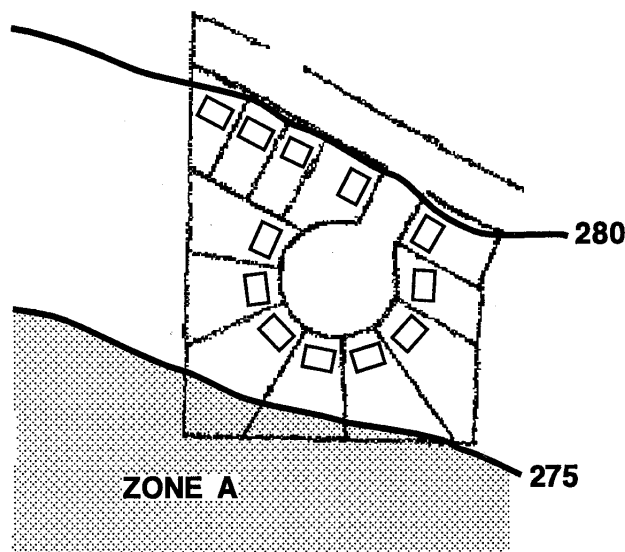


Figure 7 - Proposed 6.7 Acre Subdivision

For developments that exceed the thresholds identified in NFIP regulations Subparagraph 60.3(b)(3), BFEs must be either obtained from other sources or developed using detailed methodologies comparable to those contained in a Flood Insurance Study. Section V describes some of the detailed methodologies available that can be used to develop BFE data when none are available from the sources listed in Section IV.

If the size of the new subdivision or other proposed development falls below the thresholds specified in NFIP regulations Subparagraph 60.3(b)(3) and no BFE data are available from the sources listed in Section IV, the community must still apply, at a minimum, the requirements of Subparagraph 60.3(a)(3) to proposed structures or Subparagraph 60.3(a)(4) to subdivisions and other developments within approximate Zone A areas. These paragraphs require that permit officials:

Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall (i) be designed (or modified) and adequately anchored to prevent floatation, collapse, or lateral movement..., (ii) be constructed with materials resistant to flood damage, (iii) be constructed by methods and practices that minimize flood damages, and (iv) be constructed with electrical, heating, ventilation, plumbing, and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding. [44 CFR 60.3(a)(3)]

Review subdivision proposals ... including manufactured home parks or subdivisions ... to assure that (i) all such proposals are consistent with the need to minimize flood damage within the flood-prone area, (ii) all public utilities and facilities ... are located and constructed to minimize or eliminate flood damage, and (iii) adequate drainage is provided to reduce exposure to flood hazards; [44 CFR 60.3(a)(4)]

One way that communities can ensure that building sites will be reasonably safe from flooding for proposed developments that fall below the thresholds in Subparagraph 60.3(b)(3) is to use the simplified methods outlined in Section V for estimating a BFE. Another approach to ensure that a building site is reasonably safe from flooding is to require the structure to be elevated above the highest adjacent grade by a specified number of feet based on the local official's knowledge of flood conditions in the area. In the absence of available BFE data from other sources, the community may require the permit applicant to elevate the structure two or more feet above the highest adjacent grade which qualifies the structure for reduced flood insurance rates. Elevation of the structure to four feet above the highest adjacent grade will enable the structure to qualify for substantially reduced flood insurance rates.

However, some states and communities require that BFE data be developed for all subdivisions and/or floodplain development within approximate Zone A areas, not just those subdivisions

which meet the 50-lot or 5-acre threshold. A community may, at its discretion, require the use of detailed methods for such development. While this requirement is more restrictive than NFIP minimum requirements, the NFIP regulations specifically recognize and encourage states and communities to adopt and enforce more restrictive floodplain management regulations in those instances where the state or community believes that it is in the best interest of its citizens.

No matter what the size of the subdivision or other development proposal, requests to revise or amend effective Flood Insurance Study information through the procedures outlined in Part 65 and Part 70 of the NFIP regulations must be based on detailed methodologies presented in Section V or other methodologies comparable to those found in a Flood Insurance Study. The analysis used to develop the BFEs must be certified by a registered professional engineer or licensed land surveyor, as appropriate, if the BFEs are to be used to revise or amend an NFIP map.

Use of Draft or Preliminary Flood Insurance Study Data

The data from a draft or preliminary flood insurance study constitutes "available data" under Subparagraph 60.3(b)(4). Communities must reasonably utilize the draft or preliminary flood insurance study data under the section of their ordinance that requires the use of other base flood data when detailed BFE data has not been published in a flood insurance study. Communities are given discretion in using draft or preliminary flood insurance study data only to the extent that the technical or scientific validity of the proposed flood elevation data is questioned. If a community decides not to use the draft or preliminary flood insurance data in a FIS because it is questioning the data through a valid appeal, the community must still assure that buildings are constructed using methods and practices that minimize flood damages in accordance with the requirements under Subparagraphs 60.3(a)(3) and (4).

When all appeals have been resolved and a notice of final flood elevations has been provided by FEMA, communities are required to use the data from the flood insurance study for regulating floodplain development in accordance with Subparagraph 60.3(b)(4) since the data represents the best data available. Communities must regulate floodplain development using the flood insurance study data under Subparagraph 60.3(b)(4) until such time as the community has adopted the effective FIRM and flood insurance study.

Advantages of Developing BFE Data

While the NFIP regulations do not require that communities develop BFE data in approximate Zone A areas when proposed development is below the thresholds in NFIP regulations Subparagraph 60.3(b)(3), there are significant advantages and financial benefits for communities and individual property owners that develop BFE data. These advantages and benefits include:

- protecting structures up to the BFE will minimize and reduce future flood losses, resulting in long-term savings to the individual, the community, and the National Flood Insurance Fund;
- flood insurance policies in approximate Zone A areas that are rated using a BFE will often qualify for significantly lower insurance rates than policies that are rated without a BFE. The difference in flood insurance premiums could be substantial;
- less burden will be placed on the permit official because he or she can require protection to a specified elevation. Without a BFE, the permit official must make judgements as to what constitutes "reasonably safe from flooding" and "constructed with materials and practices that minimize flood damages";
- the NFIP's Community Rating System establishes flood insurance premium discounts of up to 45 percent for policy holders within communities that have a floodplain management program that exceeds NFIP minimum requirements. Sizable Community Rating System credits are available for Community Rating System communities that develop BFEs for areas designated as approximate Zone A on their Flood Hazard Boundary Map or FIRM, or that require site-specific engineering analyses for development proposals; and
- by specifying a BFE in an approximate Zone A area, a building or property can, in some circumstances, be removed from the floodplain by issuance of a Letter of Map Amendment or Letter of Map Revision in accordance with Part 65 and Part 70 of the NFIP regulations. *While these procedures eliminate the requirement that flood insurance be purchased as a condition of obtaining a loan from a Federally insured or regulated lender, a lending institution may, at its discretion, require the purchase of flood insurance.*

IV. OBTAINING EXISTING BASE (100-YEAR) FLOOD ELEVATIONS

The NFIP Regulations at 44 CFR 60.3 require that structures be elevated or floodproofed (non-residential structures only) to provide protection from flood damage. A BFE must be established before such flood protection measures can be used. There are a variety of computational methods that can be employed to determine BFEs. However, these methods can be costly. Before computational methods are used, every attempt should be made to obtain information, in the form of floodplain studies or computations, from Federal, State, or local agencies. Data obtained from these agencies may be adequate to determine BFEs with little or no additional research, computation, or cost.

Local officials who obtain BFE data should maintain the information for future reference. Local officials should also consider making a search for BFE data for the entire community. By doing so, the local officials may not have to conduct a search each time a floodplain development permit is requested. If the data reasonably reflect flooding conditions, a community should consider adopting the information into its floodplain management ordinance.

Provided below are a list of agencies that can be contacted to determine if any BFE data have already been developed. When obtained, these data should be evaluated to ensure that they reasonably reflect flooding conditions expected at the site during the 100-year flood, are scientifically or technically correct, and represent the best data available.

Three major sources of existing data are highlighted in this section: FEMA, other Federal agencies, and State and local agencies.

FEMA

FEMA's technical evaluation contractors maintain libraries that contain technical and administrative data developed during the preparation of Flood Insurance Studies, as well as the resulting Flood Insurance Study reports and NFIP maps. FEMA can be contacted to determine whether or not sufficient information exists in the back-up data to calculate BFEs. For some flooding sources that are designated as approximate Zone A, FEMA may have detailed flooding information that has not yet been incorporated into the community's Flood Insurance Study. FEMA can be contacted to obtain this information where it exists.

FEMA regularly conducts restudies of flood hazards in an effort to keep Flood Insurance Studies accurate and up-to-date. As part of these restudies, detailed BFE data for approximate Zone A areas may be developed. During the time that elapses between FEMA obtaining restudy data and the incorporation of BFE data areas into a revised Flood Insurance Study, a community may reasonably use the BFE data from the restudy in approximate Zone A areas in accordance with Subparagraph 60.3(b)(4).

In addition, flooding sources restudied by FEMA may often impact several communities. FEMA may be unable to immediately update the Flood Insurance Study for every community impacted due to funding constraints. Therefore, BFEs may have been developed for streams within a community that have not yet been incorporated into the Flood Insurance Study.

It is also possible that a previous request to revise flood hazards along a stream or lake may be on file with FEMA, and that BFEs, which may be applicable to other areas of the same stream or lake, may have been computed for that request.

FEMA data should be sought when trying to obtain or determine BFEs for an approximate Zone A area, so that if BFEs have already been determined for an approximate Zone A area, then other BFE determinations in the same area can be based on the same methodology. However, if it is determined that a more scientifically or technically accurate determination than that which is available in FEMA's back-up data is warranted, then a more detailed methodology, such as those described in Section V, should be utilized.

Data requests should be directed to the appropriate FEMA technical evaluation contractor at the address listed on the following page:

FEMA Regions I-V
(States East of the Mississippi
River and Minnesota)

Flood Insurance Information Specialist
c/o Dewberry & Davis
2953 Prosperity Avenue
Fairfax, Virginia 22031
FAX: (703) 876-0073
Phone: (703) 876-0148

FEMA Regions VI-X
(States West of the
Mississippi River)

FEMA Project Library
c/o Michael Baker, Jr., Inc.
3601 Eisenhower Avenue
Suite 600
Alexandria, Virginia 22304
FAX: (703) 960-9125
Phone: (703) 960-8800

An instruction sheet entitled Flood Insurance Study (FIS) Data Requests is provided in Appendix 2. This sheet contains pertinent information and instructions for requesting Flood Insurance Study data.

A fee is charged for locating, retrieving, copying, and mailing Flood Insurance Study back-up data based on the cost of materials and a standard hourly rate for time spent to fill the request. FEMA will inform the requestor if the requested data are available and of the required fee. The requestor should allow two to four weeks for the request to be processed.

Other Federal Agencies

Information regarding BFEs may be obtained from other Federal agencies involved in floodplain management. A fee may be required to obtain some of the products or services available through these agencies. The following is a list of some of the Federal Agencies involved in floodplain management and the information, which may be useful in obtaining and determining BFEs, that they produce.

<u>AGENCY</u>	<u>PRODUCT</u>
U.S. Army Corps of Engineers	Floodplain Information Reports Technical Manuals Computer Programs Computational Assistance
U.S. Department of the Interior, Geological Survey	Topographic Maps Water Resource Investigations Technical Bulletins Water Supply Papers Computer Programs
U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)	Watershed Studies Technical Releases Computer Programs
U.S. Department of Transportation, Federal Highway Administration	Floodplain Studies Design Manuals Computer Programs
U.S. Department of Commerce National Technical Information, Service	Design Manuals Computer Programs
Tennessee Valley Authority	Floodplain Studies

Other State and Local Agencies

If back-up data from Federal agencies are unavailable or are not useful, information regarding BFEs may be obtained from State or local agencies involved in floodplain management. On the following page is a list of State and local agencies involved in floodplain management that may be contacted to obtain BFE information. Again, fees may be applicable for this information.

For example, some state agencies, such as a Department of Natural Resources or a Geological Survey, may conduct floodplain studies using state funds. In some states, these agencies may maintain a repository for flood data. The NFIP state coordinating agency can also be contacted. A list of the State coordinating agencies is provided in Appendix 3. Other state agencies, such as a Department of Transportation, do engineering for specific types of projects, such as road and bridge construction, in which BFE data may have been developed for these projects. In general, when calling these agencies, the

caller should ask for a copy of any back-up data (reports, computations, computer models, maps) associated with a FLOODPLAIN STUDY or DRAINAGE STUDY, for the area of the particular stream of interest. In addition, some state agencies, such as a Department of Natural Resources, may maintain historic lake level data.

The local public works department or the local transportation department may have developed flood data in designing sewer and storm drainage systems and local roads. For example, plans for a sanitary sewer line which runs parallel to the stream and area of interest may have 100-year flood elevations on the profile of the sanitary sewer. Also, if there are culverts or bridges which cross the same stream within 1,000 feet of the area of interest, there may be hydrologic and hydraulic information pertaining to the 100-year flood discharge and elevation which may be pertinent to the site. Finally, if there are any nearby residential or commercial developments along the same stream, the development (site) plans for these projects may also include information about the 100-year flood.

Other possible sources of data include regional organizations, such as Flood Control Districts, Levee Improvement Districts, Watershed Districts, or Soil and Water Conservation Districts. These organizations may have developed flood profiles for smaller streams or for reaches of streams impacted by flood control or drainage projects.

State Agencies:

Departments of Environmental Conservation
Departments of Environmental Protection
Departments of Floodplain Management
Departments of Natural Resources
Departments of Transportation
Departments of Water Resources
Geological Survey

Local or Regional Agencies:

Flood Control Districts
Levee Improvement Districts
Local Planning Commissions
Local Public Works Departments
Municipal Utility Districts
River Basin Commissions
Water Control Boards

A partial list of Federal and State agencies is provided in Appendix 3.

V. DEVELOPING BASE (100-YEAR) FLOOD ELEVATIONS

If sufficient BFE information cannot be obtained from the sources described in Section IV, then the community should consider conducting, or requiring the applicant to conduct, a site specific engineering analysis to determine a BFE. This section describes several simplified and detailed methods for estimating or developing BFE data, and provides guidance for using them.

As noted in Section III, a detailed method is required under Subparagraph 60.3(b)(3) of the NFIP regulations for proposed development greater than 50 lots or 5 acres, whichever is the lesser. If the BFEs developed will be used to revise or amend NFIP maps, they must be developed using the detailed methodologies described in this section or other methods comparable to those in a Flood Insurance Study.

If no BFE data are available and the proposed development is below the thresholds specified in Subparagraph 60.3(b)(3) of the NFIP regulations, the simplified methods for estimating BFEs described in the following section may be used. Simplified methods are less expensive and less time consuming than the detailed methods described later in this section. However, communities have the discretion to determine which method should be used when a proposed development is below the aforementioned thresholds.

Simplified Methods

There are situations in which a simplified approach for estimating the BFE may yield an acceptable level of accuracy. For simplified methods to be used, very specific conditions must be met as discussed below.

Simplified methods are appropriate for floodplain management purposes only. These methods may be used for the purpose of meeting the requirements of NFIP regulations Subparagraphs 60.3(a)(3) and 60.3(a)(4) for developments, such as isolated small subdivisions in rural areas which are below the threshold in Subparagraph 60.3(b)(3), or single lots. Subparagraphs 60.3(a)(3) and 60.3(a)(4) require the community to determine whether proposed building sites are reasonably safe from flooding and ensuring that subdivision proposals are consistent with the need to minimize flood damage within flood-prone areas.

Simplified methods may not be used by the community to complete an Elevation Certificate used for flood insurance rating. Communities must use the detailed methodologies described in this section or other methods comparable to those in a Flood Insurance Study for completing the Elevation Certificate. A flood insurance policy for a structure for which a simplified method is used may be rated without an elevation certificate. However, the flood insurance rate may be higher than if the structure is rated using an Elevation Certificate.

Contour Interpolation

Contour interpolation involves superimposing approximate Zone A boundaries onto a topographic map in order to estimate a BFE. BFEs obtained by this method can only be assumed to be as accurate as one-half of the contour interval of the topographic map that is used. Therefore, the smaller the contour interval of the topographic map, the higher the accuracy of the BFE determined from the map. The procedures for using this method are outlined below. Steps 1 through 5 are the same for both riverine and lacustrine (lake) flooding sources.

- Step 1* - Obtain a topographic map showing the site being analyzed
- Step 2* - Reduce or enlarge the FIRM or topographic map as necessary so that the two are at the same scale
- Step 3* - Superimpose the approximate Zone A (100-year) floodplain boundary from the FIRM onto the topographic map
- Step 4* - Determine if this method is within the acceptable accuracy limits. The floodplain boundary must generally conform with the contour lines along the flooding source in question. The difference between the water-surface elevations determined on the right overbank and the left overbank must be within one-half of the map contour interval. For lacustrine flooding sources, the difference between the highest and lowest determined water-surface elevations around the flooding source must be within one-half of the map contour interval. Otherwise, this method is not acceptable.
- Step 5* - If the method is acceptable, then determine the BFE. Detailed guidance for determining the BFE is provided below.

Determining BFEs for Riverine flooding:

On each side of the stream in the vicinity of the site, determine the ground elevation at which the superimposed Zone A boundary lies by interpolating between two contour lines. Add one-half of the map contour interval to the lower of the two interpolated elevations. This is the approximate BFE for the site (be sure to perform this method at each structure location).

By adding one-half of the contour interval to the lowest interpolated water-surface elevation, two things are achieved: 1) the final BFE is within one-half of the contour interval of both interpolated water-surface elevations and, therefore, is still within the acceptable tolerance of the topographic map (generally regarded as \pm one-half of the map contour interval); 2) it is a conservative estimate of the BFE. If the BFE determined under this procedure seems too high, then a detailed analysis may be performed to justify lowering it.

Example 1

Using a county topographic map with a contour interval of 5 feet, the approximate Zone A boundary crosses contour elevations on the left and right bank at 323 and 325 feet, respectively, as shown in Figure 8, "Contour Interpolation Method - Riverine Flooding Example 1." The difference between these two water-surface elevations is 2 feet, which is less than one-half of the contour interval or 2.5 feet. Therefore, this method is acceptable for use on this portion of the stream. Add 323 feet (lowest interpolated water-surface elevation) plus 2.5 feet (one-half of the contour interval), which yields a BFE of 325.5.

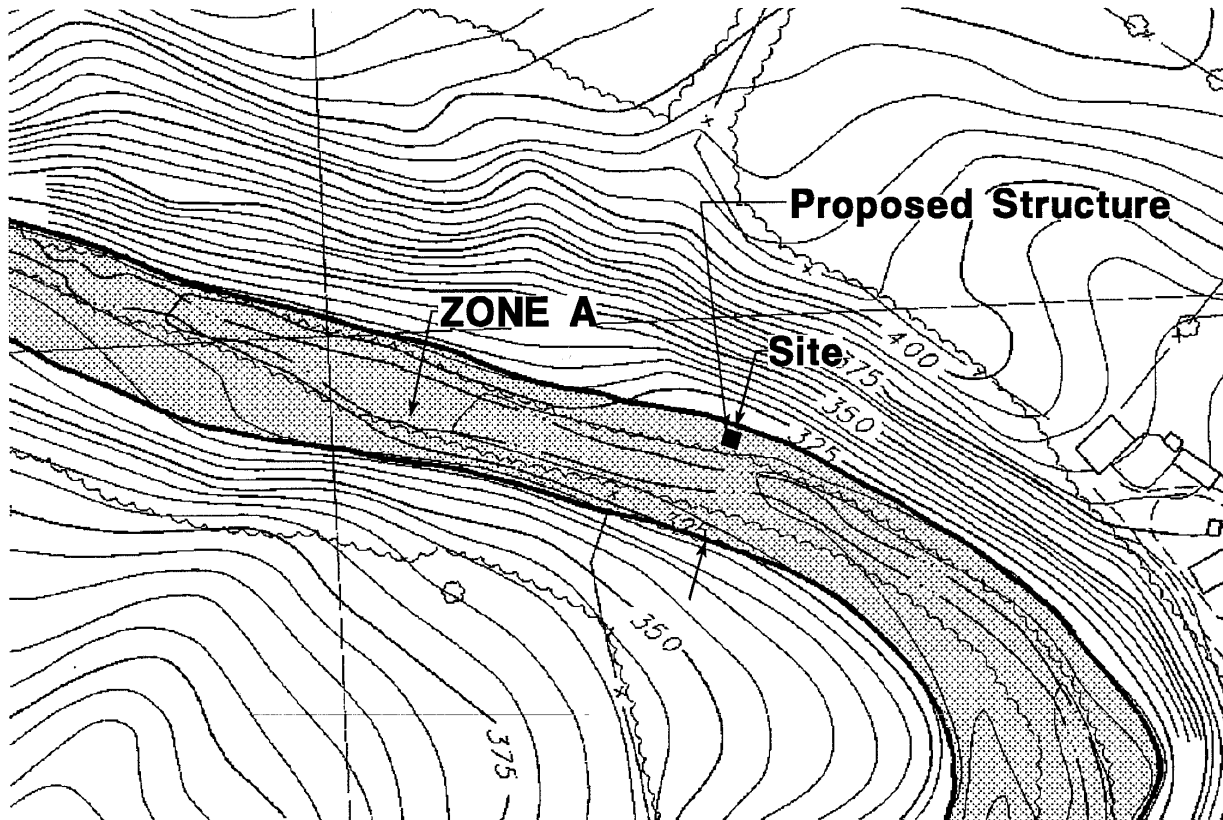


Figure 8 - Contour Interpolation Method -
Riverine Flooding Example 1

Example 2

Using a U.S. Geological Survey quadrangle map with a contour interval of 10 feet, the approximate Zone A boundary crosses contour elevations on the left and right bank of 422 and 430 feet, respectively, as shown in Figure 9, "Contour Interpolation Method - Riverine Flooding Example 2." The difference between these two water-surface elevations is 8 feet, which is greater than one-half of the contour interval or 5 feet. Therefore, this method is not acceptable for use on this portion of the stream, and another method must be used to determine the BFE.

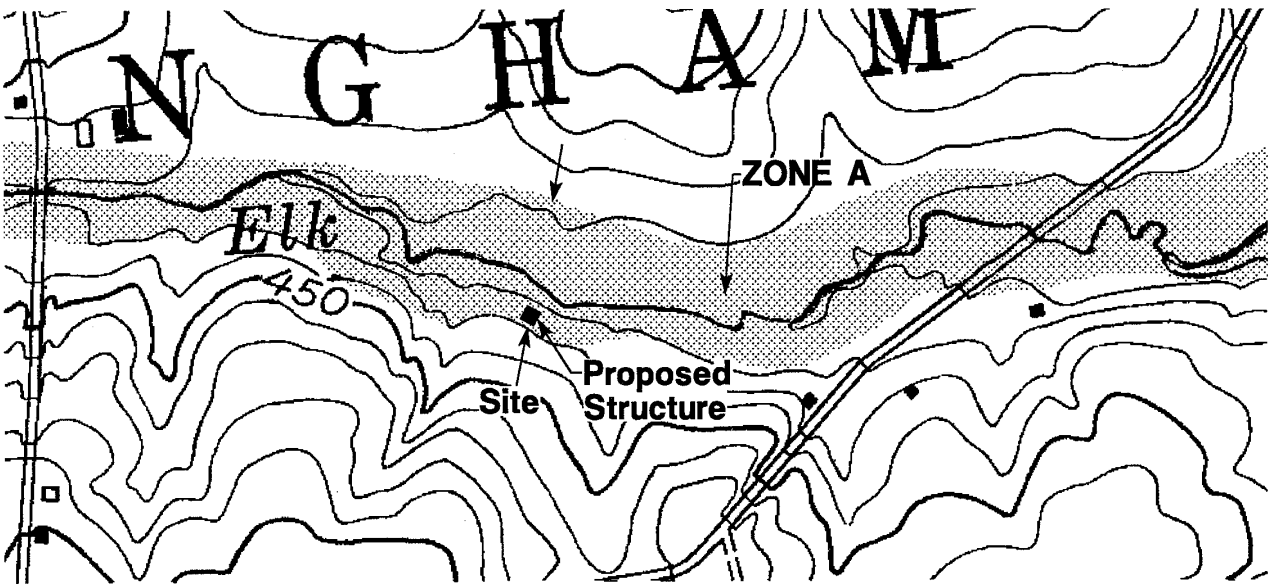


Figure 9 - Contour Interpolation Method -
Riverine Flooding Example 2

Determining BFEs for Lacustrine (Lake) flooding:

Determine the contour elevations that the approximate Zone A boundary crosses (i.e. the BFE) around the perimeter of the lake or ponding area. Assuming that the highest and lowest determined water-surface elevations are within one-half of the map contour interval of each other, add one-half of the map contour interval to the **lowest** water-surface elevation to determine the BFE for the site.

Example 3

Using a U.S. Geological Survey quadrangle map with a contour interval of 10 feet, the approximate Zone A boundary crosses low and high determined water-surface elevations along the perimeter of the ponding area of 280 and 283 feet, respectively, as shown in Figure 10, "Contour Interpolation Method - Lacustrine Flooding Example 3." The difference between these two water-surface elevations is 3 feet, which is less than one-half of the contour interval or 5 feet. Therefore, this method is acceptable for use on this ponding area. Add 280 feet (lowest water-surface elevation) and 5 feet (one-half of the contour interval), which yields a BFE of 285 feet.

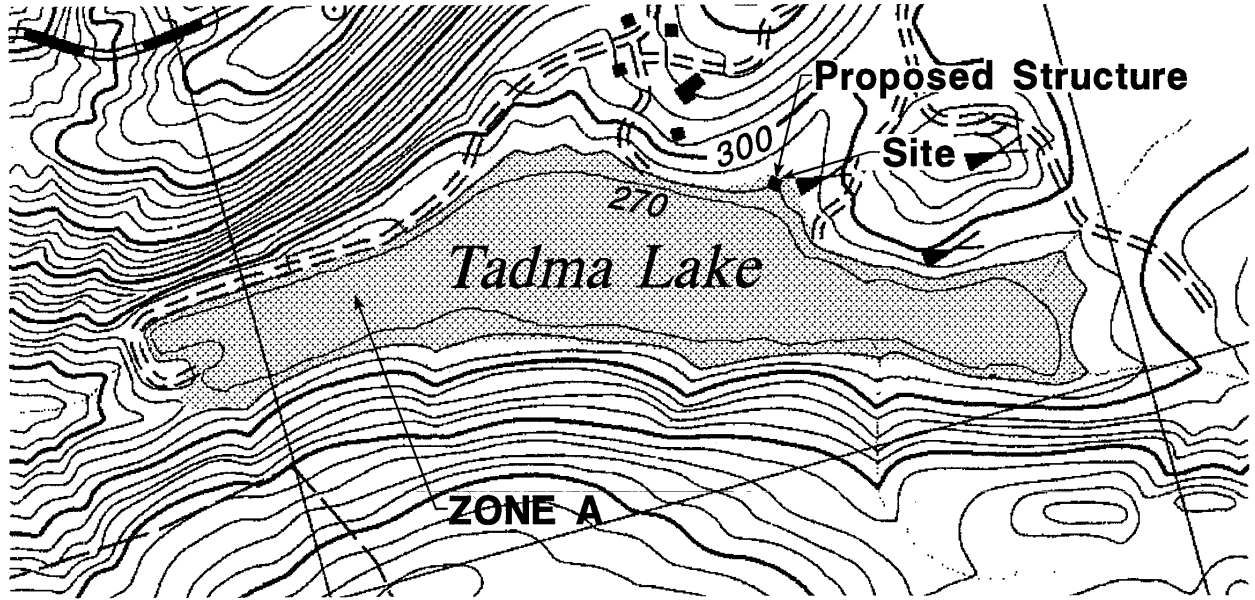


Figure 10 - Contour Interpolation Method -
Lacustrine Flooding Example 3

Data Extrapolation

If a site is within 500 feet upstream of a stream reach for which a 100-year flood profile has been computed by detailed methods, and the floodplain and channel bottom slope characteristics are relatively similar to the downstream reaches, data extrapolation may be used to determine the BFE. The stream in the vicinity of the site, however, must be free of backwater effects from downstream hydraulic structures. The procedure for using this method is outlined below.

Step 1 - Determine the location of the site on the flood profile for the detailed study stream

Step 2 - Extrapolate the last segment of the 100-year flood profile that has a constant water-surface slope to the location of the site. The BFE at the site can then be obtained directly from the profile

Figures 11-12 on the following pages depict situations (i.e., properties "Y" and "Z"), in which the data extrapolation method may and may not be used. Figures 13-14 depict a situation in which the data extrapolation method may not be used because the highway may have an effect on the 100-year water-surface elevations. If the 100-year flood profile changes just prior to the limit of detailed study, as shown in Figure 15, the data extrapolation method should not be used.

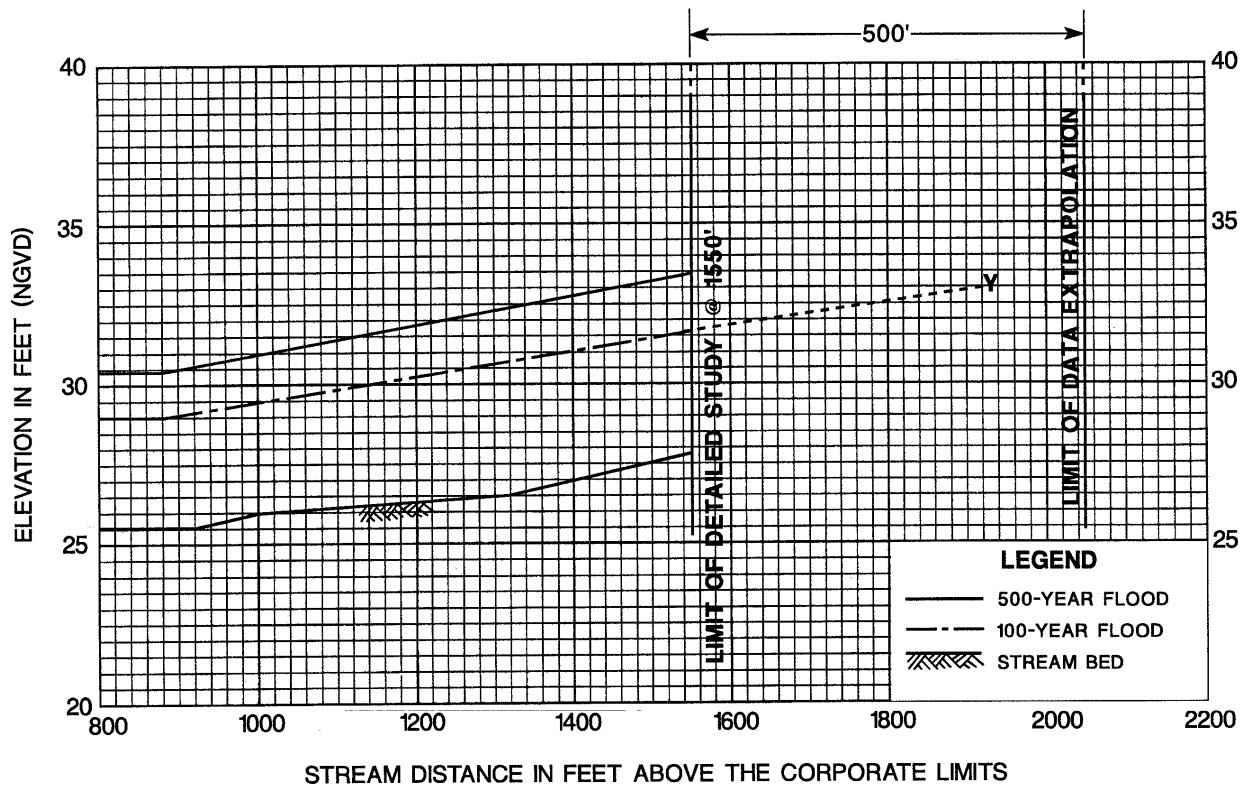


Figure 11 - Data Extrapolation Method - Profile

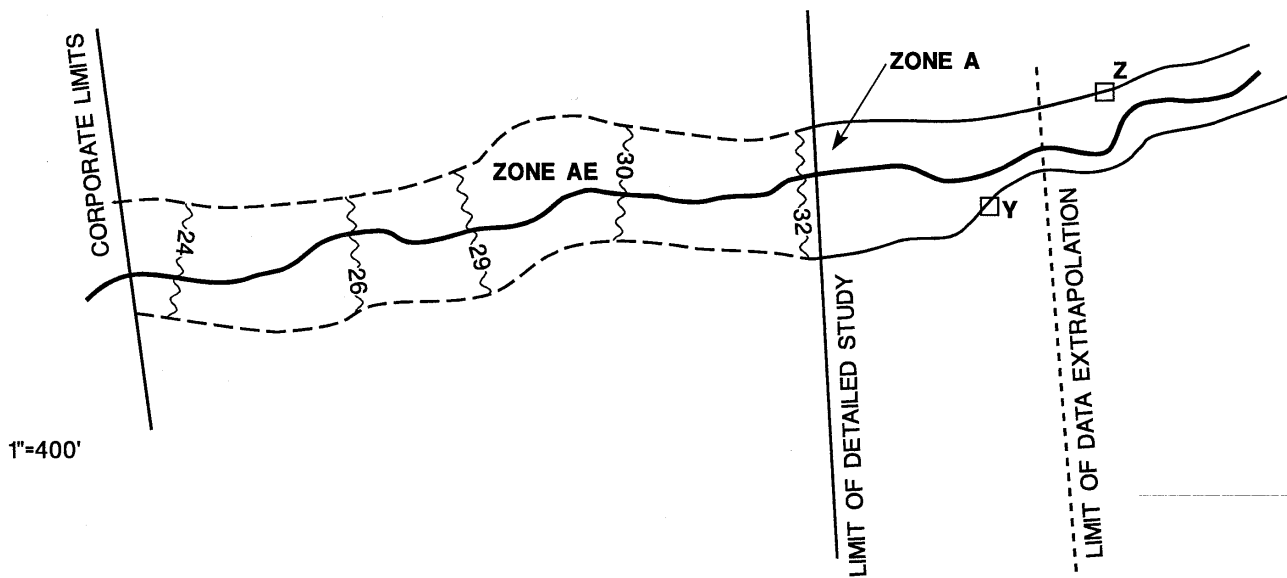


Figure 12 - Data Extrapolation Method - Plan View

-Property Y is approximately 370' upstream of the limit of detailed study (as measured along the streamline). Using the profile below, we can extrapolate the 100-year flood profile to determine that the BFE for property Y is equal to 33'.

-Property Z is approximately 700' upstream of the limit of detailed study (as measured along the streamline), and is therefore beyond the limit of data extrapolation.

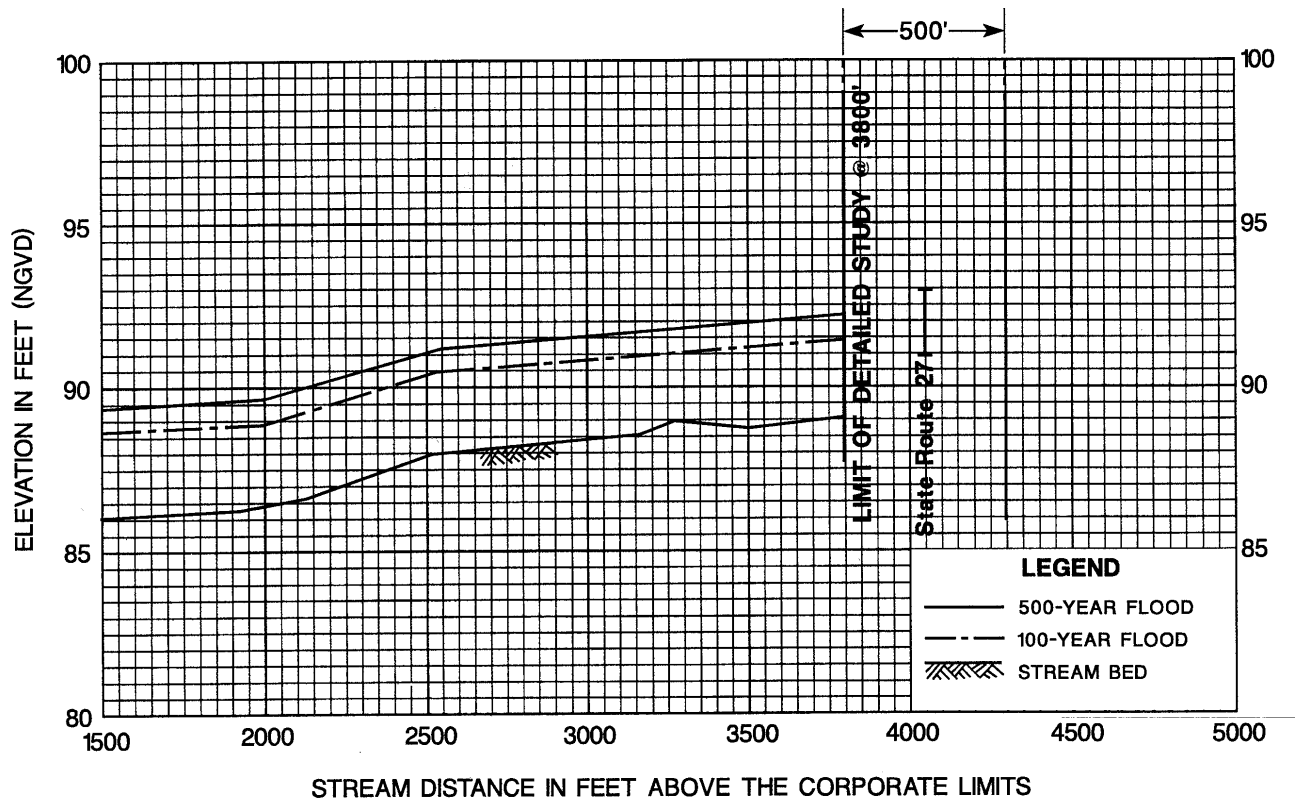


Figure 13 - Data Extrapolation Method - Profile

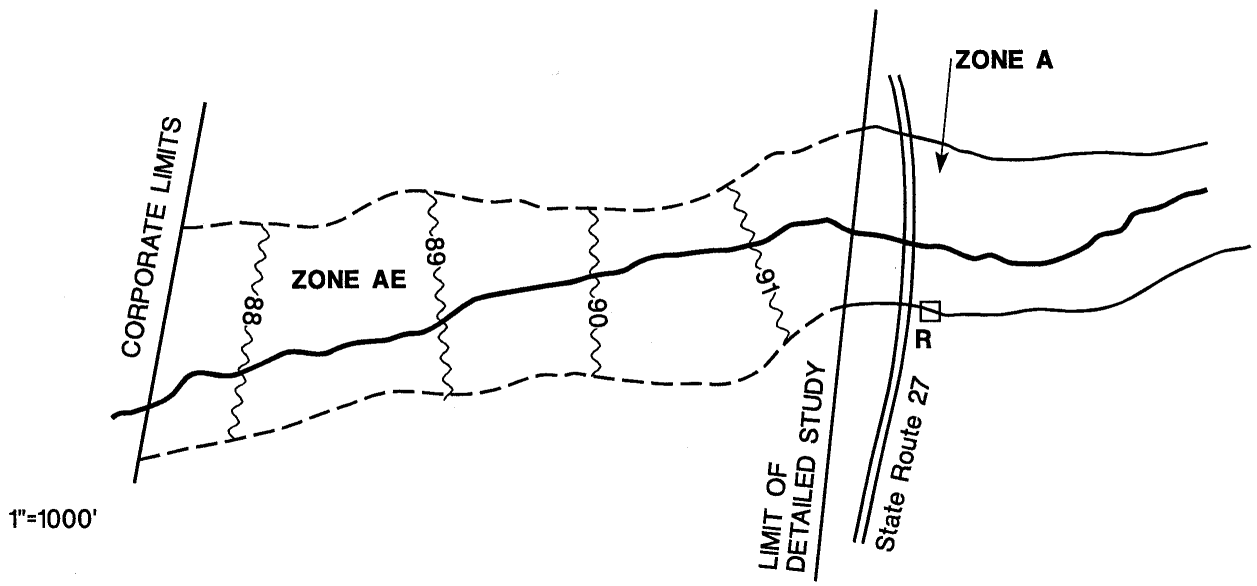


Figure 14 - Data Extrapolation Method - Plan View

-State Route 27 may have an effect on the 100-year water-surface elevations. Therefore, data extrapolation should not be used to obtain a BFE for property R.

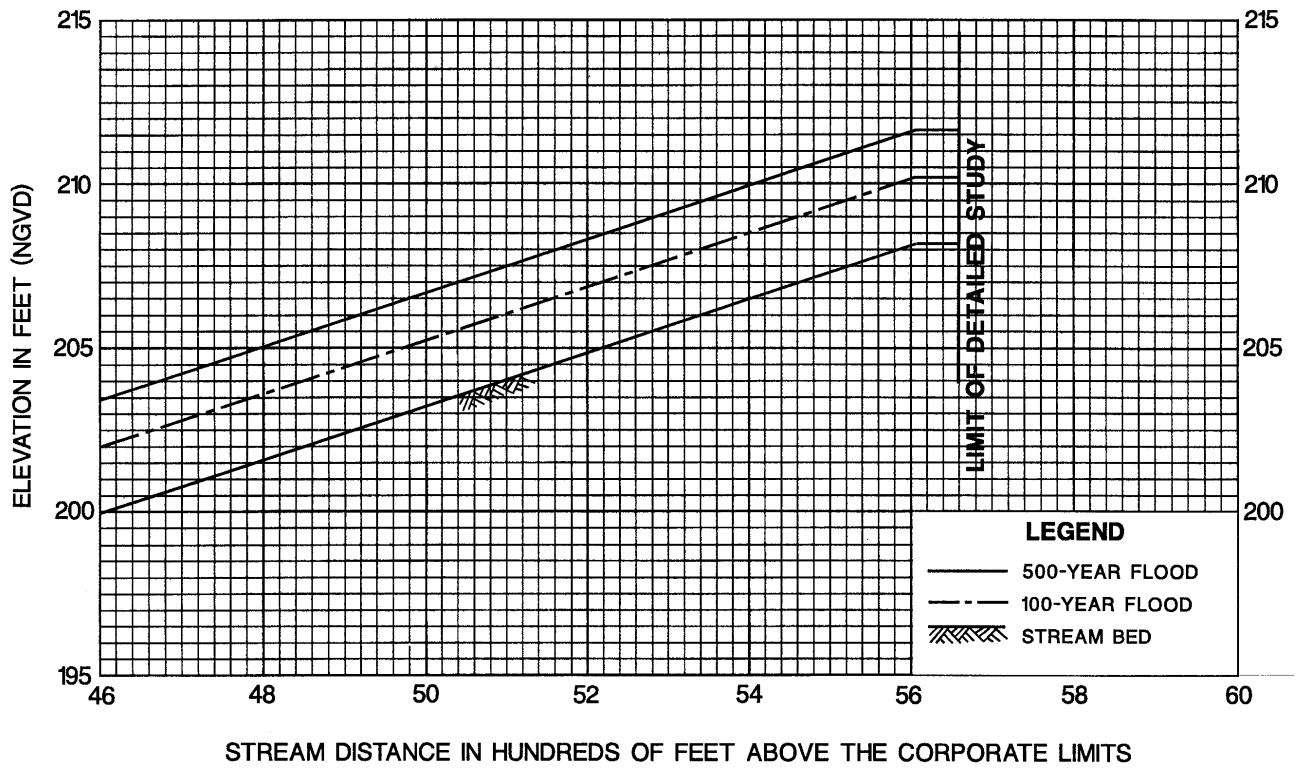


Figure 15 - Data Extrapolation Method - Profile

Detailed Methods

Three essential factors must be determined either by hand calculations or by computer model to determine a BFE by detailed methods. These factors are: 1) floodplain geometry (topography); 2) flood discharge and/or volume (hydrology); and 3) flood height (hydraulics).

Topography involves the measurement of the geometry of a cross section(s) of the floodplain, which includes horizontal and vertical coordinates. The vertical coordinate, or elevation, is related to a vertical datum, such as the National Geodetic Vertical Datum of 1929 or North American Vertical Datum of 1988. The horizontal coordinate, or station, is measured from a reference point along the cross section to establish actual ground points.

Hydrology for the particular location along a stream involves the determination of the peak rate of stream flow [usually measured in cubic feet per second (cfs)] that will occur during a flood (for purposes of determining the BFE, the 100-year flood). When determining lake or pond elevations, a 100-year flood hydrograph is required to determine the BFE.

Hydraulics involves the determination of the water-surface elevation that will occur during a flood (for purposes of determining the BFE, the 100-year flood), the selection of a method to relate the flood discharge to a flood depth, and the selection of Manning's roughness coefficients or "n" values. These "n" values vary depending on the type of materials; degree of irregularity; variation of shape, obstructions, and vegetation; and degree of meandering related to the channel and the floodplain of a stream.

The following sections discuss various methods for determining the topography, hydrology, and hydraulics for a particular location in order to determine a BFE.

Topography

Existing Topographic Maps

Before initiating field surveys, determine if there is existing detailed topographic mapping that can be used to generate cross-section data. To adequately describe a floodplain and for use with a hydraulic method to calculate a BFE, topographic map scales and contour intervals must be the same as, or more detailed than, those used to prepare the

community's Flood Insurance Study. The greater the level of detail on the topographic map, the more accurate the BFE determination. If the community does not have a Flood Insurance Study, an existing topographic survey should, at a minimum, be as detailed as the U.S. Geological Survey quadrangle map for the area. Regardless of the level of detail of the existing topographic map used, it is suggested that the geometry of the actual stream channel be obtained by a site visit if the cross sections are to be used for hydraulic analyses.

Datum Requirements for Field Surveys

If a greater level of detail is desired than is available from existing topographic mapping, then a field survey should be performed. If it is necessary to establish a BFE for insurance purposes or to meet the requirements of 60.3 of the NFIP Regulations, the survey must be referenced to the same datum that is used to produce the FIRM, which is usually the National Geodetic Vertical Datum of 1929 or the North American Vertical Datum of 1988. Reference marks giving elevations to this datum are given in the published Flood Insurance Studies. If the reference marks cannot be located in the field, or are simply too far away, additional reference mark information may be obtained from the State's U.S. Geological Survey or Transportation office. Local surveyors are generally familiar with nearby reference marks. In approximate Zone A areas, if it is not economically feasible to reference survey information to a known reference mark, an assumed datum may be used, provided that the BFE, structure, and lot elevations are referenced to the same assumed datum; however, data developed using such an assumed datum may not be sufficient to revise a FIRM. All surveys must be certified by a registered professional engineer or land surveyor.

If the sole purpose of determining relative flood heights is to meet the requirements set forth in Section 60.3(a) of the NFIP regulations, any assumed datum may be used. In this instance, a depth of flooding can be established at a particular location without having to reference it to a datum (i.e., National Geodetic Vertical Datum). However, in order for an insurable structure to be eligible for a lower insurance rate based on the BFE, the survey may need to be referenced to the same datum that was used for the FIRM (i.e., National Geodetic Vertical Datum or North American Vertical Datum).

Number of Cross Sections Required

If the determination of the BFE is for only one lot, one cross section is required across the 100-year floodplain through the property in question. For large parcels and multi-lot subdivisions, at least one cross section is required at each end of the parcel or subdivision. Additional cross sections must be added if the difference in the computed 100-year water-surface elevations at the two cross sections is more than one foot and the distance between the cross sections is greater than 500 feet.

Proper Location of Cross Sections

The following guidelines should be used to determine the proper location for cross sections:

- Flow Path: Cross sections must be oriented perpendicular to the anticipated flow path of the 100-year flood, as shown in Figure 16, "Cross Section Orientation."
- Channel Characteristics: Cross sections should be located where changes in channel characteristics, such as slope, shape, and roughness, occur.
- Discharge: Cross sections should be located at points along a stream where changes in flood discharge occur, such as upstream of tributaries, as shown in Figure 17, "Locate Cross Sections at Points of Flood Discharge Changes."
- Structures: A minimum of two cross sections are required to compute a BFE at or near a structure, such as a bridge or dam. If the floodplain configurations upstream and downstream of the structure are similar, two cross sections may be used. One cross section should represent the structure profile including the profile of the road or embankment. When obtaining the structure profile in the field, measurements of the structure opening, if there is one, and any piers should also be obtained. The other cross section should represent the natural valley cross section downstream of the structure and should not include any part of the structure or embankment. The natural valley cross section should be located at a distance equal to the width of the structure opening, W , measured from the downstream foot of the embankment or wing walls, as shown in Figure 18, "Cross Section Locations at Structures."

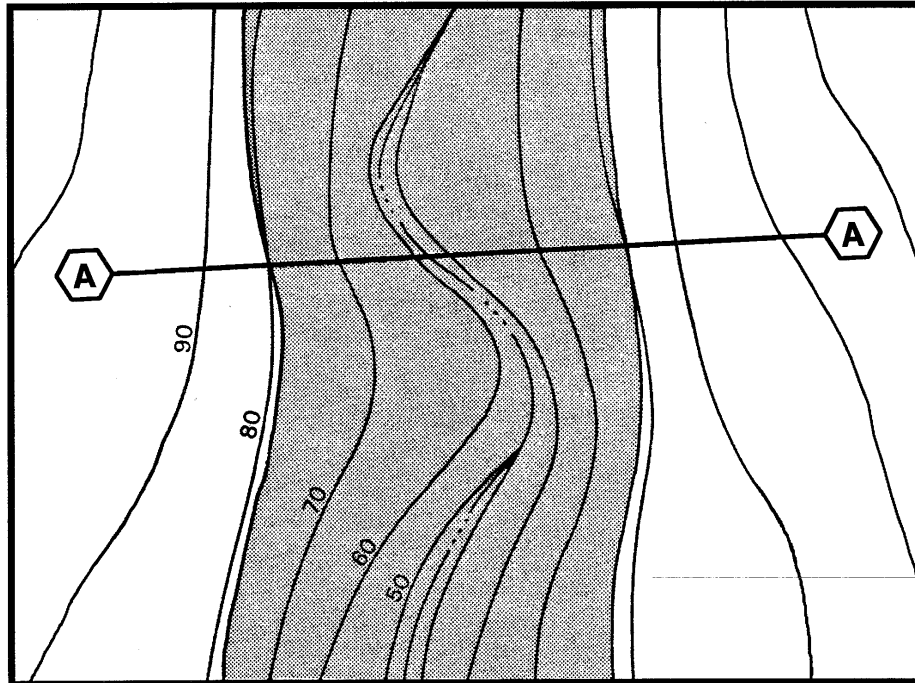


Figure 16 - Cross Section Orientation

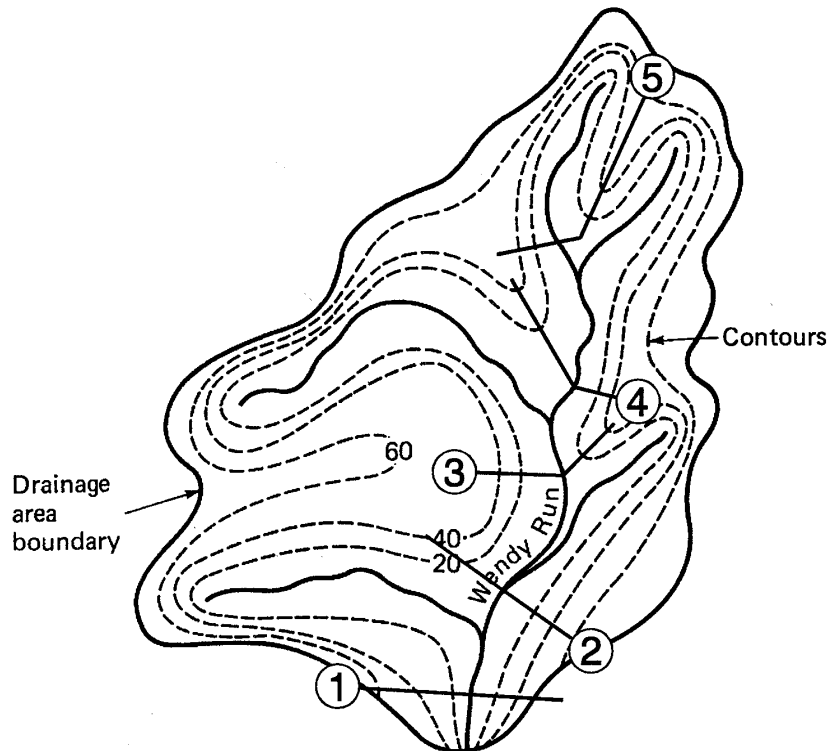


Figure 17 - Locate Cross Sections at Points of Flood Discharge Changes

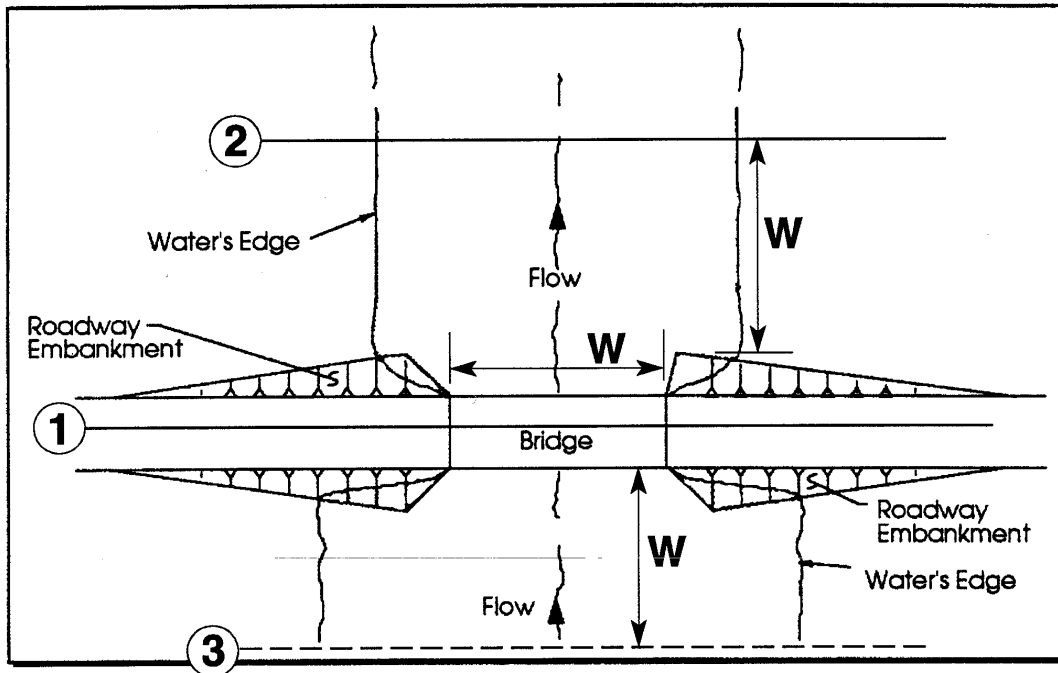


Figure 18 - Cross Section Locations at Structures

If the floodplain configurations upstream and downstream of the structure are different and the structure is a bridge, an additional cross section should be used upstream of the structure. The cross section should be located at a distance equal to the width of the structure opening upstream of the structure as measured from the foot of the embankment or wing walls.

The stations and elevations for cross section ground points outside of the stream channel may be obtained from a topographic map. The size of the structure opening, piers, and channel geometry, however, should be obtained by field survey.

Hydrology

There are a number of methodologies that may be used to develop flood discharges for approximate Zone A areas. The methods discussed below were selected because they are fairly simple to use, require information that is easily obtainable, and provide reasonable discharge estimates for streams where more detailed hydrologic analyses have not been performed. These methods, which have been ordered based on ease of use and expected level of accuracy, include discharge-drainage area relationships, regression equations, the NRCS TR-55 graphical peak discharge and tabular hydrograph methods,

and the rational formula. Other hydrograph methods will also be noted but not described in detail due to their complexity.

Discharge-Drainage Area Relationships

This method is suggested for approximate Zone A areas because it is straightforward and the only data needed are drainage areas and corresponding 100-year flood discharges. These data can be obtained from the Summary of Discharges table in a Flood Insurance Study report.

The relationship between drainage area and discharge is non-linear in most cases; therefore, the drainage areas and corresponding 100-year flood discharges from the Flood Insurance Study should be plotted on log-log paper as shown in Figure 20 from the example which begins on the following page. The streams plotted may have varying drainage areas; however, other watershed characteristics should be similar. A straight line should be drawn through the plotted points as shown in Figure 21. The 100-year flood discharge for a particular location can then be estimated based on the drainage area at the location as shown in Figure 21 from the example.

Limitations - If the relationship of plotted points cannot be approximated by a straight line, then this method should not be used. In addition, this method is not appropriate when the stream along which the site is located is regulated by dams, detention ponds, canals, or other flow control structures or diversions.

EXAMPLE: DISCHARGE-DRAINAGE AREA RELATIONSHIPS

The following is a Summary of Discharges table from a Flood Insurance Study report.

TABLE 1 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-YEAR	50-YEAR	100-YEAR	500-YEAR
PINE CREEK					
At confluence with Saddle River	20.39	2,220	4,165	5,310	9,010
At Calvin Street	16.3	1,907	3,617	4,612	7,300
At Caitlin Avenue	14.9	1,860	3,285	4,090	6,570
ROCK RUN					
Downstream of confluence of Ramsey Brook	12.6	1,640	2,895	3,605	5,795
Upstream of confluence of Ramsey Brook	10.1	1,390	2,455	3,055	4,910
GOOSE CREEK					
Downstream of confluence of Valentine Brook	9.1	1,285	2,270	2,825	4,540
Upstream of confluence of Valentine Brook	6.2	965	1,700	2,120	3,405
COON CREEK					
Downstream of confluence of Allendale Brook	14.3	1,805	3,185	3,965	6,370
Upstream of confluence of Allendale Brook	12.9	1,670	2,950	3,670	5,900

Assume that Wendy Run is a stream within the same community as the streams listed in the table, and that the Wendy Run drainage basin, shown in Figure 19, has similar characteristics to the stream basins from the table. First, plot the drainage areas and corresponding 100-year discharges on log-log paper as shown in Figure 20 on the following page. Then draw a straight line through the plotted points as shown in Figure 21.

At Property A, the drainage area for Wendy Run is 8.5 square miles. Using the drainage area curve created from the Flood Insurance Study Summary of Discharges table, the 100-year discharge at Property A is estimated to be 2,750 cfs, as shown on Figure 21. At Property B, with a drainage area of 12.0 square miles, an estimated 100-year discharge of 3,600 is obtained, as shown on Figure 21.

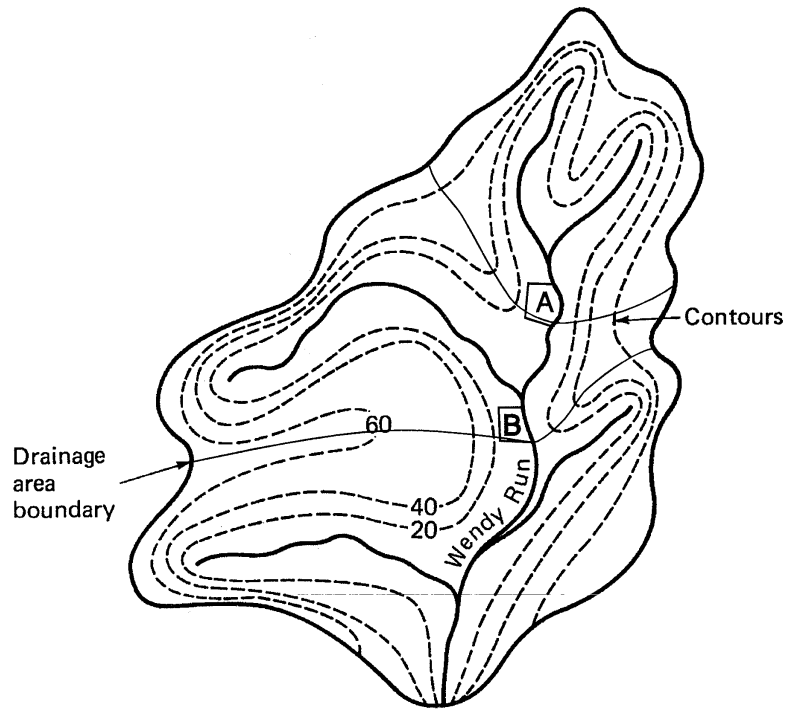


Figure 19 - Wendy Run Drainage Basin

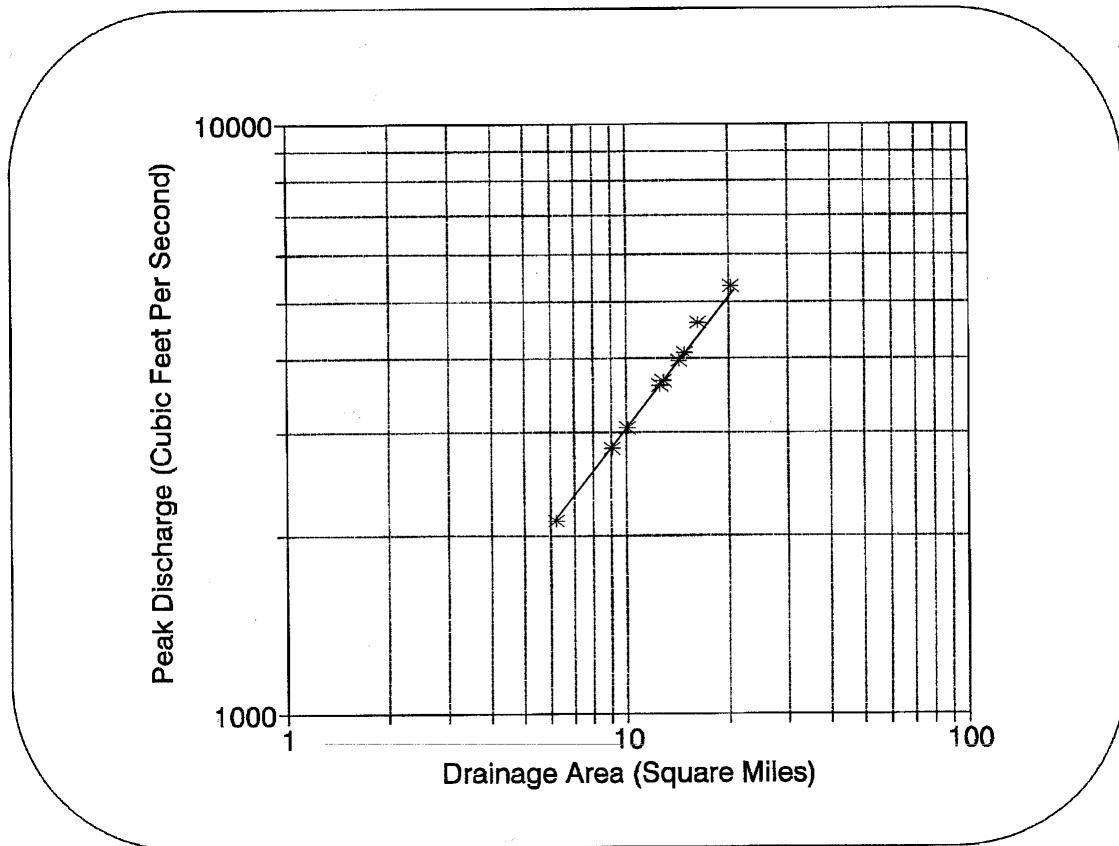


Figure 20 - Discharge-Drainage Area Plot

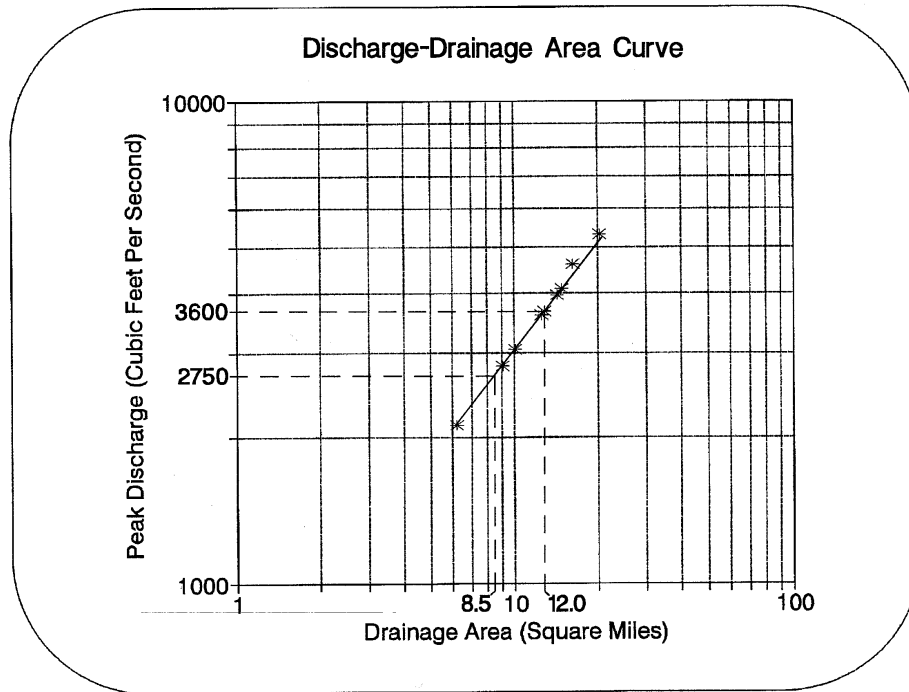


Figure 21 - 100-year Discharge Estimates for Site A and Site B

Regression Equations

Another methodology that can be used for determining discharges for approximate Zone A areas is the application of the appropriate regression equation found in a U.S. Geological Survey publication (Water Resources Investigation or Open File report). A list of these publications applicable to each State is in Appendix 4. The U.S. Geological Survey has also released Version 1.1 of the National Flood Frequency Computer Program. The National Flood Frequency Program contains the regression equations for all of the continental United States. The use of regression equations involves the determination of specific variables for a watershed (drainage area, mean annual precipitation, forest cover, stream slope, etc.). Regression equations are based on actual stream gage data and are usually developed to determine discharges for the 2-year event up to the 100-year event (for purposes of determining the BFE, determine the 100-year discharge).

The general form of these regression equations is:

$$Q = K * A^x * B^y * C^z$$

where: Q = discharge (cfs)
K = regression equation constant
A,B,
and C = watershed variables
X,Y,
and Z = exponents

Watershed variables may include parameters such as drainage area (in square miles), stream slope (in feet/mile), and impervious area (in percent).

Limitations - Care must be taken when using these publications because restrictions generally apply when the watershed is heavily urbanized (i.e., high percentage of impervious land), or where the runoff is regulated by the use of dams, detention ponds, canals and other flow diversions. Other restrictions based on the physical parameters of the watershed, such as drainage area or stream slope, may also apply. Limitations of these equations are normally stated in each report and should be examined closely.

TR-55

The NRCS TR-55 "Urban Hydrology for Small Watersheds" contains two methods for computing flood discharges: the Graphical Peak Discharge method and the Tabular Hydrograph method. TR-55 is straightforward in its approach and method of computation. TR-55 takes into account the effects of urbanization, rainfall distribution, soil types and conditions, ground cover types, and other watershed characteristics. A method for estimating the effects of storage on peak flood discharges is also included in TR-55.

Limitations - In general, TR-55 should not be used in areas where flow is divided between closed storm sewer systems and overland conveyance areas, or where drainage areas exceed 2,000 acres. More specific limitations for using TR-55 are contained in Chapters 2 through 6 of the NRCS TR-55 manual.

Rational Formula

This method estimates peak discharge rates for small watershed areas not covered by regression equations and for areas where the NRCS TR-55 method is not applicable. The Rational Formula

is based on the drainage area, rainfall intensity, watershed time of concentration, and a runoff coefficient. The generalized equation is:

$$Q = C * I * A$$

where: Q = discharge (cfs)
C = runoff coefficient
I = rainfall intensity (inches/hour)
A = drainage area (acres)

The runoff coefficient, C, varies with soil type, land use, and terrain slope and can be obtained from text books on hydrology.

The intensity of rainfall, I, is determined based on the total rainfall for a selected exceedence probability and a duration equal to the time of concentration for the watershed. The time of concentration for the watershed can be computed using the method described in the NRCS TR-55 manual or methods described in hydrology text books. For approximate Zone A areas, the exceedence probability is equal to 1 percent (100-year storm frequency). The 1 percent exceedence probability total rainfall (100-year rainfall) for the computed duration can be obtained from Technical Paper No. 40, Hydro 35, and precipitation-frequency atlases published by the National Weather Service. Dividing the total rainfall by the computed duration will yield the intensity of rainfall.

Limitations - This method must not be used where the runoff is regulated by the use of dams, detention ponds, canals and other flow diversions. Also, this method is not recommended for drainage areas greater than 200 acres, but can be used with caution for drainage areas up to 640 acres (one square mile).

Other Hydrograph Methods

There are numerous other methods that can be used to determine flood discharges based on rainfall-runoff relationships. The following hydrograph methods are described in detail within their respective technical reports and, therefore, will not be described in detail within this guide. These methodologies in general are good for any size watershed, and most of the methods include computations that take into consideration areas where the runoff is regulated by the use of dams, detention ponds, canals and other flow diversions. These methods are recommended for determining BFEs for ponds or lakes that are designated as approximate Zone A. Besides TR-55, two of the more widely used hydrograph methods are the NRCS' TR-20 and the U.S. Army Corps of Engineers' HEC-1 computer programs.

TR-20 and HEC-1 provide a very detailed calculation of discharge through the generation, addition, and routing of runoff hydrographs. The effect on peak flood discharges due to dams, road crossings, and large floodplain storage areas is more accurately assessed with these programs. These models require experience on the part of the user if they are to produce realistic determinations of peak discharge.

Limitations - The limitations of these methods are thoroughly described in their manuals. Because these methods involve many variables and assumptions, the potential for error is great. The users of these models must be thoroughly versed in the limitations and assumptions of the computational methods contained in these models. As with any synthetic model depicting rainfall-runoff relationships, extreme care needs to be taken to ensure that the results of the model are reasonable.

It is highly recommended that the discharges produced by these hydrograph methods be compared to discharges produced by another hydrologic method of equal accuracy or by calibrating the model to an actual storm event.

Hydraulics

There are various hydraulic methods that may be used to determine BFEs along riverine flooding sources. The appropriate method to use depends on flow conditions and the size of the area that is being analyzed. For developments of equal to or less than 50 lots or 5 acres, the normal depth method, which is described in greater detail below, is usually adequate for determining BFEs. After normal depth has been computed, flow conditions should be analyzed. If flow is classified as subcritical (i.e., normal depth is greater than critical depth), normal depth is used as the BFE. If flow is classified as supercritical (i.e., normal depth is less than critical depth), then critical depth is used as the BFE for natural channels. For engineered channels, supercritical (normal) depth may be used for the BFE, provided that the backwater from the normal depth of the downstream cross section is considered properly. If more than one cross section is required, step-backwater computations should be used to determine BFEs along riverine flooding sources.

The procedures for computing normal depth, critical depth, and step-backwater by hand are outlined below. As an alternative to hand calculations, the QUICK-2 computer program may be used.

QUICK-2 is a user-friendly computer program developed by FEMA that may be used for normal depth, critical depth, or step-backwater computations for regular or irregular shaped cross sections. To aid the users of this guide in computing BFEs, the QUICK-2 computer program and user's manual are located in Appendix 6. The user's manual contains a tutorial section which leads a new user through the calculation process using "real life" examples. For those not using the QUICK-2 program, the following sections on Normal Depth and Critical Depth illustrate how to compute these depths by hand (see Appendix 8 for an example of a Normal Depth hand calculation).

Normal Depth

Normal depth is the depth expected for a stream when the flow is uniform, steady, one-dimensional, and is **not affected by downstream obstructions or flow changes**. For uniform flow, the channel bottom slope, water-surface slope, and energy slope are parallel and are, therefore, equal. For normal depth computations, the flow is considered steady because the discharge is assumed to be constant; therefore, the depth of flow does not change during the time interval under consideration.

Normal depth calculations (also called the "slope/area method") compute BFEs at a cross section. The standard formula for determining normal depth at a cross section is Manning's formula. The standard Manning's equation is:

$$Q = 1.486 \times A \times (R^{.667}) \times S^{.5} / n$$

where: Q = discharge (cfs)
 A = cross section area (ft²)
 R = hydraulic radius (ft) = A/WP
 WP = wetted perimeter (ft)
 S = energy slope (ft/ft)
 n = Manning's roughness coefficient

The cross section area refers to the area below the water-surface elevation, and the wetted perimeter refers to the length of the ground surface along the cross section below the water-surface elevation. The channel bottom slope is used in lieu of the energy slope.

As noted earlier, Manning's "n" values vary depending on the physical features of the stream channel and the channel overbanks. The results of normal depth calculations can differ

significantly depending on the Manning's "n" values used; therefore, care should be taken to ensure that the Manning's "n" values selected accurately reflect conditions at the site being analyzed. Manning's "n" values should be selected based on field inspection, field photographs, and topographic mapping. A list of accepted Manning's "n" values has been included in Appendix 5. Various methods for computing normal depth are described below.

Computer Programs for Computing Normal Depth

In addition to QUICK-2, the following Federal Government computer programs have the capability to perform normal depth computations:

<u>Computer Program</u>	<u>Agency</u>
HEC-2	U.S. Army Corps of Engineers
HEC-RAS	U.S. Army Corps of Engineers
WSPRO	U.S. Geological Survey
WSP2	NRCS
SFD	FEMA
PSUPRO	FEMA

Please note that HEC-RAS is still being tested and had not yet been released to the general public when this guide was published. Furthermore, FEMA has not yet approved the model for requests to revise NFIP maps. Please contact our Headquarters office to determine the current status of HEC-RAS.

In addition to the above-referenced programs, there are other engineering computer programs and models, which perform normal depth calculations, that are available through various commercial vendors. References for the hydraulic computer programs listed above are in Appendix 7.

Normal Depth Hand Calculations

If a computer is not available, it is possible to perform hand computations to calculate normal depth for the 100-year flood at a cross section by following steps 1-11 listed below.

- Step 1 - Obtain a topographic map or conduct a field survey to obtain a cross section at the site where normal depth should be determined. If a topographic map is used, the channel geometry should be obtained from measurements taken in the field. The cross section should be oriented perpendicular to the expected 100-year floodplain.

- Step 2 - Compute the 100-year discharge by applying one of the methods described in the hydrology section of this guide.
- Step 3 - Plot the cross section on graph paper with the stations and the corresponding elevations. (The stations and elevations are obtained from the topographic map and/or from field survey).
- Step 4 - Select the left and right channel bank stations. The channel bank stations are those stations where the ground slope becomes flatter moving away from the channel bottom as shown in Figure 22, "Channel Bank Stations." Photographs taken in the field and the contours on the topographic maps are also helpful when defining the channel bank stations. Do not place the channel bank stations at the bottom of the channel.

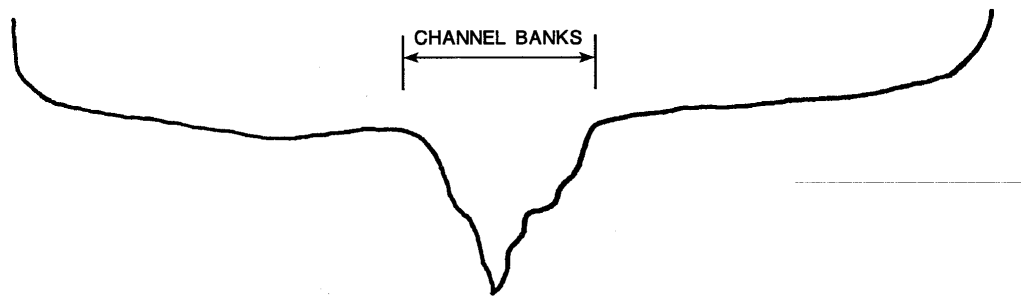


Figure 22 - Channel Bank Stations

- Step 5 - Select appropriate Manning's roughness coefficients for the left overbank, channel, and right overbank from the "n" values given in Appendix 5. These values should be determined by reviewing the field photographs and visiting the site.
- Step 6 - Compute the cross section area, wetted perimeter, hydraulic radius, and conveyance for each segment (i.e., left overbank, channel, and right overbank) for at least three elevations. The conveyance, K, of a segment is given as:

$$K = (1.486/n) \times A \times R^{0.667}$$

where:

A = cross section area (ft²)
 R = hydraulic radius (ft)
 WP = wetted perimeter (ft)
 R = A/WP

- Step 7 - Compute the channel bottom slope, S, from the topographic map or from field survey.
- Step 8 - Compute the discharge, Q, for each segment of the cross section at each elevation by multiplying K by S^{0.5}.
- Step 9 - Add the discharges from each segment at the same elevation to obtain the total discharge.
- Step 10 - Plot the total discharges and the corresponding elevations on graph paper.
- Step 11 - The BFE can be determined from this graph for the 100-year flood discharge computed in Step 2.

An example of a normal depth hand calculation is included in Appendix 8.

Critical Depth

After computing normal depth, the type of flow should be checked. If the velocity head from the normal depth computation is equal to or more than half the hydraulic depth, the flow is supercritical and the critical depth should be used to establish the BFE. The velocity head, HV, for an irregular cross section is computed using the following equation:

$$HV = \alpha V^2 / 2g$$

- where:
- α = velocity coefficient
 - V = mean velocity = Q_T / A_T (fps)
 - Q_T = total discharge (cfs)
 - A_T = total flow area (ft²)
 - g = acceleration due to gravity = 32.2 ft/sec²

The velocity coefficient, α , is determined using the following equation:

$$\frac{[(K_L^3/A_L^2) + (K_C^3/A_C^2) + (K_R^3/A_R^2)]}{K_T^3/A_T^2}$$

where: K_L, K_C, K_R, K_T = conveyance for left overbank, channel, right overbank, and total conveyance, respectively
 A_L, A_C, A_R, A_T = flow area for left overbank, channel, right overbank, and total flow area, respectively

Hydraulic depth, h , is computed by using the following relationship:

$$h = A_T / T$$

where: T = top water-surface width at the normal depth
 A_T = Total Flow Area

If the velocity head is greater than or equal to one-half the hydraulic depth, the flow is supercritical.

For **prismatic channels**, the following equation can be used to determine the critical depth:

$$\frac{Q^2}{g} = \frac{A^3}{T} \quad \text{or} \quad Q = \sqrt{gA^3 / T}$$

For a series (3 or more) of water-surface elevations, compute the corresponding total area, A , water-surface topwidth, T , and

the critical discharge, Q , using $Q = \sqrt{gA^3 / T}$. Compute the value of right hand side of the above equation. Plot the water-surface elevations and the corresponding discharge values on graph paper. The critical water-surface elevation and, therefore, critical depth, can be determined from this graph for a range of discharge values.

For **rectangular channels**, critical depth can be computed directly from the above equation and is expressed in the following relationship:

$$D_c = \{ Q / (5.67 T) \}^{0.667}$$

The energy is minimum at the critical depth. For **irregular cross sections**, critical depth is determined from the relationship between the water-surface elevation and the energy. The energy is computed by adding the water-surface elevation and the corresponding velocity head (or energy grade elevation). For irregular cross sections, the velocity coefficient, $a(\alpha)$, must be considered when computing velocity head (HV). Several water-surface elevations should be assumed and corresponding energy grade elevations computed. These values are then plotted

on a graph of water-surface elevation versus energy grade elevation. The critical water-surface elevation and, therefore, critical depth, can be determined from this graph where the energy (i.e., energy grade elevation) is minimum.

Step-Backwater Analysis

Step-backwater computations are based on the principle of conservation of energy, which states that the energy at the upstream cross section is equal to the energy at the downstream cross section plus the losses between the two cross sections. The losses considered in the step-backwater analysis are the friction loss and the transition loss.

The equations and the procedure used in the step-backwater analysis are explained in the QUICK-2 user's manual in Appendix 6. Although hand computations can be done to perform the step-backwater analysis, it is advisable to use the QUICK-2 program or other Federally approved programs for ease of computation. The QUICK-2 program currently does not model the effects of bridges or culverts or supercritical flow.

The QUICK-2 program uses the default friction slope method, which is the average conveyance method, from the HEC-2 program to compute friction losses. For transition losses, a contraction coefficient of 0.1 and an expansion coefficient of 0.3 should be used in the computations.

The reach lengths between the two cross sections for the left overbank, channel, and right overbank are required for step-backwater computations. The distance for the left overbank should be measured between the center of the floodplains of the left overbank at each cross section. The same is true for the right overbank. The channel distance should be measured along the streambed, and therefore will account for the meandering of the stream channel.

In general, starting water-surface elevations are obtained from normal depth computations (slope/area method) at the first cross section. If there is a structure downstream of the study area, the backwater effects of the structure must be considered in determining the starting water-surface elevation. If there is a known 100-year water-surface elevation at the downstream end of the study area, that water-surface elevation should be used as the starting water-surface elevation.

Hydraulic Structures

As stated earlier, normal depth is the depth expected for a stream when the flow is uniform, steady, one-dimensional, and is not affected by downstream obstructions or flow changes. However, there are situations in which a physical structure located downstream of a particular site will cause an obstruction or alteration of the flow, resulting in a flood depth at the site higher than the normal depth. The discussion below describes the appropriate methods for determining BFEs for reaches that include hydraulic structures.

Hydraulic structures that are common in approximate Zone A areas include road and railroad crossings, including embankments, dams, bridges and culverts, and canal crossings. The flow over the road, railroad, embankment, dam or canal can be described as weir flow. Weir flow can be calculated by hand or by computer program in order to determine the BFE. When flow passes through a bridge or culvert, the BFE can be determined through the use of nomographs or computer programs. The BFE at a structure where flow travels through a bridge or culvert and over the crossing can be determined by nomographs, but is more easily determined with a computer program.

Weir Flow

Determination of the water-surface elevation for weir flow requires at least two cross sections. The first cross section represents the natural valley section downstream of the structure, and the second cross section represents the road profile and the opening of the structure (refer to Figure 18, "Cross Section Locations at Structures." If the approach velocity head is to be considered, then a third cross section is required that represents the natural valley section upstream of the structure. In most situations, however, the velocity head can be assumed to be negligible, and a third cross section is not necessary.

The water-surface elevation downstream of the structure should be determined by using normal depth computations at the first cross section, provided there are no structures further downstream that can create backwater effects (refer to the methods for determining normal depth described previously).

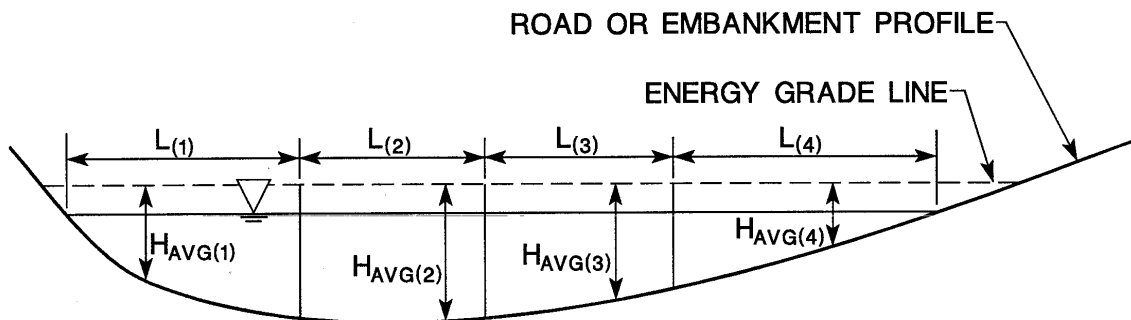
The second cross section, which represents the profile along the top of the structure including the road or the embankment, should be used to determine the weir length for use in the equation for weir flow, as shown on the following page.

$$Q = @ \times C \times L \times H^{3/2}$$

where: Q = discharge (cfs)
 @ = submergence factor
 C = weir coefficient, varies from 2.6 to 3.0 and can be obtained from hydraulic text books
 L = weir length (ft)
 H = available head (ft), measured from top of weir to the selected energy grade elevation

Several values for H should be selected and the corresponding discharge computed until the total weir flow is larger than the 100-year flood discharge. Plot the discharges and the corresponding energy grade elevations on graph paper. The 100-year flood energy grade elevation can be determined from this graph. For an approximate analysis, the computed energy gradient elevation can be considered the BFE.

If the structure profile is not horizontal, as shown in Figure 23, "Weir Flow - Embankment Profile is Not Horizontal," several structure segments should be used and an average energy depth, H, for that segment should be determined for use in the above equation for selected energy grade elevations. The sum of the weir flow from each segment will then be equal to the total weir flow for the selected energy grade elevation.



$$Q = (@ CL_{(1)} H_{AVG(1)}^{3/2}) + (@ CL_{(2)} H_{AVG(2)}^{3/2}) + (@ CL_{(3)} H_{AVG(3)}^{3/2}) + (@ CL_{(4)} H_{AVG(4)}^{3/2})$$

Figure 23 - Weir Flow - Embankment Profile is Not Horizontal

If the downstream water-surface elevation is higher than the minimum road elevation, a submergence factor may be considered in the weir flow computation. The submergence factor is dependent upon the D/H ratio, where D is the downstream depth of water above the road and H is the upstream energy grade depth above the road, as shown in Figure 24, "Weir Flow Over Road." The submergence factor must be considered when the D/H ratio is more than 0.79. For a non-horizontal road profile, the D/H ratio must be computed for each road segment. The submergence factor, @, can be determined from the curve in "Hydraulics of Bridge Waterways" (Reference 1, Figure 24) and some typical values are given in the table below.

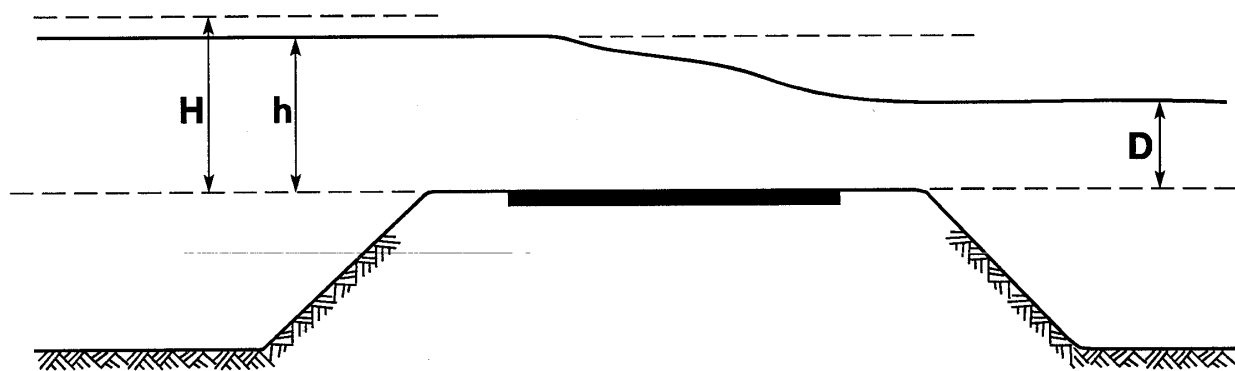


Figure 24 - Weir Flow Over Road

D/H	@	D/H	@
0.998	0.30	0.944	0.80
0.992	0.40	0.932	0.85
0.986	0.50	0.915	0.90
0.976	0.60	0.889	0.95
0.962	0.70	0.700	1.00

Other procedures used in Federal agency backwater computer programs can also be used to determine the submergence factor.

A third cross section may be used to determine a more accurate water-surface elevation upstream of the structure. This may be done by assuming water-surface elevations and calculating the corresponding velocity heads (HV) until an assumed water-surface elevation plus its velocity head at that elevation equal the same energy gradient elevation obtained from the weir flow equation. The velocity head, HV, can be calculated using the following equation:

$$HV = \alpha (Q/A)^2 / 2g$$

where: α = velocity coefficient
 Q = 100-year flood discharge (cfs)
 A = cross section area (ft²) at the assumed
water-surface elevation
 g = Acceleration due to gravity = 32.2 ft/sec²

An example of a weir flow computation is included in Appendix 9.

Flow Through Structures

Culverts

At least two cross sections are required to determine the water-surface elevation upstream of a culvert. The first cross section should represent the natural valley cross section downstream of the culvert, and the second cross section should represent the top of the embankment profile and the opening of the structure (refer to Figure 13, "Cross Section Locations at Structures"). The size, type, length, and upstream and downstream invert elevations of the culvert should be obtained by field survey. The wing wall angle and the entrance opening configuration, such as sharp edge or rounded edge, should also be determined from a field survey. The Federal Highway Administration publication "Hydraulic Design of Highway Culverts" (Reference 2) should be referenced before going to the field so that all the necessary information for culvert flow computations can be collected during one field survey. Water-surface elevations upstream of the culvert can then be computed using the nomographs contained in the above-mentioned publication and the procedures outlined below.

The first cross section should be used to determine the normal depth downstream of the culvert, which will be considered as the tailwater (refer to section on normal depth computations).

Two computations are required to determine the headwater when using Federal Highway Administration nomographs. One computation is for inlet control, and the other computation is for outlet control. The headwater elevations from the two computations are then compared. The higher of the two should be selected as the upstream headwater elevation. If this headwater elevation is higher than the top of embankment profile, weir flow will occur. Perform at least three weir flow computations for headwater elevations between the headwater that assumes that all the flow is culvert flow (the first computation) and the minimum top of embankment elevation. For each selected headwater elevation, compute the culvert flow using Federal Highway Administration nomographs. Combine the weir flow and culvert flow for each selected headwater elevation and plot on graph paper. The BFE for the 100-year flood discharge can then be obtained from this graph.

If the site in question is not located immediately upstream of a structure, a normal depth should be computed at the site. The 100-year water-surface elevation at the site should be the higher of the two elevations from the culvert computation and the normal depth computation.

Federal Highway Administration nomographs predict only the energy grade elevation upstream of the culverts. In most applications, the velocity head is assumed to be negligible and, therefore, the energy grade elevation approximates the actual water-surface elevation. If a more accurate water-surface elevation is desired, a hydraulic computer model, such as HEC-2, should be used to determine the BFE. The procedure outlined in the weir flow section to compute a water-surface elevation that corresponds to a certain energy grade elevation may also be used to determine a BFE upstream of a culvert.

Bridges

Although hand computations can be performed by following the procedures for bridge routines in Federal agency computer models, it is recommended that the water-surface elevation upstream of bridges be determined using a computer model. The number of cross sections required at the structure depends upon the type of bridge routine used. Four cross sections are required if the special bridge routine in the HEC-2 program is used, and six cross sections are required if the normal bridge routine in the HEC-2 program is used. Three cross sections are required if the bridge routines in the WSPRO program and the WSP2 program are used. A step-backwater analysis is also required to compute the water-surface elevations with these bridge routines. The following programs are recommended to compute the water-surface elevation upstream of a bridge:

<u>Computer Program</u>	<u>Agency</u>
HEC-2	U.S. Army Corps of Engineers
*HEC-RAS	U.S. Army Corps of Engineers
WSPRO	U.S. Geological Survey
WSP2	NRCS

*Not available for general use when this guide was published; please contact our Headquarters office for current status.

REFERENCE

1. U.S. Department of Transportation, Federal Highway Administration, Hydraulics of Bridge Waterways, Washington, D.C., March 1978.
2. U.S. Department of Transportation, Federal Highway Administration, Hydraulic Design of Highway Culverts, Washington, D.C., September 1985.

VI. OBTAINING LETTERS OF MAP CHANGE

Once detailed methods have been applied to develop BFE data, these data may be suitable for revising an NFIP map via a Letter of Map Correction. On October 1, 1992, FEMA implemented the use of detailed application and certification forms for requesting revisions to NFIP maps. Therefore, if a map revision is requested, the appropriate forms should be submitted.

FEMA has implemented a procedure to recover costs associated with reviewing and processing requests for modifications to published flood information and maps. Specific information about these fees is presented in the application and certification forms.

These forms, along with other useful documents pertaining to the NFIP, may be obtained from our technical evaluation contractors at the addresses listed below:

FEMA Regions I-V

Dewberry & Davis
Management Engineering and
Technical Services Division
8401 Arlington Boulevard
Fairfax, Virginia 22031
FAX: (703) 876-0073

FEMA Regions VI-X

Michael Baker, Jr., Inc.
3601 Eisenhower Avenue
Suite 600
Alexandria, Virginia 22304
FAX: (703) 960-9125

This information is also available through the FEMA Regional Offices listed in Appendix 3.

To provide additional assistance to those who develop BFE data, a worksheet that synthesizes the procedures detailed in this guide is found in Appendix 10.

Appendix 1

Glossary of Floodplain Analysis Terms

1-Percent Annual Chance Flood: the flood that has a one-percent chance of being equaled or exceeded on the average in any given year; equivalent to the 100-year flood.

100-Year Flood: the flood that is equaled or exceeded once in 100 years on the average; equivalent to the one percent annual chance flood.

Alluvial Stream: a stream that has formed its channel by the process of aggradation. The sediment in the stream is similar to the material in the bed and banks.

Base Flood: the flood having a one percent chance of being equaled or exceeded in any given year (the 100-year flood).

Base Flood Elevation (BFE): the water-surface elevation associated with the base flood.

Conveyance: a measure of the carrying capacity of the channel section. Flow (Discharge (Q)) is directly proportional to conveyance (K). The proportional factor is the square root of the energy slope; expressed as $Q = K * S^{\frac{1}{2}}$.

Cross Section: a vertical profile of the ground surface taken perpendicular to the direction of flood flow. The profile is defined by coordinates of ground elevation and horizontal distance (station).

Discharge: a measure of flow volume per unit of time. In hydrology, units of flow are usually cubic feet per second (cfs).

Exceedence Frequency: the frequency that a flood of a certain discharge will be equaled or exceeded in any given year; equal to the inverse of the recurrence interval.

Flood: (a) a general and temporary condition of partial or complete inundation of normally dry land areas from: (1) the overflow of inland or tidal waters; (2) the unusual and rapid accumulation or runoff of surface waters from any source; (3) mudslides (i.e., mudflows), which are proximately caused by flooding as defined in (a)(2) above and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, as when earth is carried by a current of water and deposited along the path of the current. (b) The collapse or subsidence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as flash flood or abnormal tidal surge, or by some similarly unusual and unforeseeable event, which results in flooding as defined in (a) (1) above.

Flood Crest: the maximum height of a flood, usually measured as an elevation or depth.

Flood Hazard: the potential for inundation that involves the risk to life, health, property, and natural floodplain values.

Appendix 1 - continued

Glossary of Floodplain Analysis Terms

Floodplain: any land area, such as the lowland and relatively flat areas adjoining inland and coastal waters, susceptible to being inundated by water from any source.

Floodway: 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 more than a designated height. The base flood is defined as the one-percent chance flood and the designated height is usually one foot above the base flood elevation; however, this height may vary (but is not more than one foot) depending on what the State has adopted.

Floodway Fringe: the area between the floodway boundary and the 100-year floodplain boundary.

Flow: equivalent to *discharge*.

Flow Area: the cross section (see discharge) area of the floodplain below a given water-surface elevation.

Hazardous Flow: conditions that exist when the product of the depth of flow and its corresponding velocity are greater than ten (10). For example a flow depth of 3 feet and a flow velocity of 4 feet per second ($3 \times 4 = 12$) would be considered hazardous flow.

Hydraulic Depth: an average depth computed as the *Flow Area* divided by the top width of the floodplain for a given water-surface elevation.

Lacustrine Flooding: Flooding produced by a lake or pond.

Peak Discharge: the maximum instantaneous discharge of a flood at a given location.

Recurrence Interval: the average interval of time required for a flood of a specific discharge to occur or be exceeded; equal to the inverse of the exceedence frequency.

Riverine Flooding: Flooding produced by a river or stream.

Shallow Flooding: a designated AO, AH, or VO zone on a community's Flood Insurance Rate Map with a one percent or greater annual chance of flooding to an average depth of one to three feet where a clearly defined channel does not exist, the path of flooding is unpredictable, and velocity flow may be evident. Such flooding is characterized by ponding or sheet flow.

Slope (Energy): the rate of energy loss of a watercourse.

Slope (Ground): the change in vertical ground elevation over a horizontal distance, usually based on the change in the vertical elevation of the stream bottom.

Steady Flow: state of flow where the depth of flow does not change with time.

Subcritical Flow: state of flow where the gravitational forces are more pronounced than the inertial forces. The flow tends to have a low velocity. In general, in this flow regime, the hydraulic depth is more than twice the *velocity head*.

Supercritical Flow: state of flow where the inertial forces become dominant. The flow tends to have a high velocity. In general, in this flow regime, the *velocity head* is equal to or more than half the *hydraulic depth*.

Appendix 1 - continued

Glossary of Floodplain Analysis Terms

Unsteady Flow: state of flow where the depth of flow changes with time.

Uniform Flow: depth is constant over channel length, and the channel shape, slope and boundary roughness are constant over the channel length.

Varied Flow: depth of flow changes along the channel length.

Gradually Varied Flow: depth of flow changes gradually over the channel length.

Rapidly Varied Flow: depth changes abruptly over a short channel length.

Velocity: a rate of movement (i.e., distance divided by time). For water, the rate is expressed in feet per second. Because water in a channel does not all move at the same velocity at every point, an average value is used to describe flow velocity. This average velocity equals the discharge divided by the flow area (Q/A).

Velocity Head: the kinetic energy term ($\alpha V^2 / 2g$), in the total energy of flow. The velocity coefficient (α) is used to adjust for the distribution of velocity in a cross section of differing roughness.

Appendix 2

Flood Insurance Study Data Request Form

FLOOD INSURANCE STUDY (FIS) DATA REQUESTS

Requests for FIS data should be made in writing to:

Regions I-V

Flood Insurance Information Specialist
c/o Dewberry & Davis
2953 Prosperity Avenue
Fairfax, Virginia 22031
FAX: (703) 876-0073

Regions VI-X

FEMA Project Library
c/o Michael Baker, Jr., Inc.
3601 Eisenhower Avenue
Suite 600
Alexandria, Virginia 22304
FAX: (703) 960-9125

The following information should be included in your written request:

- Complete community name (including county)
- Community Identification Number
- Name(s) of flooding source(s) and specific location(s) for which data are needed
- Specific data needed:
 - HEC-2 input and output files
 - Topographic data
 - etc.
- Effective date of FIRM/FBFM for which data are requested (enclose an annotated copy of FIRM/FBFM if available identifying area of interest)
- Agreement to pay costs associated with processing the request
- Fee limit after which authorization is needed
- Contact person's name, address, and phone number

The average request takes approximately 2 to 4 weeks to fill and may cost between \$100 to \$200.

You will be contacted after we have determined if the data are available and the cost to fill the request has been determined.

Do not include payment with your request letter.

Checks or money orders should be made payable to the National Flood Insurance Program and sent to:

Federal Emergency Management Agency
Fee Collection System
P.O. Box 398
Merrifield, Virginia 22116

Data will be released upon receipt of payment.

Appendix 3

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Federal Emergency Management Agency Offices

HEADQUARTERS

500 C Street, SW
Washington, D.C. 20472
(202) 646-3680
FAX: (202) 646-4596

REGION I

(Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island & Vermont)

J.W. McCormack Post Office & Courthouse Building, Room 462
Boston, MA 02109
(617) 223-9561
FAX: (617) 223-9574

REGION II

(New Jersey, New York, Puerto Rico & Virgin Islands)

26 Federal Plaza, Room 1349
New York, NY 10278
(212) 225-7200
FAX: (212) 225-7262

REGION III

(Delaware, District of Columbia, Maryland, Pennsylvania, Virginia & West Virginia)

Liberty Square Building, Second Floor
105 South Seventh Street
Philadelphia, PA 19106
(215) 931-5512
FAX: (215) 931-5501

REGION IV

(Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina & Tennessee)

1371 Peachtree Street, N.E., Suite 700
Atlanta, GA 30309
(404) 853-4400
FAX: (404) 853-4440

REGION V

(Illinois, Indiana, Michigan, Minnesota, Ohio & Wisconsin)

175 West Jackson Boulevard
Fourth Floor
Chicago, IL 60604
(312) 408-5552
FAX: (312) 408-5551

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Federal Emergency Management Agency Offices (continued)

REGION VI

(Arkansas, Louisiana, New Mexico, Oklahoma & Texas)

Federal Regional Center
800 North Loop 288
Denton, TX 76201-3698
(817) 898-5165
FAX: (817) 898-5195

REGION VII

(Iowa, Kansas, Missouri & Nebraska)

Federal Office Building, Room 300
911 Walnut Street
Kansas City, MO 64106
(816) 283-7002
FAX: (816) 283-7018

REGION VIII

(Colorado, Montana, North Dakota, South Dakota, Utah & Wyoming)

Denver Federal Center, Bldg. 710
P.O. Box 25267
Denver, CO 80225-0267
(303) 235-4830
FAX: (303) 235-4849

REGION IX

(Arizona, California, Hawaii & Nevada)

Presidio of San Francisco
Building 105
San Francisco, CA 94129
(415) 923-7100
FAX: (415) 923-7147

REGION X

(Alaska, Idaho, Oregon & Washington)

Federal Regional Center
130 - 228th Street, SW
Bothell, WA 98021-9796
(206) 487-4678
FAX: (206) 487-4613

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

ALABAMA

Alabama Department of Economics
and Community Affairs
State Planning Division
401 Adams Avenue
Montgomery, AL 36103
(205) 242-5442

U.S. Geological Survey
District Chief
Water Resources Division
520 19th Avenue
Tuscaloosa, AL 35401
(205) 752-8104

U.S. Department of Agriculture
Natural Resources Conservation
Service
665 Opelika Rd.
P.O. Box 311
Auburn, AL 36830
(205) 887-4506

NFIP State Coordinator

Mr. Gene Anderson
Director, Alabama Department
of Economic and Community Affairs
P.O. Box 5690
401 Adams Avenue
Montgomery, AL 36103-5690
(205) 242-5499

ALASKA

Alaska Department of
Community and Regional Affairs
Municipal and Regional
Assistance Division
333 West 4th Avenue, Suite 220
Anchorage, AK 99501
(907) 269-4500

U.S. Geological Survey
District Chief
Water Resources Division
4230 University Drive, Suite 201
Anchorage, AK 99508-4138
(907) 786-7100

U.S. Department of Agriculture
Natural Resources Conservation
Service
949 East 36th Avenue
Suite 400
Anchorage, AK 99504
(907) 271-2424

NFIP State Coordinator

Mr. Bob Walsh
Municipal and Regional
Assistance Division
333 West 4th Avenue, Suite 220
Anchorage, AK 99501
(907) 269-4500

ARIZONA

Arizona Department of Water Resources
15 South 15th Avenue
Phoenix, AZ 85004
(602) 242-1553

U.S. Geological Survey
District Chief
Water Resources Division
375 South Euclid
Tucson, AZ 85719
(602) 670-6671

U.S. Department of Agriculture
Natural Resources Conservation
Service
3008 Federal Building
230 N. 1st Avenue
Phoenix, AZ 85025
(602) 261-6711

NFIP State Coordinator

Ms. Elizabeth A. Rieke
Director, Arizona Department
of Water Resources
15 South 15th Avenue
Phoenix, AZ 85007
(602) 542-1540

ARKANSAS

Arkansas Soil and Water
Conservation Commission
1 Capitol Mall, Suite 2D
Little Rock, AR 72201
(501) 371-1611

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Geological Survey
Water Resources Division
401 Hardin Road
Little Rock, AR 72211
(501) 228-3600

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Office Bldg.
700 West Capitol
P.O. Box 2323
Little Rock, AR 72203
(501) 324-6335

NFIP State Coordinator

Mr. Randy Young
Director
Arkansas Soil & Water
Conservation Commission
101 East Capitol
Little Rock, AR 72201
(501) 682-1611

CALIFORNIA

California Department of
Water Resources
P.O. Box 942836
Sacramento, CA 94236-0001
(916) 653-5791

U.S. Geological Survey
District Chief
Water Resources Division
Federal Building, Room W-2233
2800 Cottage Way
Sacramento, CA 95825
(916) 978-4633

U.S. Department of Agriculture
Natural Resources Conservation
Service
2121 C 2nd Street
Davis, CA 95616
(916) 757-8200

NFIP State Coordinator

Mr. David Kennedy, Director
California Department of
Water Resources
P.O. Box 942836
Sacramento, CA 94236-0001
(916) 653-7007

COLORADO

Urban Drainage and Flood Control
District
2480 West 26th Avenue
Suite 156B
Denver, CO 80211

Colorado Water Conservation Board
State Centennial Building, Room 721
1313 Sherman Street
Denver, CO 80203
(303) 866-3441

U.S. Geological Survey
District Chief
Water Resources Division
Denver Federal Center, Building 53
Box 25046 (Mail Stop 415)
Lakewood, CO 80225-0046
(303) 236-4882

U.S. Department of Agriculture
Natural Resources Conservation
Service
655 Parfait Street
Room E200C
Lakewood, CO 80215
(303) 236-2886

NFIP State Coordinator

Mr. Daries C. Lile, P.E.
Director, Colorado Water
Conservation Board
State Centennial Building
1313 Sherman Street
Denver, CO 80203
(303) 866-3441

CONNECTICUT

State Department of
Environmental Protection
79 Elm Street, 3rd Floor
Hartford, CT 06106
(203) 424-3706

U.S. Geological Survey
Hydrologist-in-Charge
Connecticut Office
Water Resources Division
Abraham A. Ribicoff Federal
Building, Room 525
450 Main Street
Hartford, CT 06103
(203) 240-3060

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Department of Agriculture
Natural Resources Conservation
Service
16 Professional Park Road
Storrs, CT 06268
(203) 429-9361

NFIP State Coordinator

Mr. Timothy Keeney, Commissioner
State Department of Environmental
Protection
165 Capitol Avenue
State Office Building
Hartford, CT 06106
(203) 566-2110

DELAWARE

Department of Natural Resources and
Environmental Control
Division of Soil and Water
Conservation
P.O. Box 1401
89 Kings Highway
Dover, DE 19903
(302) 739-4403

U.S. Geological Survey
Hydrologist-in-Charge
Delaware Office
Water Resources Division
Federal Building, Room 1201
300 South New Street
Dover, DE 19904
(302) 734-2506

U.S. Department of Agriculture
Natural Resources Conservation
Service
3500 South DuPont Highway
Dover, DE 19901
(302) 697-6176

NFIP State Coordinator

Mr. John A. Hughes, Director
Delaware Department of Natural &
Environmental Control
Richardson and Robbins Building
P.O. Box 1401
Dover, DE 19903
(301) 736-4411

DISTRICT OF COLUMBIA

Department of Consumer
Regulatory Affairs
614 H Street Northwest
Washington, DC 20001
(202) 727-7170

U.S. Geological Survey
District Chief
Water Resources Division
208 Carroll Building
8600 La Salle Road
Towson, MD 21286
(410) 828-1535

NFIP State Coordinator

Mr. Donald G. Murray, Director
Department of Consumer Regulatory
Affairs
Office of the Director
614 H Street, NW., Suite 1120
Washington, D.C. 20001
(202) 727-7170

FLORIDA

Department of Community Affairs
East Howard Building
2740 Centerview Drive
Tallahassee, FL 32399-2100
(904) 488-8466

U.S. Geological Survey
District Chief
Water Resources Division
227 North Bronough Street,
Suite 3015
Tallahassee, FL 32301
(904) 942-9500

U.S. Department of Agriculture
Natural Resources Conservation
Service
P.O. Box 141510
Gainesville, FL 32614
(904) 338-9500

NFIP State Coordinator

Ms. Linda Lomis Shelley, Secretary
Florida Department of Community
Affairs
2740 Centerview Drive
Tallahassee, FL 32399-2100
(904) 488-8466

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

GEORGIA

Department of Natural Resources
Environmental Protection Division
Floyd Towers East, Suite 1252
205 Butler Street Southeast
Atlanta, GA 30334
(404) 656-4713

U.S. Geological Survey
District Chief
Water Resources Division
3039 Amwiler Road, Suite 130
Atlanta, GA 30360
(404) 447-9803

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building
355 East Hancock Avenue
P.O. Box 832
Athens, GA 30613
(404) 546-2272

NFIP State Coordinator

Mr. Joe D. Tanner, Commissioner
Georgia Department of Natural
Resources
205 Butler Street, S.E.
Floyd Towers East, Suite 1252
Atlanta, GA 30334
(404) 656-3500

HAWAII

Hawaii Board of Land and
Natural Resources
1151 Punchbowl Road, Room 220
Honolulu, HI 96813
(808) 587-0446

U.S. Geological Survey
District Chief
Water Resources Division
677 Ala Moana Boulevard, Suite 415
Honolulu, HI 96813
(808) 522-8290

U.S. Department of Agriculture
Natural Resources Conservation
Service
300 Ala Moana Boulevard
P.O. Box 50004
Honolulu, HI 96850
(808) 546-3165

NFIP State Coordinator

Mr. William W. Paty, Chairperson
Commission on Water Resource
Management and Board of Land and
Natural Resources
State of Hawaii
P.O. Box 621
Honolulu, HI 96809
(808) 587-0401

IDAHO

Department of Water Resources
State House
1301 North Orchard Street
Boise, ID 83706
(208) 327-7900

U.S. Geological Survey
District Chief
Water Resources Division
230 Collins Road
Boise, ID 83702
(208) 387-1300

U.S. Department of Agriculture
Natural Resources Conservation
Service
3244 Elder Street
Room 124
Boise, ID 83705
(208) 334-1601

NFIP State Coordinator

Mr. R. Keith Higginson, Director
Idaho Department of Water Resources
1301 N. Orchard
Boise, ID 83706
(208) 327-7900

ILLINOIS

Illinois Department of Transportation
Local Flood Plains Programs
310 South Michigan, Room 1606
Chicago, IL 60604
(312) 793-3123

U.S. Geological Survey
District Chief
Water Resources Division
Champaign County Bank Plaza
102 East Main Street
Fourth Floor
Urbana, IL 61801
(217) 398-5353

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building
2110 West Park Court
Suite C
Champaign, IL 61821
(217)398-5212

NFIP State Coordinator

Mr. Michael Lene, Secretary
Illinois Department of Transportation
2300 S. Dirksen Parkway
Springfield, IL 62764
(217) 728-5597

INDIANA

Department of Natural Resources
608 State Office Building W-256
402 West Washington Street
Indianapolis, IN 46204-2748
(317) 232-4020

U.S. Geological Survey
District Chief
Water Resources Division
5957 Lakeside Boulevard
Indianapolis, IN 46278
(317) 290-3333

U.S. Department of Agriculture
Natural Resources Conservation
Service
6013 Lakeside Boulevard
Indianapolis, IN 46275
(317) 290-3030

NFIP State Coordinator

Mr. James B. Ridenour, Director
Indiana Department of Natural
Resources
608 State Office Building
Indianapolis, IN 46204
(317) 232-4020

IOWA

Iowa Department of Natural Resources
Wallace State Office Building
Des Moines, IA 50319-0034
(515) 281-5385

U.S. Geological Survey
District Chief
Water Resources Division
P.O. Box 1230
Iowa City, IA 52244-1230

(Street Address:
Federal Building, Room 269
400 South Clinton Street)
(319) 337-4191

U.S. Department of Agriculture
Natural Resources Conservation
Service
Wallace Building
Des Moines, IA 50319
(515) 284-5851

NFIP State Coordinator

Mr. Larry Wilson, Director
Iowa Department of Natural Resources
Wallace State Office Building
Des Moines, IA 50319
(515) 281-5385

KANSAS

Division of Water Resources
Kansas State Board of Agriculture
901 South Kansas Avenue, 2nd Floor
Topeka, KS 66612-1283
(913) 296-3717

U.S. Geological Survey
District Chief
Water Resources Division
4821 Quail Crest Place
Lawrence, KS 66049
(913) 842-9901

U.S. Department of Agriculture
Natural Resources Conservation
Service
P.O. Box 600
760 South Broadway
Salina, KS 67401
(913) 823-4500

NFIP State Coordinator

Mr. David L. Pope, P.E.
Chief Engineer & Director
Kansas State Board of Agriculture
Division of Water Resources
901 S. Kansas, 2nd Floor
Topeka, KS 66612-1283
(913) 296-3717

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

KENTUCKY

Kentucky Department
of Natural Resources
Division of Water
Fort Boone Plaza
14 Reilly Road
Frankfort, KY 40601
(502) 564-3410

U.S. Geological Survey
District Chief
Water Resources Division
2301 Bradley Avenue
Louisville, KY 40217
(502) 582-5241

U.S. Department of Agriculture
Natural Resources Conservation
Service
771 Corporate Drive, Suite 110
Lexington, KY 40503
(606) 224-7350
FTS 355-2749

NFIP State Coordinator

Mr. Jack Wilson, Director
Kentucky Division of Water
18 Reilly Road
Fort Boone Plaza
Frankfort, KY 40601
(502) 564-3410

LOUISIANA

Louisiana Department of
Urban and Community Affairs
P.O. Box 94455, Capitol Station
Baton Rouge, LA 70804
(504) 342-9794

U.S. Geological Survey
District Chief
Water Resources Division
P.O. Box 66492
Baton Rouge, LA 70896
(Street Address:
6554 Florida Boulevard
Baton Rouge, LA 70806)
(504) 389-0281

U.S. Department of Agriculture
Natural Resources Conservation
Service
3636 Government Street
Alexandria, LA 71301
(318) 487-8094

NFIP State Coordinator

General Jude W. P. Patlin, Secretary
Louisiana Department of
Transportation & Development
P.O. Box 94245
Baton Rouge, LA 70804-9245
(504) 379-1200

MAINE

Maine State Planning Office
State House Station 38
184 State Street
Augusta, ME 04333
(207) 287-3261

U.S. Geological Survey
Hydrologist-in-Charge
Maine Office
Water Resources Division
26 Ganneston Drive
Augusta, ME 04330
(207) 622-8208

U.S. Department of Agriculture
Natural Resources Conservation
Service
USDA Building
University of Maine
5 Godfrey Drive
Orono, ME 04473
(207) 866-7241

NFIP State Coordinator

Mr. Michael W. Aube, Commissioner
Department of Economic and
Community Development
State House Station 59
State Street
Augusta, ME 04333
(207) 287-2656

MARYLAND

Maryland State Resources
Administration
Tawes State Office Building, D-2
501 Taylor Avenue
Annapolis, MD 21401
(410) 974-3041

U.S. Geological Survey
District Chief
Water Resources Division
208 Carroll Building
8600 La Salle Road
Towson, MD 21286
(410) 828-1535

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Department of Agriculture
Natural Resources Conservation
Service
339 Busch's Frontage Road
Suite 301
Annapolis, MD 21401-5534
(410) 757-0861

NFIP State Coordinator

Ms. Catherine Pieper Stevenson
Director, Maryland Water Resources
Administration
Tawes State Office Building D-2
Annapolis, MD 21401
(301) 974-3896

MASSACHUSETTS

Massachusetts Water
Resources Commission
State Office Building
100 Cambridge Street
Boston, MA 02202
(617) 727-3267

U.S. Geological Survey
District Chief
Water Resources Division
28 Lord Road
Marlborough, MA 01752
(508) 485-6360

U.S. Department of Agriculture
Natural Resources Conservation
Service
451 West Street
Amherst, MA 01002
(413) 253-4350

NFIP State Coordinator

Mr. Peter C. Webber, Commissioner
Massachusetts Department of
Environmental Management
State Office Building
100 Cambridge Street
Boston, MA 02202
(617) 727-3180 x600

MICHIGAN

Engineering Water
Management Commission
Michigan Department of
Natural Resources
P.O. Box 30028
Lansing, MI 48909
(517) 373-3930

U.S. Geological Survey
District Chief
Water Resources Division
6520 Mercantile Way, Suite 5
Lansing, MI 48910
(517) 887-8903

U.S. Department of Agriculture
Natural Resources Conservation
Service
Room 101
1405 S. Harrison Road
East Lansing, MI 48823
(517) 337-6701

NFIP State Coordinator

Mr. Roland Harms, Director
Michigan Department of Natural
Resources
Land and Water Management Division
P.O. Box 30028
Lansing, MI 48909
(517) 373-3930

MINNESOTA

Flood Plains/Shoreline
Management Section
Division of Waters
Department of Natural Resources
500 Lafayette Road, Box 30
St. Paul, MN 55515-4032
(612) 297-2405

U.S. Geological Survey
District Chief
Water Resources Division
2280 Woodale Road
Moundsville, MN 55112
(612) 783-3100

U.S. Department of Agriculture
Natural Resources Conservation
Service
600 Farm Credit Building
375 Jackson Street
St. Paul, MN 55101
(612) 290-3675

NFIP State Coordinator

Mr. Ronald Nargang, Director
Minnesota Department of Natural
Resources
Division of Water
500 LaFayette Road, Box 32
St. Paul, MN 55515-0432
(612) 296-4800

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

MISSISSIPPI

Mississippi Research and
Development Center
3825 Ridgewood Road
Jackson, MI 39211
(601) 982-6376

U.S. Geological Survey
District Chief
Water Resources Division
Federal Office Building, Suite 710
100 West Capitol Street
Jackson, MS 39269
(601) 965-4600

U.S. Department of Agriculture
Natural Resources Conservation
Service
100 W. Capitol
Suite 1321
Federal Building
Jackson, MS 39269
(601) 969-5205

NFIP State Coordinator

Mr. J. E. Maher, Director
Mississippi Emergency Management
Agency
1410 Riverside Drive
P.O. Box 4501
Jackson, MS 39216
(601) 352-9100

MISSOURI

Department of Natural Resources
P.O. Box 176
205 Jefferson Street
Jefferson City, MO 65102
(314) 751-4422

U.S. Geological Survey
District Chief
Water Resources Division
1400 Independence Road,
(Mail Stop) 200
Rolla, MO 65401
(314) 341-0824

U.S. Department of Agriculture
Natural Resources Conservation
Service
601 Business Loop
70 West Parkdale Center, Suite 250
Columbia, MO 65202
(314) 876-0903

NFIP State Coordinator

Director
Missouri Department of Natural
Resources
101 N. Jefferson Street
P.O. Box 176
Jefferson City, MO 65102
(314) 751-4422

MONTANA

Montana Department of Natural
Resources and Conservation
1520 East Sixth Avenue
Helena, MT 59620
(406) 444-6646

U.S. Geological Survey
Federal Building, Room 428
Drawer 10076
301 South Park Avenue
Helena, MT 59626-0076
(406) 449-5302

U.S. Department of Agriculture
Natural Resources Conservation
Service
10 E. Babcock
Room 443
Bozeman, MT 59715
(406) 587-6811

NFIP State Coordinator

Mr. Mark Simonich, Director
Montana Department of Natural
Resources and Conservation
1520 East 6th Ave.
Helena, MT 59620
(406) 444-6699

NEBRASKA

Nebraska Natural Resources
Commission
P.O. Box 94876
Lincoln, NE 68509-4876
(402) 471-2081

U.S. Geological Survey
District Chief
Water Resources Division
Federal Building, Room 406
100 Centennial Mall North
Lincoln, NE 68508
(402) 437-5082

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building, Rm. 345
U.S. Courthouse
100 Centennial Mall, North
P.O. Box 82502
Lincoln, NE 68508-3866
(402) 437-5300

NFIP State Coordinator

Mr. Dayle Williamson, Director
Nebraska Natural Resources
Commission
P.O. Box 94876
Lincoln, NE 68509
(402) 471-2081

NEVADA

Division of Emergency Management
State of Nevada
Capitol Complex
Carson City, NV 89710
(702) 885-4240

U.S. Geological Survey
Hydrologist-in-Charge
Nevada Office
Water Resources Division
Federal Building, Room 224
705 North Plaza Street
Carson City, NV 89701
(702) 882-1388

U.S. Department of Agriculture
Natural Resources Conservation
Service
5301 Longway Lane
Building F, Suite 201
Reno, NV 89511
(702) 784-5863

NFIP State Coordinator

Mr. David McNinch
Nevada Division of Emergency
Management
2525 S. Carson
Capitol Complex
Carson City, NV 89710
(702) 885-4240

NEW HAMPSHIRE

Office of Emergency Management
State Office Park South
107 Pleasant Street
Concord, NH 03301
(603) 271-2231

U.S. Geological Survey
Hydrologist-in-Charge
New Hampshire Office
Water Resources Division
525 Clinton Street, RFD 2
Bow, NH 03304
(603) 225-4681

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building
2 Madbury Road
Durham, NH 03824
(603) 868-7581

NFIP State Coordinator

Col. George L. Iverson, Director
Governor's Office of
Emergency Management
State Office Park South
107 Pleasant Street
Concord, NH 03301
(603) 271-2231

NEW JERSEY

New Jersey Department of
Environmental Protection and Energy
Flood Plain Management Section
CN 419
Trenton, NJ 08625-0419
(609) 292-2296

New Jersey Department of
Environmental Protection and Energy
Division of Natural and Historic
Resources Engineering and
Construction
Element
Floodplain Management Section
Station Plaza 5
501 East State Street, 1st Floor
Trenton, New Jersey 08625-0419
(609) 292-2296

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Geological Survey
District Chief
Water Resources Division
Mountain View Office Park,
Suite 206
810 Bear Tavern Road
West Trenton, NJ 08628
(609) 771-0065

U.S. Department of Agriculture
Natural Resources Conservation
Service
1370 Hamilton Street
Somerset, NJ 08873
(908) 725-3848

NFIP State Coordinator

Mr. Scott A. Weiner, Commissioner
New Jersey Department of
Environmental Protection and Energy
CN 402
Trenton, NJ 08625
(609) 292-2885

NEW MEXICO

New Mexico State Engineer's Office
Bataan Memorial Building
P.O. Box 25102
Santa Fe, NM 87504-5102
(505) 827-6091

U.S. Geological Survey
District Chief
Water Resources Division
4501 Indian School Road, NE
Suite 200
Albuquerque, NM 87110
(505) 262-5300

U.S. Department of Agriculture
Natural Resources Conservation
Service
P.O. Box 2007
517 Gold Avenue, SW., Rm. 301
Albuquerque, NM 87102
(505) 766-3277

NFIP State Coordinator

Mr. Keith Lough
Office of Emergency Planning
and Coordination
Department of Public Safety
P.O. Box 1628
Santa Fe, NM 87503
(505) 827-6091

NEW YORK

Flood Protection Bureau
New York Department of
Environmental Conservation
50 Wolf Road
Albany, NY 12233-3507
(518) 457-3157

U.S. Geological Survey
District Chief
Water Resources Division
445 Broadway, Room 343
Albany, NY 12201
(518) 472-3107

U.S. Department of Agriculture
Natural Resources Conservation
Service
441 South Salina Street
5th floor, Suite 354
Syracuse, NY 13202
(315) 477-6508
FTS 950-5521

NFIP State Coordinator

Mr. James F. Kelly, Director
Flood Protection Bureau
New York State Department of
Environmental Conservation
50 Wolf Road, Room 330
Albany, NY 12233-3507
(518) 457-3157

NORTH CAROLINA

North Carolina Department of
Crime Control and Public Safety
Division of Emergency Management
116 West Jones Street
Raleigh, NC 27603
(919) 733-3867

U.S. Geological Survey
District Chief
Water Resources Division
P.O. Box 30728
3916 Sunset Ridge Road
Raleigh, NC 27622
(919) 856-4510

U.S. Department of Agriculture
Natural Resources Conservation
Service
4405 Bland Avenue
Suite 205
Raleigh, NC 27609
(919) 790-2888

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

NFIP State Coordinator

Mr. Joseph F. Myers, Director
North Carolina Division of
Emergency Management
116 West Jones Street
Raleigh, NC 27603
(919) 733-3867

U.S. Department of Agriculture
Natural Resources Conservation
Service
Room 522
Federal Building
200 North High Street
Columbus, OH 43215
(614) 469-6962

NORTH DAKOTA

State Water Commission
900 East Boulevard
Bismarck, ND 58505
(701) 224-2750

U.S. Geological Survey
District Chief
Water Resources Division
821 East Interstate Avenue
Bismarck, ND 58501
(701) 250-4601

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building, Rm. 270
Rosser Ave. & Third St.
P.O. Box 1458
Bismarck, ND 58502
(701) 250-4435

NFIP State Coordinator

Mr. David A. Sprynczynatyk
State Engineer
North Dakota State Water Commission
900 E. Boulevard
Bismarck, ND 58505
(701) 224-4940

OHIO

Ohio Department of Natural Resources
Flood Plain Planning Unit
Division of Water
1939 Fountain Square
Columbus, OH 43224
(614) 265-6750

U.S. Geological Survey
District Chief
Water Resources Division
975 West Third Avenue
Columbus, OH 43212
(614) 469-5553

NFIP State Coordinator

Mrs. Frances S. Buchholzer, Director
Ohio Department of Natural
Resources
Fountain Square
Columbus, OH 43224
(614) 264-6875

OKLAHOMA

Oklahoma Water Resources Board
600 North Harvey Avenue
P.O. Box 150
Oklahoma City, OK 73101-0150
(405) 231-2500

U.S. Geological Survey
District Chief
Water Resources Division
202 NW Sixty Sixth, Building 7
Oklahoma City, OK 73116
(405) 843-7570

U.S. Department of Agriculture
Natural Resources Conservation
Service
100 USDA
Suite 203
Stillwater, OK 74074
(405) 742-1200

NFIP State Coordinator

Mrs. Patricia P. Eaton
Executive Director
Oklahoma Water Resources Board
600 N. Harvey
Oklahoma City, OK 73101
(405) 231-2500

OREGON

Department of Land Conservation
and Development
1175 Court Street Northeast
Salem, OR 97310
(503) 373-0050

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Geological Survey
Hydrologist-in-Charge
Oregon Office
Water Resources Division
847 Northeast 19th Avenue,
Suite 300
Portland, OR 97323
(503) 251-3200

(717) 782-2202
FTS 590-2202

PUERTO RICO

Puerto Rico Planning Board
1492 Ponce De Leon Avenue, Suite 417
Santurce, Puerto Rico 00907
(809) 729-6920

U.S. Department of Agriculture
Natural Resources Conservation
Service
2115 SE Morrison
Portland, OR 97214
(503) 231-2270

U.S. Geological Survey
District Chief
Water Resources Division
GPO Box 4424
San Juan, PR 00936
(Street Address:
GSA Center, Building 652
Highway 28, Pueblo Viejo)
(809) 783-4660

NFIP State Coordinator

Mr. Richard Benner
Oregon Department of Land
Conservation and Development
1175 Court Street, N.E.
Salem, OR 97310
(503) 378-4928

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building, Rm. 639
Chardon Avenue
GPO Box 4868
San Juan, PR 00936
(809) 753-4206

PENNSYLVANIA

Department of Community Affairs
317 Forum Building
Harrisburg, PA 17120
(717) 787-7160
U.S. Geological Survey
District Chief
Water Resources Division
840 Market Street
Harrisburg, PA 17043-1586
(717) 730-6900

NFIP State Coordinator

Ms. Norma N. Burgos, President
Puerto Rico Planning Board
P.O. Box 41119
San Juan, PR 00940-9985
(809) 727-4444

Ms. Karen A. Miller, Secretary
Pennsylvania Department of
Community Affairs
P.O. Box 155
317 Forum Building
Harrisburg, PA 17120
(717) 787-7160

RHODE ISLAND

Statewide Planning Program
Rhode Island Office of State Planning
1 Capitol Hill
Providence, RI 02908
(401) 277-2656

U.S. Department of Agriculture
Natural Resources Conservation
Service
One Credit Union Place
Suite 340
Harrisburg, PA 17110-2993

U.S. Geological Survey
Hydrologist-in-Charge
Rhode Island Office
Water Resources Division
275 Promanade Street, Suite 150
Providence, RI 02908
(401) 331-9050

NFIP State Coordinator

Federal Building
U.S. Courthouse
805 985
Federal Square Station
Harrisburg, PA 17108

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

U.S. Department of Agriculture
Natural Resources Conservation
Service
40 Quaker Lane, Suite 46
West Warwick, RI 02886
(401) 828-1300

NFIP State Coordinator

Mr. Daniel W. Varin
Associate Director
Department of Transportation
Office of Systems Planning
1 Capitol Hill
Providence, RI 02908-5872
(401) 277-6578

SOUTH CAROLINA

South Carolina Water and Natural
Resources Commission
1201 Main Street, Suite 1100
Columbia, SC 29201
(803) 737-0800

U.S. Geological Survey
District Chief
Water Resources Division
Stevenson Center, Suite 129
720 Gracern Road
Columbia, SC 29210-7651
(803) 750-6100

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Bldg., Rm. 950
1835 Assembly St.
Columbia, SC 29201
(803) 765-5681

NFIP State Coordinator

Mr. Danny Johnson, Director
Surface Water Division
South Carolina Water Resources
Commission
1201 Main Street, Suite 1100
Columbia, SC 29201
(803) 737-0800

SOUTH DAKOTA

Disaster Assistance Programs
Emergency and Management Services
500 East Capitol
Pierre, SD 57501
(605) 773-3231

U.S. Geological Survey
District Chief
Water Resources Division
Federal Building, Room 317
200 Fourth Street Southwest
Huron, SD 57350-2469
(605) 353-7176

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building, Rm. 203
200 4th Street, SW
Huron, SD 57350
(605) 353-1092

NFIP State Coordinator

Mr. Gary N. Whitney, Director
South Dakota Department of
Military and Veteran Affairs
Division of Emergency and
Disaster Services
500 E. Capitol
Pierre, SD 57501
(605) 773-3231

TENNESSEE

Tennessee Department of Economic
and Community Development
Division of Community Development
320 Sixth Avenue North, Sixth Floor
Nashville, TN 37243-0405
(615) 741-1888

U.S. Geological Survey
District Chief
Water Resources Division
810 Broadway, Suite 500
Nashville, TN 37203
(615) 736-5424

U.S. Department of Agriculture
Natural Resources Conservation
Service
U.S. Courthouse, Rm. 675
801 Broadway Street
Nashville, TN 37203
(615) 736-5471
FTS 852-5471

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

NFIP State Coordinator

Mr. Michael McGuire
Assistant Commissioner
Tennessee Department of Economic and
Community Development
320 Sixth Avenue
North Nashville, TN 37219-5408
(615) 741-2211

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Building
125 S. State Street
P.O. Box 11350
Salt Lake City, UT 84147
(801) 524-5068

TEXAS

Texas Natural Resource
Conservation Commission
P.O. Box 13087
Capitol Station
Austin, TX 78711-3087
(512) 239-1000

U.S. Geological Survey
District Chief
Water Resources Division
8011 Cameron Road
Austin, TX 78754
(512) 873-3000

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Bldg.
101 S. Main Street
Temple, TX 76501
(817) 774-1214

NFIP State Coordinator

Mr. Jesus Galza
Executive Director
Texas Water Commission
P.O. Box 13087
Capitol Station
Austin, TX 78711-3087
(512) 463-7791

UTAH

Office of Comprehensive
Emergency Management
State Office Building, Room 1110
Salt Lake City, UT 84114
(801) 538-3400

U.S. Geological Survey
District Chief
Water Resources Division
2363 Foothill Drive
Salt Lake City, UT 84109
(801) 467-7970

NFIP State Coordinator

Ms. Lorayne Frank, Director
Department of Public Safety
Division of Comprehensive Emergency
Management
State Office Building, Room 1110
450 North Main
Salt Lake City, UT 84114
(801) 538-3400

VERMONT

Agency of Natural Resources
Department of Environmental
Conservation
Water Quality Division
103 South Main Street - 10N
Waterbury, VT 05671-0408
(802) 241-3777

U.S. Geological Survey
District Chief
Water Resources Division
P.O. Box 628
Montpelier, VT 05602
(802) 828-4479

U.S. Department of Agriculture
Natural Resources Conservation
Service
69 Union Street
Winooski, VT 05404
(802) 951-6795

NFIP State Coordinator

Mr. Chuck Clarde, Secretary
Agency of Natural Resources
Center Building
103 South Main Street
Waterbury, VT 05671-0301
(802) 244-7347

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

VIRGIN ISLANDS

Virgin Islands of the U.S.
Virgin Islands Planning Department
and Natural Resources
Charlotte Amalie
Nisky Center, Suite 231
St. Thomas, VI 00802
(809) 774-3320

U.S. Geological Survey
District Chief
Water Resources Division
GPO Box 4424
San Juan, PR 00936
(Street Address:
GSA Center, Building 652
Highway 28, Pueblo Viejo)
(809) 783-4660

NFIP State Coordinator

Mr. Roy E. Adams, Commissioner
Virgin Islands Department of
Planning and Natural Resources
Suite 231, Nisky Center
Charlotte Amalie
St. Thomas, VI 00802
(809) 774-3320

VIRGINIA

Virginia State Department of
Environmental Quality
4900 Cot Road
Glen Allen, VA 23060
(804) 527-5000

U.S. Geological Survey
Hydrologist-in-Charge
Virginia Office
Water Resources Division
3600 West Broad Street
Room 606
Richmond, VA 23230
(804) 771-2427

U.S. Department of Agriculture
Natural Resources Conservation
Service
1606 Santa Rosa Road
Suite 209
Richmond, VA 23229
(804) 287-1689

NFIP State Coordinator

Mr. Roland B. Geddes, Director
Department of Conservation and
Historic Resources
203 Governor Street, Suite 206
Richmond, VA 23219
(804) 786-4356

WASHINGTON

Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
(206) 407-6000

U.S. Geological Survey
District Chief
Water Resources Division
1201 Pacific Avenue, Suite 600
Tacoma, WA 98402
(206) 593-6510

U.S. Department of Agriculture
Natural Resources Conservation
Service
316 Boone Avenue
Suite 456
Spokane, WA 99201
(509) 353-2336

NFIP State Coordinator

Mr. Chuck Clark
Washington Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
(206) 459-6168

WEST VIRGINIA

West Virginia Office of
Emergency Services
Room EB-80, Capitol Building
Charleston, WV 25305
(304) 348-5380

U.S. Geological Survey
District Chief
Water Resources Division
11 Dunbar Street
Charleston, WV 25301
(304) 347-5130

U.S. Department of Agriculture
Natural Resources Conservation
Service
75 High Street, Rm. 301
Morgantown, WV 26505
(304) 291-4151

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

Other Federal and State Agencies

NFIP State Coordinator

Mr. Carl Bradford, Director
West Virginia Office of
Emergency Services
Room EB1-80
Capitol Building
Charleston, WV 25305
(304) 348-5380

U.S. Department of Agriculture
Natural Resources Conservation
Service
Federal Office Building
100 East "B" Street
Casper, WY 82601
(307) 261-5231

WISCONSIN

Department of Natural Resources
Dam Safety/Floodplain
Management Section
P.O. Box 7921
Madison, WI 53707
(608) 266-2621

NFIP State Coordinator

Mr. Joe Daly, Coordinator
Wyoming Emergency Management
Agency
P.O. Box 1709
Cheyenne, WY 82003
(307) 777-7566

U.S. Geological Survey
District Chief
Water Resources Center
University of Wisconsin/Madison
1975 Willard Drive
Madison, WI 53706-4042
(608) 262-3577

U.S. Department of Agriculture
Natural Resources Conservation
Service
6515 Watts Road
Suite 200
Madison, WI 53719
(608) 264-5341

NFIP State Coordinator

Mr. Carroll D. Besandy, Secretary
Wisconsin Department of Natural
Resources
P.O. Box 7921
Madison, WI 53707
(608) 266-2121

WYOMING

Wyoming Emergency Management Agency
P.O. Box 1709
Cheyenne, WY 82003-1709
(307) 777-4900

U.S. Geological Survey
District Chief
Water Resources Division
P.O. Box 1125
Cheyenne, WY 82003
(Street Address:
2617 East Lincoln Way
Cheyenne, WY 82001
(307) 772-2153

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

U.S. Army Corps of Engineers

U.S. Army Corps of Engineers
Headquarters
20 Massachusetts Ave., NW
Washington, D.C. 20314-1000
Attn: CECW-PF
202/272-0169

U.S. Army Corps of Engineers
Lower Miss. Valley Division
P.O. Box 80
Vicksburg, MS 39181-0080
Attn: CELMV-PD-CM
601/634-5827

U.S. Army Corps of Engineers
Memphis District
167 North Main Street, B-202
Memphis, TN 38103-1894
Attn: CELMM-PD-M
901/544-3968

U.S. Army Corps of Engineers
New Orleans District
P.O. Box 60267
New Orleans, LA 70160-0267
Attn: CELMN-PD-FG
504/865-1121

U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, MO
63103-2833
Attn: CELMS-PD-M
314/331-8483

U.S. Army Corps of Engineers
Vicksburg District
2101 North Frontage Road
Vicksburg, MS 39180-0060
Attn: CELMK-PD-FS
601/631-5416

U.S. Army Corps of Engineers
Missouri River Division
12565 West Center Road
Omaha, NE 68104-3869
Attn: CEMRD-PD-F
402/221-7273

U.S. Army Corps of Engineers
Kansas City District
700 Federal Building Kansas
City, MO 64106-2896
Attn: CEMRK-PD-P
816/426-3674

U.S. Army Corps of Engineers
Omaha District
215 North 17th Street
Omaha, NE 68102-4978
Attn: CEMRO-PD-F
402/221-4596

U.S. Army Corps of Engineers
North Atlantic Division
90 Church Street
New York, NY 10007-2979
Attn: CENAD-PL-FP
212/264-7482

U.S. Army Corps of Engineers
Baltimore District
Supervisor of Baltimore Harbor
P.O. Box 1715
Baltimore, MD 21201-1715
Attn: CENAB-PL-B
410/962-7608

U.S. Army Corps of Engineers
New York District, Planning Division,
Floodplain Management Section
26 Federal Plaza
New York, NY 10278
Attn: CENAN-PL-FP
212/264-8870

U.S. Army Corps of Engineers
Norfolk District
Supervisor of Norfolk Harbor
803 Front Street
Norfolk, VA 23510-1096
Attn: CENAO-PL-FP
804/441-7779

U.S. Army Corps of Engineers
Philadelphia District
U.S. Customs House
2nd & Chestnut Streets
Philadelphia, PA 19106-2991
Attn: CENAP-PL-F
215/656-6516

U.S. Army Corps of Engineers
North Central Division
111 North Canal Street, 14th Floor
Chicago, IL 60606
Attn: CENCD-PD-FP
312/353-1279

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Federal Emergency Management Agency Offices
and Other Federal and State Agencies

U.S. Army Corps of Engineers

U.S. Army Corps of Engineers
Buffalo District, Planning Division,
Floodplain Management Section
1776 Niagara Street
Buffalo, NY 14207-3199
Attn: CENCB-PD-FP
716/879-4104

U.S. Army Corps of Engineers
Chicago District
111 North Canal Street
14th Floor
Chicago, IL 60606
Attn: CENCC-PD-R
312/353-6400

U.S. Army Corps of Engineers
Detroit District
477 Michigan Avenue
Detroit, MI 48226
Attn: CENCE-PD-PF
313/226-6773

U.S. Army Corps of Engineers
Rock Island District
P.O. Box 2004
Clock Tower Building
Rock Island, IL 61204-2004
Attn: CENCR-PD-F
309/788-4750

U.S. Army Corps of Engineers
St. Paul District
190 Phipps Street East
St. Paul, MN 55101-1638
Attn: CENCS-PD-FS
612/290-5200

U.S. Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, MA 02254-9149
Attn: CENED-PL-B
617/647-8111

U.S. Army Corps of Engineers
North Pacific Division
333 Southwest 1st Avenue
Portland, OR 97204
Attn: CENPD-PL-FS
503/326-6021

U.S. Army Corps of Engineers
Alaska District
P.O. Box 898
Anchorage, AK 99506-0898
Attn: CENPA-EN-PL-FP
907/753-2504

U.S. Army Corps of Engineers
Portland District
P.O. Box 2946
Portland, OR 97208-2946
Attn: CENPP-PL-CF
503/326-6411

U.S. Army Corps of Engineers
Seattle District
P.O. Box 3755
Seattle, WA 98124-2255
Attn: CENPS-EN-HH
206/764-3660

U.S. Army Corps of Engineers
Walla Walla District
Bldg. 602 City-County Airport
Walla Walla, WA 99362-9265
Attn: CENPW-PL-FP
509/522-6589

U.S. Army Corps of Engineers
Ohio River Division
P.O. Box 59
Louisville, KY 40201-0059
Attn: CEORD-PD-J
502/582-5782

U.S. Army Corps of Engineers
Huntington District
502 8th Street
Huntington, WV 25701-2070
Attn: CEORH-PD-S
304/529-5644

U.S. Army Corps of Engineers
Louisville District
P.O. Box 59
Louisville, KY 40201-0059
Attn: CEORL-PD-S
502/582-5742

U.S. Army Corps of Engineers
Nashville District
P.O. Box 1070
Nashville, TN 37202-1070
Attn: CEORN-ED-P
615/736-5055

U.S. Army Corps of Engineers
Pittsburgh District
William S. Moorehead Fed. Bldg.
1000 Liberty Avenue
Pittsburgh, PA 15222-4186
Attn: CEORP-PD-J
412/644-6924

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

U.S. Army Corps of Engineers

U.S. Army Corps of Engineers Pacific Ocean Division Ft. Shafter, HI 96858-5440 Attn: CEPOD-ED-PH 808/438-7009	U.S. Army Corps of Engineers Sacramento District 1325 G Street Sacramento, CA 95814-4794 Attn: CESPKE-PD-F 916/557-6700
U.S. Army Corps of Engineers Charleston District, P.O. Box 919 Charleston, SC 29402-0919 Attn: CESAC-EN-PH 803/727-4263	U.S. Army Corps of Engineers San Francisco District 211 Main Street San Francisco, CA 9410S-1905 Attn: CESPNE-PE-W 415/744-3029
U.S. Army Corps of Engineers South Atlantic Division 611 South Cobb Drive Marietta, GA 30060 Attn: CESAD-PD-A 404/421-5296	U.S. Army Corps of Engineers Southwestern Division 1114 Commerce Street Dallas, TX 75242-0216 Attn: CESWD-PL-M 214/767-2310
U.S. Army Corps of Engineers Jacksonville District P.O. Box 4970 Jacksonville, FL 32232-0019 Attn: CESAJ-PD-FP 904/232-2234	U.S. Army Corps of Engineers Albuquerque District P.O. Box 1580 Albuquerque, NM 87103-1580 Attn: CESWA-ED-PH 505/766-2635
U.S. Army Corps of Engineers Mobile District P.O. Box 2288 Mobile, AL 36628-0001 Attn: CESAM-PD-P 205/694-3879	U.S. Army Corps of Engineers Fort Worth District P.O. Box 17300 Fort Worth, TX 76102-0300 Attn: CESWF-PL-F 817/334-3207
U.S. Army Corps of Engineers Savannah District P.O. Box 889 Savannah, GA 31402-0889 Attn: CESAS-PD-F 912/652-5822	U.S. Army Corps of Engineers Galveston District P.O. Box 1229 Galveston, TX 77553-1229 Attn: CESWG-PL-P 409/766-3023
U.S. Army Corps of Engineers Wilmington District P.O. Box 1890 Wilmington, NC 28402-1890 Attn: CESAW-PD-F 910/251-4822	U.S. Army Corps of Engineers Little Rock District P.O. Box 867 Little Rock, AR 72203-0867 Attn: CESWL-PL-F 501/378-5611
U.S. Army Corps of Engineers South Pacific Division, Room 720 630 Sansome Street San Francisco, CA 94111-2206 Attn: CESPDP-PD-P 415/705-2427	U.S. Army Corps of Engineers Tulsa District P.O. Box 61 Tulsa, OK 74121 0061 Attn: CESWT-PL-GF 918/581-7896
U.S. Army Corps of Engineers Los Angeles District P.O. Box 2711 Los Angeles, CA 90053-2325 Attn: CESPL-PD-WF 213/894-5450	

Appendix 3 - continued

Federal Emergency Management Agency Offices
and Other Federal and State Agencies

River Basin Commissions

Delaware River Basin Commission
25 State Police Drive
Box 7360
West Trenton, NJ 08628
609/883-9500

Susquehanna River Basin Commission
1721 North Front Street
Harrisburg, PA
717/238-0422

Appendix 4

State Hydrology Reports

ALABAMA

Olin, D.A. and Bingham, R.H., 1982, **Synthesized flood frequency of urban streams in Alabama:** U.S. Geological Survey Water-Resources Investigations 82-683.

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ALASKA

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ARIZONA

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ARKANSAS

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CALIFORNIA

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COLORADO

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**Appendix 4 - continued
State Hydrology Reports**

CONNECTICUT

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DISTRICT OF COLUMBIA

None listed

FLORIDA

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GEORGIA

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HAWAII

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Appendix 4 - continued
State Hydrology Reports

IDAHO

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ILLINOIS

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INDIANA

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IOWA

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KANSAS

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Hedman, E.R., Kastner, W.M., and Hejl, H.R., 1974, **Selected streamflow characteristics as related to active-channel geometry of streams in Kansas:** Kansas Water Resources Board Technical Report No. 10.

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KENTUCKY

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Appendix 4 - continued
State Hydrology Reports

LOUISIANA

Lee, F.N., 1985, **Floods in Louisiana, Magnitude and Frequency, Fourth Edition:** Department of Transportation and Development, Water Resources Technical Report No. 36.

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MAINE

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MARYLAND

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MASSACHUSETTS

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MICHIGAN

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MINNESOTA

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MISSISSIPPI

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MISSOURI

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**Appendix 4 - continued
State Hydrology Reports**

MISSOURI continued

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MONTANA

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NEBRASKA

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NEVADA

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NEW JERSEY

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Appendix 4 - continued
State Hydrology Reports

NEW MEXICO

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NEW YORK

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NORTH CAROLINA

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Appendix 5

Manning's "n" Values

The value of "n" may be computed by

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)m_5$$

where:

n_0	=	basic "n" value for a straight, uniform, smooth channel
n_1	=	value added to correct for the effect of surface irregularities
n_2	=	value added for variation in the shape and size of the channel cross section
n_3	=	value added for obstructions
n_4	=	value added for vegetation and flow conditions
m_5	=	correction factor for meandering of the channel

Proper values of n_0 to n_4 and m_5 may be selected from the following table according to the given conditions:

Channel Conditions		Values	
Material involved	Earth	n_0	0.020
	Rock cut		0.025
	Fine gravel		0.024
	Coarse gravel		0.028
Degree of irregularity	Smooth	n_1	0.000
	Minor		0.005
	Moderate		0.010
	Severe		0.020
Variations of channel cross section	Gradual	n_2	0.000
	Alternating occasionally		0.005
	Alternating frequently		0.010-0.015
Relative effect of obstructions	Negligible	n_3	0.000
	Minor		0.010-0.015
	Appreciable		0.020-0.030
	Severe		0.040-0.060
Vegetation	Low	n_4	0.005-0.010
	Medium		0.010-0.025
	High		0.025-0.050
	Very High		0.050-0.100
Degree of meandering	Minor	m_5	1.000
	Appreciable		1.150
	Severe		1.300

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The computed "n" values should be compared with the typical "n" values from the following pages, or with those in the U.S. Geological Survey Report (Reference 2) or the Federal Highway Administration Report (Reference 3).

Appendix 5 - continued
Manning's "n" Values

Type of channel and description	Minimum	Normal	Maximum
A. Closed Conduits Flowing Partly Full			
A-1. Metal			
a. Brass, smooth	0.009	0.010	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	0.024	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	0.010	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	0.013	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	0.014	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	0.013	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	0.016	0.018
g. Brickwork			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030

Appendix 5 - continued
Manning's "n" Values

Type of channel and description	Minimum	Normal	Maximum
B. Lined or Built-up Channels			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	0.012	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	0.013	0.015
2. In cement mortar	0.012	0.015	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	0.500

Appendix 5 - continued
Manning's "n" Values

Type of channel and description	Minimum	Normal	Maximum
C. Excavated or Dredged			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. Natural Streams			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pods	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Appendix 5 - continued
Manning's "n" Values

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Floodplains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage below branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	0.060
b. Irregular and rough section	0.035	0.100

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Appendix 6

QUICK-2 Computer Program Manual

Q U I C K - 2

Computer Program

***COMPUTATION OF WATER SURFACE
ELEVATIONS IN OPEN
CHANNELS***

VERSION 1.0

JANUARY 1995

QUICK-2

Computation of Water Surface Elevations in Open Channels

User's Guide

Federal Emergency Management Agency

1995

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Chapter 1: Introduction

QUICK-2 is a user friendly program that assists in the computation of flood Water Surface Elevations (WSEs) in open channels of all types. It is much easier to use than the United States Army Corps of Engineers (USACE) HEC-2 program. However, a QUICK-2 step-backwater file can also be used, as is, with the HEC-2 program, which is also included in the QUICK-2 package of programs. Therefore a HEC-2 output file can be generated with a QUICK-2 input data file, without ever leaving the QUICK-2 environment; and, without having to know how to set-up and run the HEC-2 program. This version of QUICK-2 (Version 1.0) however, does not perform hydraulic calculations through bridges or culverts.

QUICK-2 was primarily developed to accompany the FEMA technical guidance manual titled, "MANAGING FLOODPLAIN DEVELOPMENT IN ZONE A AREAS - A GUIDE FOR OBTAINING AND DEVELOPING BASE FLOOD ELEVATIONS." That manual is intended to assist local community officials who are responsible for administering and enforcing the floodplain management requirements of the National Flood Insurance Program (NFIP). The purpose of that manual is to provide guidance for obtaining and developing base flood (100-year) elevations (BFEs) where Special Flood Hazard Areas (SFHAs) on a community's Flood Hazard Boundary Map (FHBM) or Flood Insurance Rate Map (FIRM) have been identified and designated as Zone A.

QUICK-2 will also be useful to community engineers, architect/engineer firms, developers, builders and others at the local level who may be required to develop BFEs for use in Special Flood Hazard Areas.

This manual includes four other chapters: **Overview**, **Getting Started**, **Tutorials** and **Formulas**. The Formulas section describes the "complex" equations and methodologies used in the development of the program. An Appendix is also included that contains a list of Definitions of the variables shown on the screen and on the printouts.

To get started as quickly as possible in using QUICK-2 we recommend that the user read the Overview and Getting Started chapters; and then work through the Tutorials.

MINIMUM SYSTEM REQUIREMENTS

Random Access Memory (RAM)	-	512K
Hard disk storage	-	800K
Monitor	-	Color or Monotone
Printer (prints to LPT1)	-	Dot-matrix to LaserJet
Disk Operating System (DOS)	-	Version 3.0 or higher

Chapter 2: Overview

√ FOUR OPTIONS

This user friendly program computes:

- *Critical Depth*,
- *Cross Section Capacity* (Rating Curves),
- *Normal Depth*, and
- *Step-Backwater Analysis* (similar to the USACE HEC-2 program)

CRITICAL DEPTH: This option should be used to determine a Base Flood Elevation (BFE) if a previous calculation using the Normal Depth option computed a depth that was determined to be SUPERCRITICAL. Super Critical depths are generally not accepted for use as BFEs.

CHANNEL CAPACITY: This option is used to determine a rating curve for a cross section. The program computes a discharge based on the entered depth. Repeating with other depths produces a rating curve. A BFE may be determined by interpolation with the correct discharge.

NORMAL DEPTH: This is the usual option to use in determining BFEs. The user should watch the "Flow Type" message to make sure that the calculation is CRITICAL or SUBCRITICAL. Use Option 1 if SUPERCRITICAL.

STEP-BACKWATER: This option should be used to calculate BFEs if more than one cross-section is warranted to cover the extent of the property. Generally if the property parallels more than 500 feet of a flooding source this option should be used.

√ HANDLES "REGULAR" AND "IRREGULAR" SHAPED CROSS SECTIONS

The REGULAR shape cross-sections include:

- *V-shape*,
- *Trapezoidal*,
- *Rectangular*, and
- *Circular*

For IRREGULAR cross-sections:

- up to 40 points can be input to describe the ground points
- Ground points are easily modified using the Insert or Delete Keys
- Encroachments or other changes in the floodplain are easily modeled
- An unlimited number of cross sections may be modeled

In addition, ground points and other input variables for the irregular shape cross-sections can be saved to a file, for later use.

√ **SINGLE SCREEN DATA INPUT, COMPUTATION AND OUTPUT**

One of the most user-friendly aspects of this program that sets it apart from many other computational programs is that all of the data input, the computation, and the printing or plotting, is performed from the same screen. You will not get lost in a maze of menus.

√ **GRAPHICS**

- *Cross-Section Plots,*
- *Water Surface Elevation Profiles,* and
- *Rating Curve Plots*

Cross section plots and water surface elevation profiles from QUICK-2's step-backwater analysis can be viewed on the screen using the USACE PLOT-2 program that comes with the QUICK-2 package of programs. The channel capacity option of QUICK-2 can be used to generate rating curve plots of individual cross sections that can be viewed on screen and printed.

√ **AUTOMATIC ERROR CHECKING**

This software is designed to virtually eliminate the need for user's manuals. The program incorporates error-checking routines and warning messages to alert the user to incorrect input data or potentially incorrect output data. The program prompts the user for the required input data so that there is no need to worry about which columns to put data in; whether or not it needs to be left-justified, or right-justified, etc.

SPECIAL FEATURES OF QUICK-2**»» Critical Depth, Channel Capacity, and Normal Depth Options ««**

EASY VIEW: All of the input data is viewed on the same screen (and changes can be made) before starting the computations

EASY CHANGE: After an initial calculation, the following parameters can be changed, and the above options can be re-calculated in seconds:

Discharge	Channel Slope	Manning's N
Base width or Diameter	Channel Side Slope	Ground Points
Channel Stations		

AUTO-SAVE: For irregular channels the program automatically stores all the input variables to a file designated as "TEMP.XSC", which is stored in the C:\QUICK2\DATA Directory.

RATING CURVES: A special feature of the Channel Capacity Option for irregular channels is the Rating Curve Print Option. A rating curve plot can be automatically generated with 20 computations of water surface elevation versus discharge. The maximum elevation of the rating curve will be just lower than the channel depth specified by the user. The rating curve can be viewed on the screen and/or printed.

»» Step-Backwater Option ««

EASY VIEW: All of the input data is viewed on the same screen (and changes can be made) before starting the computations

PRECISE: Balances the energy equation to within .01 foot.

COMPUTES CRITICAL DEPTH AUTOMATICALLY: After up to 40 energy balance trials (without a balance) the program automatically computes critical depth.

OUTPUT OPTIONS: Detailed and Summary printouts are available

AUTO-SAVE: The program automatically saves the first cross-section into a file designated as T0.XSC, and subsequent cross-sections are saved adding the Channel distance (XLCH) to the previous cross-section's file name. Therefore, if we run 3 cross-sections that are 200 feet apart their filenames will be: T0.XSC, T200.XSC, and T400.XSC. These files are automatically stored in a directory named C:\QUICK2\DATA.

HEC-2 RUNS WITH QUICK-2 FILES: The backwater option also automatically saves all of the cross-sections into a HEC-2 compatible file called HEC2.DAT, which is stored in the C:\QUICK2 Directory. The QUICK-2 program is linked with the USACE HEC-2 program such that any backwater computation that is run using QUICK-2 can also be run using the HEC-2 program within the QUICK-2 environment. The user does not need to have any previous experience in running the HEC-2 model.

AUTOMATIC ERROR CHECKS AND WARNING MESSAGES

ERROR CHECKS

Error checks prevent the user from continuing by re-prompting the user for correct input data. The following are error checks performed automatically by the program:

- Ground Point (GR) stations should be increasing
 - Stations of the left and right bank should match a GR point
-

WARNING MESSAGES

Warning messages instruct the user that the program has had to modify the input data in order to complete a calculation, or that the completed calculation may not be valid. The following are warning messages performed by the program:

Extended Cross Section

The computed water surface elevation is higher than one or both ends of the cross-section, and the program automatically extended the end(s) of the cross-section vertically to complete the computation.

Divided Flow

There is a ground point(s) within the cross-section which is higher than the computed water surface elevation which is dividing the flow within the cross-section.

No Energy Balance ... Computing Critical Depth

The program attempted up to 40 trial computations and could not arrive at an energy balance; and therefore, critical depth is assumed to occur at this cross-section.

Computing Critical Depth ... Critical Depth Assumed

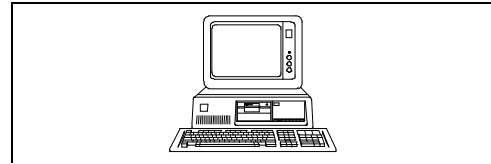
Either the initial Starting Water Surface Elevation or an energy balance between two cross sections occurred at an elevation for which the froude number or the index froude number was equal to or greater than 1. Thus, the computed water surface elevation is suspected of being below the critical depth. Therefore the critical depth is computed and compared to the previous calculated water surface elevation. In this case the critical depth elevation was higher, and thus Critical Depth is Assumed.

Computing Critical Depth ... Critical Depth Not Assumed

Same as above except, the critical depth is computed and compared to the previous calculated water surface elevation; and, in this case the critical depth elevation was lower, and thus Critical Depth is **Not** Assumed.

Chapter 3: Getting Started

This section provides you with convenient installation and run procedures that will enable you to run the program from the hard disk drive or the floppy disk drive.



HARD DISK INSTALLATION AND RUN PROCEDURE

To install and run QUICK-2 simply place the floppy disk in either your "A" disk drive or your "B" disk drive.

For "A" Drive users: Type **A:\AQ2** and Press <Enter>

For "B" Drive users: Type **B:\BQ2** and Press <Enter>

Follow the screen message to start the program. That's it!

The program resides in a C:\QUICK2 directory. To run the program in the future, just change to that directory and type Q2 and press <Enter>.

FLOPPY DISK INSTALLATION AND RUN PROCEDURE

To install and run QUICK-2 from the floppy disk drive simply place the floppy disk in either your "A" disk drive or your "B" disk drive.

For "A" Drive users: Type **A:\FAQ2** and Press <Enter>

For "B" Drive users: Type **B:\FBQ2** and Press <Enter>

Follow the screen message to start the program. That's it!

To run the program in the future, just place the disk in your floppy drive, change to that directory and type Q2 and press <Enter>. *Although the program will run from the floppy disk drive it will run much faster if installed and run on the hard disk drive.*

REMINDER:

Entering and editing data, as well as moving around within the input screens is performed using the Function keys, the Backspace Key and the Enter Key. **DO NOT USE THE CURSOR CONTROL KEYS (ARROW KEYS) FOR ENTERING, DELETING, OR EDITING DATA.**

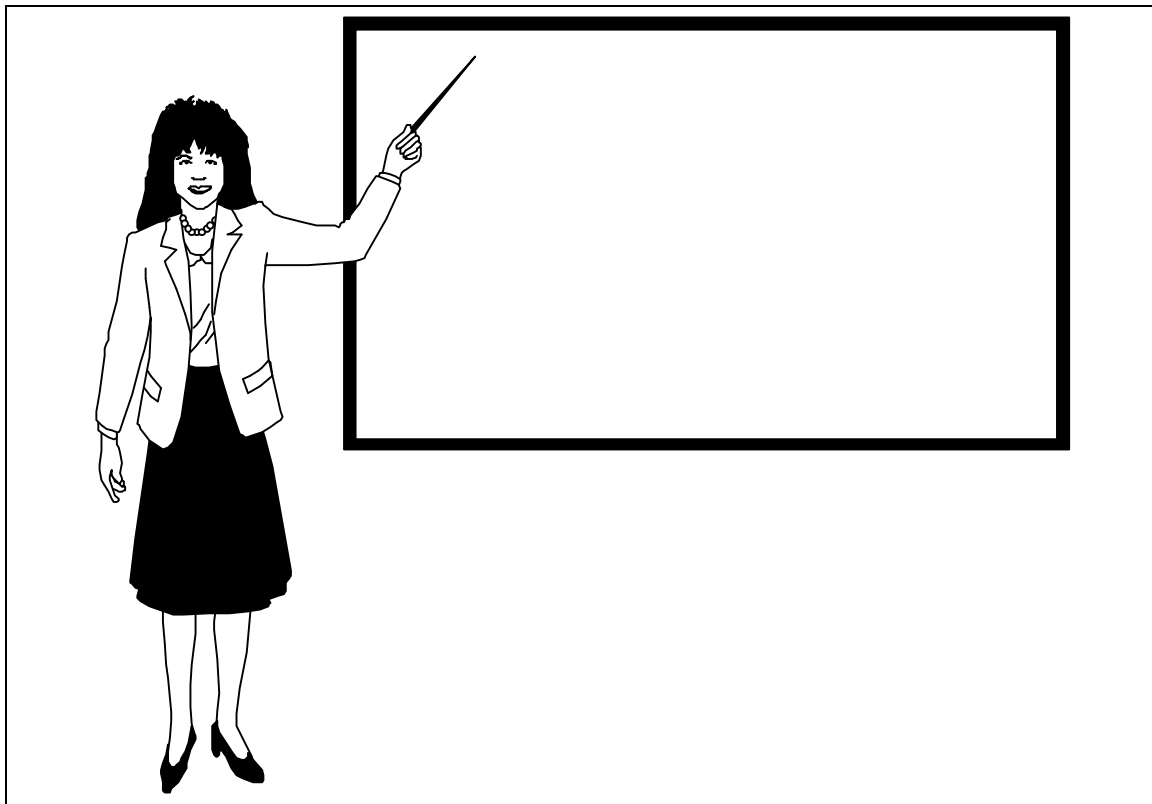
Chapter 4: TUTORIALS

Normal Depth

Step-Backwater

Channel Capacity

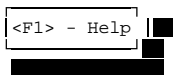
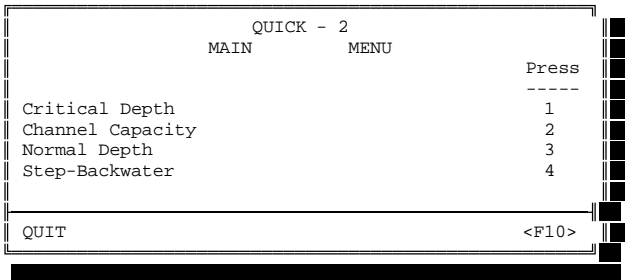
PLOT - 2



{TIME REQUIRED TO COMPLETE ALL THE TUTORIALS IS ABOUT ONE HOUR}

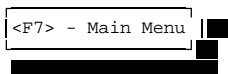
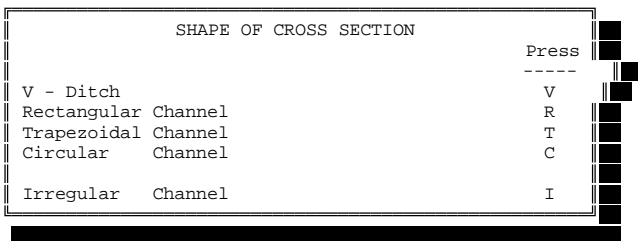
NORMAL DEPTH {Tutorial Time: 5 to 10 minutes}

After pressing **Q2** and **<Enter>** to start the program you will come to the Main Menu screen of QUICK-2 as shown below.



1. Press **3** and then press **<Enter>** to start the Normal Depth Option.

Next you will see the Shape of Cross Section screen:



Let's try the Trapezoidal Channel option.

2. Press **T** and then press **<Enter>** to perform a Normal Depth calculation for a trapezoidal channel.

The next screen you will see is the Input / Output screen:

```

NORMAL DEPTH
TRAPEZOIDAL CHANNEL

INPUT VARIABLES
L Side Slope (H:V)      :1  R Side Slope (H:V)      :1
Bottom Width (ft)      Manning's n
Discharge (cfs)        Depth (ft)
Slope (ft/ft)

OUTPUT VARIABLES
Area (sq ft)           Wet Perimeter (ft)
Velocity (ft/s)        Hyd Radius
Top Width (ft)         Froude #
                       Flow Type

Enter Left Side Slope and Press <Enter>      :1
<- Back Tab <F2>                               Main Menu <F7>
    
```

The program is currently prompting you to enter the Left Side Slope (in terms of the Number of Horizontal feet (H) to every 1 foot Vertical (H : 1)). **Let's say our left side slope is 3 to 1 (3:1).**

3. Enter 3 and then Press **<Enter>**.

The next screen you will see is the Input / Output screen with a new prompt:

```

NORMAL DEPTH
TRAPEZOIDAL CHANNEL

INPUT VARIABLES
L Side Slope (H:V) 3.0:1  R Side Slope (H:V)      :1
Bottom Width (ft)  Manning's n
Discharge (cfs)    Depth (ft)
Slope (ft/ft)

OUTPUT VARIABLES
Area (sq ft)       Wet Perimeter (ft)
Velocity (ft/s)    Hyd Radius
Top Width (ft)     Froude #
                   Flow Type

Enter Right Side Slope and Press <Enter>      :1
<- Back Tab <F2>                               Main Menu <F7>
    
```

Notice that the **3** has been entered to the right of "L Side Slope (H:V)"

The program is currently prompting you to enter the Right Side Slope (in terms of the Number of Horizontal feet (H) to every 1 foot Vertical (H : 1)). **Let's say our right side slope is 2 to 1 (2:1).**

4. Enter 2 and then Press **<Enter>**.

```

NORMAL DEPTH
TRAPEZOIDAL CHANNEL

INPUT VARIABLES
L Side Slope (H:V) 3.0:1   R Side Slope (H:V) 2.0:1
Bottom Width (ft)
Discharge (cfs)           Depth (ft)
Slope (ft/ft)

OUTPUT VARIABLES
Area (sq ft)              Wet Perimeter (ft)
Velocity (ft/s)           Hyd Radius
Top Width (ft)           Froude #
                          Flow Type

Enter "....." and Press <Enter>

<- Back Tab <F2>                Main Menu <F7>
    
```

The program will continue to prompt you for input data.

Let's say our channel is 10 feet wide, with a Manning's n value of 0.035, the discharge is 300 cfs, and the channel slope is .005 ft/ft.

SCREEN PROMPT - "Enter Bottom Width and Press <Enter>"

5. Enter 10 and then Press <Enter>.

SCREEN PROMPT - "Enter Manning's n and Press <Enter>"

6. Enter .035 and then Press <Enter>.

SCREEN PROMPT - "Enter Discharge and Press <Enter>"

7. Enter 300 and then Press <Enter>.

SCREEN PROMPT - "Enter Slope and Press <Enter>"

8. Enter .005 and then Press <Enter>.

```

NORMAL DEPTH
TRAPEZOIDAL CHANNEL

INPUT VARIABLES
L Side Slope (H:V) 3.0:1   R Side Slope (H:V) 2.0:1
Bottom Width (ft)  10.0   Manning's n      0.0350
Discharge (cfs)    300    Depth (ft)       0.00
Slope (ft/ft)     0.0050

OUTPUT VARIABLES
Area (sq ft)              Wet Perimeter (ft)
Velocity (ft/s)           Hyd Radius
Top Width (ft)           Froude #
                          Flow Type

Begin Calculations <Enter>

<- Back Tab <F2>                Main Menu <F7>
    
```

After all the data is input your screen should look like this

To begin the calculation simply ...

9. Press <Enter>.

After a split second the screen should look like this:

NORMAL DEPTH TRAPEZOIDAL CHANNEL			
INPUT VARIABLES			
L Side Slope (H:V)	3.0:1	R Side Slope (H:V)	2.0:1
Bottom Width (ft)	10.0	Manning's n	0.0350
Discharge (cfs)	300	Depth (ft)	3.27
Slope (ft/ft)	0.0050		
OUTPUT VARIABLES			
Area (sq ft)	59.6	Wet Perimeter (ft)	27.7
Velocity (ft/s)	5.0	Hyd Radius	2.2
Top Width (ft)	26.4	Froude #	0.6
		Flow Type	SUBCRITICAL
Begin Calculations	<Enter>		
Print	<F5>		
<- Back Tab	<F2>	Main Menu	<F7>

Notice that the Depth is no longer 0.00, but equals **3.27** feet, which is the Normal Depth for this particular Trapezoidal cross-section. **If 300 cfs represents the 100-year discharge, then the 100-year flood depth would equal 3.27 feet.** All of the output variables have also been computed and listed.

10. To print the output simply Press the <F5> Function key.

The printed output is shown below.

QUICK - 2
NORMAL DEPTH
Trapezoidal Channel

	INPUT VARIABLES	OUTPUT VARIABLES
$\overline{\quad}$ \wedge Depth $\underline{\quad}$ \vee	<p>Base Width = 10.0 Slope = 0.0050</p>	<p>Depth (ft) 3.27 Discharge (cfs) 300.0 Velocity (ft/s) 5.04 Top Width (ft) 26.4 Froude No. 0.59 Flow Type: SUBCRITICAL</p>

CHANGING THE VARIABLES

NORMAL DEPTH TRAPEZOIDAL CHANNEL			
INPUT VARIABLES			
L Side Slope (H:V)	3.0:1	R Side Slope (H:V)	2.0:1
Bottom Width (ft)	10.0	Manning's n	0.0350
Discharge (cfs)	300	Depth (ft)	3.27
Slope (ft/ft)	0.0050		
OUTPUT VARIABLES			
Area (sq ft)	59.6	Wet Perimeter (ft)	27.7
Velocity (ft/s)	5.0	Hyd Radius	2.2
Top Width (ft)	26.4	Froude #	0.6
		Flow Type	SUBCRITICAL
Begin Calculations	<Enter>		
Print	<F5>		
<- Back Tab	<F2>	Main Menu	<F7>

Let's say we want to run this calculation again but with a discharge of 500 cfs instead of 300 cfs.

1. Press the Function Key <F2>

NORMAL DEPTH TRAPEZOIDAL CHANNEL			
INPUT VARIABLES			
L Side Slope (H:V)	3.0:1	R Side Slope (H:V)	2.0:1
Bottom Width (ft)	10.0	Manning's n	0.0350
Discharge (cfs)	300	Depth (ft)	3.27
Slope (ft/ft)	0.0050		
OUTPUT VARIABLES			
Area (sq ft)	59.6	Wet Perimeter (ft)	27.7
Velocity (ft/s)	5.0	Hyd Radius	2.2
Top Width (ft)	26.4	Froude #	0.6
		Flow Type	SUBCRITICAL
Enter Slope and Press <Enter>			
<- Back Tab	<F2>	Main Menu	<F7>

The above screen is what you should be looking at. The <F2> key will move the prompt backwards through all the variables. Note that since we want to change the Discharge (from 300 to 500), we will need to Press <F2> again to come to the Enter Discharge prompt. Follow the steps as shown on the following page to rerun this calculation with a new discharge.

SCREEN PROMPT - "Enter Slope and Press <Enter>"

2. Press <F2>.

SCREEN PROMPT - "Enter Discharge and Press <Enter>"

3. Enter 500 and then Press <Enter>.

SCREEN PROMPT - "Enter Slope and Press <Enter>"

4. Press <Enter>.

After all of the data is input your screen should look like this:

NORMAL DEPTH TRAPEZOIDAL CHANNEL			
INPUT VARIABLES			
L Side Slope (H:V)	3.0:1	R Side Slope (H:V)	2.0:1
Bottom Width (ft)	10.0	Manning's n	0.0350
Discharge (cfs)	500	Depth (ft)	3.27
Slope (ft/ft)	0.0050		
OUTPUT VARIABLES			
Area (sq ft)	59.6	Wet Perimeter (ft)	27.7
Velocity (ft/s)	5.0	Hyd Radius	2.2
Top Width (ft)	26.4	Froude #	0.6
		Flow Type	SUBCRITICAL
Begin Calculations <Enter>			
<- Back Tab	<F2>	Main Menu	<F7>

5. Press **<Enter>** to begin the calculation.

After a split second the screen should look like this:

```

NORMAL DEPTH
TRAPEZOIDAL CHANNEL

INPUT VARIABLES
L Side Slope (H:V) 3.0:1  R Side Slope (H:V) 2.0:1
Bottom Width (ft) 10.0  Manning's n 0.0350
Discharge (cfs) 500  Depth (ft) 4.22
Slope (ft/ft) 0.0050

OUTPUT VARIABLES
Area (sq ft) 86.7  Wet Perimeter (ft) 32.8
Velocity (ft/s) 5.8  Hyd Radius 2.6
Top Width (ft) 31.1  Froude # 0.6
Flow Type SUBCRITICAL

Begin Calculations <Enter>
Print <F5>
<- Back Tab <F2> Main Menu <F7>
    
```

Let's return to the Main Menu... Just **Press** the **<F7>** Function Key

```

QUICK - 2
MAIN MENU
Press
-----
Critical Depth 1
Channel Capacity 2
Normal Depth 3
Step-Backwater 4

QUIT <F10>
    
```

```

<F1> - Help
    
```

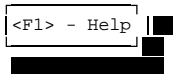
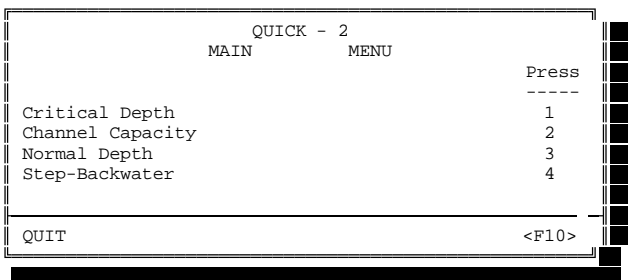
➤ If you want to continue and to perform the Step-Backwater Tutorial, then *turn to the next page.* ➡➡➡➡

➤ If you want to exit out of the program for now, **Press <F10>.** ⏪

STEP-BACKWATER {Tutorial Time: 20 to 25 minutes}

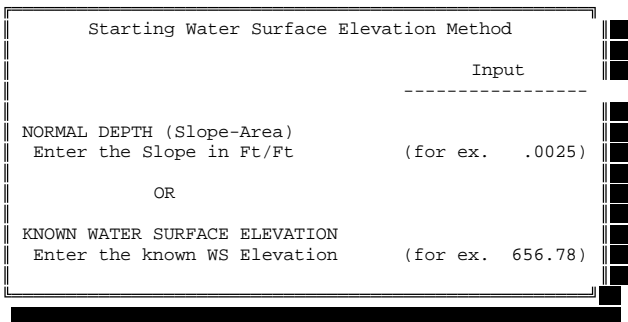
Let's say that we have a piece of property located in an unnumbered Zone A, and we need to determine if our property is really in or out of the floodplain. We will be referring to Figure 1 on the next page which represents a plan view of our proposed floodplain study (step-backwater analysis). We have field surveyed 3 cross-sections to use in the step-backwater analysis. The next page lists all of the data from the field surveyed cross-sections.

If you have continued from the previous Normal Depth Tutorial you should see the screen below. If you are just starting the program, you will see the screen below after pressing **Q2** and **<Enter>**.



1. Press **4** and then press **<Enter>** to start the Step-Backwater Option.

Next you will see the Starting Water Surface Elevation Method screen:



Enter a Slope or an Elevation:

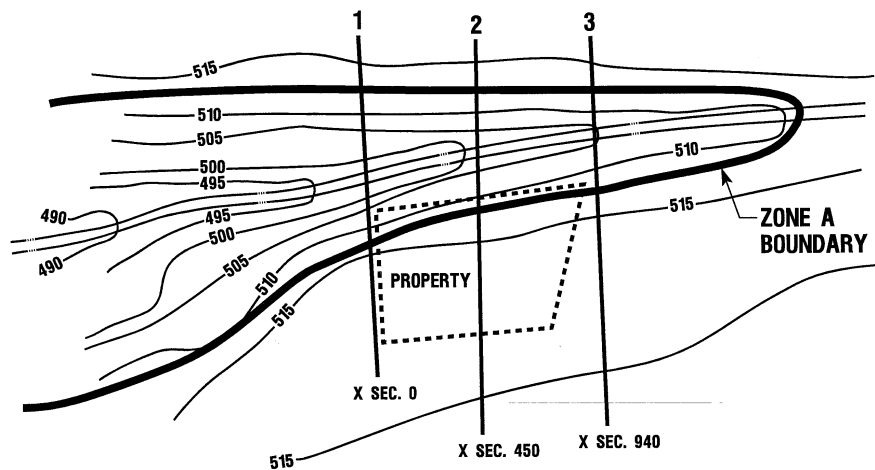
Let's say that we do not have any previous information about flood elevations for our sample stream. Thus we need to start the step-backwater analysis assuming that the flow in our first cross-section is at Normal Depth. (This assumes that the channel slope downstream of our first cross-section will approximate the slope of the energy grade at the first cross-section of our study.) Let's assume that our calculated downstream channel slope is .0029 ft/ft.

2. Type **.0029** and then press **<Enter>**.

CROSS SECTION INFORMATION

Cross-Section 1		Cross-Section 2		Cross-Section 3	
<u>GROUND POINTS</u>					
Station	Elevation	Station	Elevation	Station	Elevation
362	505.0	0	510.0	0	515.0
425	499.1	150	504.8	433	510.1
509	498.0	233	502.2	600	506.3
512	496.9	236	500.9	614	504.9
602	496.9	331	500.9	701	504.8
605	498.2	334	501.8	725	506.5
732	500.1	402	505.5	866	511.1
1020	504.7	591	510.1	1240	514.6
<u>CHANNEL BANK STATIONS</u>					
Left 509	Right 605	Left 233	Right 334	Left 600	Right 725
<u>MANNING'S N VALUES</u>					
Left .065		Left .055		Left .065	
Channel .040		Channel .040		Channel .040	
Right .060		Right .060		Right .060	
<u>CHANNEL REACH LENGTHS</u>					
Left ---		Left 450		Left 490	
Channel ---		Channel 450		Channel 490	
Right ---		Right 450		Right 490	
<u>LOSS COEFFICIENTS</u>					
Cont ---	Expan ---	Cont 0.1	Expan 0.3	Cont 0.1	Expan 0.3
<u>100-YEAR DISCHARGE</u>					
3000		3000		3000	

FIGURE 1



The next screen you will see is the Input / Output screen as shown:

```

XSEC ID:      0          >> STEP - BACKWATER <<         GROUND POINTS
STAT          ELEV      STAT          ELEV          STAT          ELEV          STAT          ELEV

```

```

CHANNEL BANK STATIONS:    Left           Right
MANNING'S N VALUES:    Left           Channel       Right
CHANNEL REACH LENGTHS:  Left           Channel       Right
LOSS COEFFICIENTS:      Contractn  Expansn      :Dschrq
WS ELEV                 Depth       Top Wid      Kratio
EG ELEV                 Flow Regime ChanVel      Froud#

```

```

|F2}<-Back Tab F5}List Files F6}Retrieve File F7}Main Menu F10}Ed/Ex GrPt
|F3}Insert GrPt F4}Delete GrPt           F1 }HELP

```

Before we go on let's read about how data is to be input for this screen.

3. Press **<F1>** to access the Help screen.
4. When you are finished reading the Help screen just **Press <Enter>**.

If you refer to the previous page, you will see a tabulation of the Ground Points for the first field surveyed cross-section listed by Station and Elevation. You will also see the Channel Bank Stations, Manning's N values, and Discharge.

5. Following the method explained in the Help Screen, enter the Ground Points one at a time, by their respective Station and Elevation. Be sure to Press **<Enter>** after you have typed in each correct number.

Once you have entered all of the Ground Points correctly ...

6. Press **<F10>** to Exit from entering Ground Point data

NOTE: The **<F10>** Key will EXIT you from the top of the screen, or it will RETURN you to the top of the screen if you need to go back to EDIT the Ground Points.

Your screen should now look like this:

XSEC ID:	>> STEP - BACKWATER <<					GROUND	POINTS
STAT	ELEV	STAT	ELEV	STAT	ELEV	STAT	ELEV
362	505.0	425	499.1	509	498.0	512	496.9
602	496.9	605	498.2	732	500.1	1020	504.7

CHANNEL BANK STATIONS:	Left		Right
MANNING'S N VALUES:	Left	Channel	Right
CHANNEL REACH LENGTHS:	Left	Channel	Right
LOSS COEFFICIENTS:	Contractn	Expansn	Dschrg
WS ELEV	Depth	Top Wid	Kratio
EG ELEV	Flow Regime	ChanVel	Froud#

F2} <- Back Tab F5} PRINT F6} SAVE F7} Main Menu F8} New XSEC F10} Ed/Ex GrPt
Enter LEFT Channel Bank Station and Press <Enter>

The program is currently prompting you to **enter the Left Channel Bank Station**. Using the information contained on the previous page, we know that our Left Channel Bank Station is **509**. Therefore ...

7. Enter **509** and then Press **<Enter>**. (Notice that the **509** has been entered to the right of "CHANNEL BANK STATIONS: Left".)

Next you will see the Input / Output screen with a new prompt:
SCREEN PROMPT - "Enter RIGHT Channel Bank Station and Press <Enter>"

Using the information for Cross-section 1, simply follow the screen prompts to input the required data, as follows:

SCREEN PROMPT - "Enter RIGHT Channel Bank Station and Press <Enter>"

8. Type **605** and then Press **<Enter>**.

SCREEN PROMPT - "Enter LEFT Manning's n Value and Press <Enter>"

9. Type **.065** and then Press **<Enter>**.

SCREEN PROMPT - "Enter CHANNEL Manning's n Value and Press <Enter>"

10. Type **.040** and then Press **<Enter>**.

SCREEN PROMPT - "Enter RIGHT Manning's n Value and Press <Enter>"

11. Type **.060** and then Press **<Enter>**.

SCREEN PROMPT - "Enter Discharge and Press <Enter>"

12. Type **3000** and then Press **<Enter>**.

Before we move on to enter the data for the next cross-section let's obtain a printout of this first calculation.

_ Press <F5>.

The screen prompt will be ...

PRINT: Summary or Detailed? Press S or D and <Enter>

Let's obtain a Detailed Printout ... Therefore ...

_ Press **D** and then Press <Enter>.

Assuming your printer is turned on, the detailed printout will look like this:

```

Cross Section: 0
XLOB: 0 XLCH: 0 XROB: 0 CC: 0 CE: 0
NLOB: .065 STCHL: 509 NCHL: .04 STCHR: 605 NROB: .06
STAT      ELEV      STAT      ELEV      STAT      ELEV      STAT      ELEV
362.00    505.00    425.00    499.10    509.00    498.00    512.00    496.90
602.00    496.90    605.00    498.20    732.00    500.10    1020.00   504.70
CWSEL      EG      ELMIN      QLOB      QCH      QROB
Chan Vel   HV      KRATIO     ALOB      ACH      AROB
Depth      HL      Top Width  STAT-L    ST-MIDCH STAT-R
Discharge  OL      Froude #   CH-Slope  EG-Slope  FlowRegim
501.03     501.317  496.90     493       2003      505
5.10       0.29     1.00       228       392       265
4.13       0.00     385        404.4     557.0     789.9
3000       0.00     0.50       0.0000    0.0029    ---

```

If any of the above variables are unfamiliar, a description of each is provided in Appendix 1.

If you want to save the cross-section data to a different name and/or directory, **before pressing** <F8>, you can Press <F6>, (**F6**}SAVE) , to perform this.

Now we need to enter the data for the 2nd cross-section. Since we are entering a new cross-section (**New XSEC**), we need to ...

_ Press <F8>.

Before the Screen changes you will notice that at the bottom of the screen a message will briefly appear ...

SAVING TEMPORARY FILE C:\QUICK2\DATA\T0.XSC

This alerts you that your cross-section data has been saved to a file called T0.XSC, which is located in your C:\QUICK2\DATA directory.

Your screen should be blank again as shown below:

```

XSEC ID:      0          >> STEP - BACKWATER <<          GROUND POINTS
STAT      ELEV      STAT      ELEV      STAT      ELEV      STAT      ELEV

CHANNEL BANK STATIONS:      Left      Right
MANNING'S N VALUES:      Left      Channel      Right
CHANNEL REACH LENGTHS:      Left      Channel      Right
LOSS COEFFICIENTS: Contractn      Expansn      :Dschrng
WS ELEV      Depth      Top Wid      Kratio
EG ELEV      Flow Regime      ChanVel      Froud#

F2}<-Back Tab F5}List Files F6}Retrieve File F7}Main Menu F10}Ed/Ex GrPt
F3}Insert GrPt F4}Delete GrPt          F1 }HELP
    
```

_ Following the method used before, for the 1st cross-section, enter the Ground Points one at a time, by their respective Station and Elevation for the 2nd cross-section using the data provided. Be sure to Press <Enter> after you have typed in each correct number.

_ Once you have entered all of the Ground Points correctly, remember to Press <F10> to Exit from entering Ground Point data .

_ Follow the on screen prompts to enter all of the other data.

Remember that if any of the data on the screen has been typed in incorrectly, the user can simply press the <F2> key to toggle backwards through all of the input data, even back to the Ground Points. (You can also Press <F10> to go back to the Ground Points immediately for editing).

After entering all the data your screen should now look like this:

```

XSEC ID:      450          >> STEP - BACKWATER <<          GROUND POINTS
STAT      ELEV      STAT      ELEV      STAT      ELEV      STAT      ELEV
|  0      510.0    150      504.8    233      502.2    236      500.9 |
| 331      500.9    334      501.8    402      505.5    591      510.1 |

CHANNEL BANK STATIONS:      Left 233.0      Right 334.0
MANNING'S N VALUES:      Left 0.0550 Channel 0.0400 Right 0.0600
CHANNEL REACH LENGTHS:      Left 450 Channel 450 Right 450
LOSS COEFFICIENTS: Contractn 0.1 Expansn 0.3 :Dschrng 3000
WS ELEV      Depth      Top Wid      Kratio
EG ELEV      Flow Regime      ChanVel      Froud#

F2}<- Back Tab F5}PRINT F6}SAVE F7}Main Menu F8}New XSEC F10}Ed/Ex GrPt
TO BEGIN CALCULATIONS      Press <Enter>
    
```

The program is now ready to begin the calculations since all of the required data has been entered for the 2nd cross-section of our step-backwater analysis.

_ Press **<Enter>** to Begin the Calculations.

Once the calculation is finished you may ...

_ Press **<F5>** to obtain a printout

_ Press **<F6>** to save the data to another name and/or directory

Finally, to finish our analysis we need to enter in the data for the 3rd cross-section.

_ Press **<F8>**

Before the Screen changes you will notice that at the bottom of the screen a message will briefly appear ...

SAVING TEMPORARY FILE C:\QUICK2\DATA\T450.XSC

This alerts you that your 2nd cross-section data has been saved to a file called T450.XSC, which is located in your C:\QUICK2\DATA directory. Notice that the **450**, represents the channel distance between the 1st and 2nd cross-sections.

_ Following the method used before for the other cross-sections, enter the Ground Points one at a time, by their respective Station and Elevation for the 3rd cross-section using the data provided. Be sure to Press **<Enter>** after you have typed in each correct number.

_ Once you have entered all of the Ground Points correctly, remember to Press **<F10>** to Exit from entering Ground Point data .

_ Follow the on screen prompts to enter all of the other data.

After entering all the data for the 3rd cross-section ...

_ Press **<Enter>** to Begin the Calculations.

Once the calculation is finished you may ...

_ Press **<F5>** to obtain a printout

_ Press **<F6>** to save the data to another name and/or directory

TO EXIT OUT OF THIS SCREEN NOW THAT OUR ANALYSIS IS COMPLETED ...

_ Press **<F7>**

You will see a screen prompt at the bottom ...

SUMMARY PRINTOUT: Press <F5>, otherwise Press <Enter>


To print a summary of the output for all 3 cross-sections then ...

_ Press <F5>, otherwise just Press <Enter>

The on screen Summary or the printed summary will look like this:

SECNO	Q	XLCH	CWSEL	FR#	ELMIN	AVG.VEL.	AREA	TOPWID
0	3000.0	0	501.03	0.50	496.90	3.39	885.0	385.5
450	3000.0	450	503.96	1.06	500.90	7.54	398.1	196.9
940	3000.0	490	508.54	0.71	504.80	4.95	606.5	286.2

If we carefully compare the Computed Water Surface Elevations (CWSELS) at each cross-section, to the topographic contours on Figure 1, we will see that the property is clearly higher than the CWSEL at every cross-section. Therefore this analysis with more detailed cross-section data has proven that the property has been inadvertently included in an unnumbered Zone A Special Flood Hazard Area.

Turn to the next page to continue 

RUNNING HEC-2 USING QUICK-2 FILES {Tutorial Time: 5 minutes}

_ You will be prompted one more time to Press <Enter>. The next prompt will ask you a question concerning running the HEC-2 or PLOT-2 programs.

Press Y and <Enter> to rerun w/HEC-2 or PLOT-2: If NO Press <Enter>

_ For purposes of this tutorial let's answer "Y" , (and Press <Enter>) to run the HEC-2 program. The next screen that will appear will include the following:

To Run	Type
-----	-----
QUICK-2	Q2
HEC-2	H2
AUTOHEC-2	AH2
PLOT-2	P2
VIEW/PRINT	LIST

_ Type **AH2** and Press <Enter>.

Once the HEC-2 run is complete it will return you to the above-mentioned screen.

NOTE: Typing **AH2** runs the HEC-2 program automatically using the QUICK-2 generated HEC2.DAT, HEC-2 data file.

*If you are using a HEC-2 data file other than HEC2.DAT, then Type **H2** and Press <Enter>. Follow the directions on the screen for naming the Input, Output and Tape95 files; pressing <Enter> after each filename is typed in.*

_ Type **LIST** and Press <Enter>, and then enter your output filename, (Default is HEC2.OUT), to view the results. *Note that you move up, down and across the screen using the <Page UP>, <Page Down>, the cursor keys, etc.*

_ To **Print** the data that appears on the screen simply **Press P**.

_ To **Exit** from the screen simply **Press X** or the **Escape** key.

If you would like to complete the next tutorial example, then

Type Q2 and Press <Enter>; and, *turn to the next page.* =====>>>>

RERUNNING USING SAVED CROSS-SECTION FILES

{Tutorial Time: 5 minutes}

Let's say that in the analysis that was performed in the previous tutorial, we want to change the discharge from 3000 to 5000, and run the step-backwater option again with the same cross-sections. This is quite easily done. Just follow the steps as shown below.

1. At the Main Menu Screen **Type 4 and Press <Enter>**
2. At the Starting Water Surface Elevation Method Screen
Type .0029 and Press <Enter>
3. At the Input/Output Screen **Press <F6>** to retrieve a saved cross-section file

Assuming your 1st cross-section file is stored as
C:\QUICK2\DATA\T0.XSC

Type C and Press <Enter> when prompted for the directory
Type QUICK2\DATA & Press <Enter> when prompted for the subdirectory
Type T0 and Press <Enter> when prompted for the filename

4. **Press <F2>** to toggle back to the "Enter Discharge" prompt
5. **Type 5000 and Press <Enter>** to enter the new discharge
6. **Press <Enter>** to Begin the Calculations

7. **Press <F8>** to input another cross-section
Press <F6> to retrieve a saved cross-section file

Assuming your 2nd cross-section file is stored as
C:\QUICK2\DATA\T450.XSC

Type C and Press <Enter> when prompted for the directory
Type QUICK2\DATA & Press <Enter> when prompted for the subdirectory
Type T450 and Press <Enter> when prompted for the filename

8. **Press <F2>** to toggle back to the "Enter Discharge" prompt
9. **Type 5000 and Press <Enter>** to enter the new discharge
10. **Press <Enter>** to Begin the Calculations

11. Press <F8> to input another cross-section

Press <F6> to retrieve a saved cross-section file

Assuming your 3rd cross-section file is stored as
C:\QUICK2\DATA\T940.XSC

Type C and Press <Enter> when prompted for the directory

Type QUICK2\DATA & Press <Enter> when prompted for the subdirectory

Type T940 and Press <Enter> when prompted for the filename

12. Press <F2> to toggle back to the "Enter Discharge" prompt

13. Type 5000 and Press <Enter> to enter the new discharge

14. Press <Enter> to Begin the Calculations

_ **Press <F7>** to Exit out of the screen

_ **Press <F5>** to obtain a summary printout

_ **Press <Enter>** twice to get back to the main menu

_ **Press <F10>** to leave the program

Q.E.D.

CHANNEL CAPACITY OPTION WITH THE RATING CURVE PLOT

{Tutorial Time: 5 to 10 minutes}

Let's say that we need to determine a Base Flood Elevation (BFE) for the property shown in Figure 1. We do not want to exempt the entire property from the flood plain, only a structure which is located in the middle of the property. Therefore, we can use one cross-section (the 2nd cross-section (T450.XSC) from our previous tutorial and shown on Figure 1), to compute a BFE.

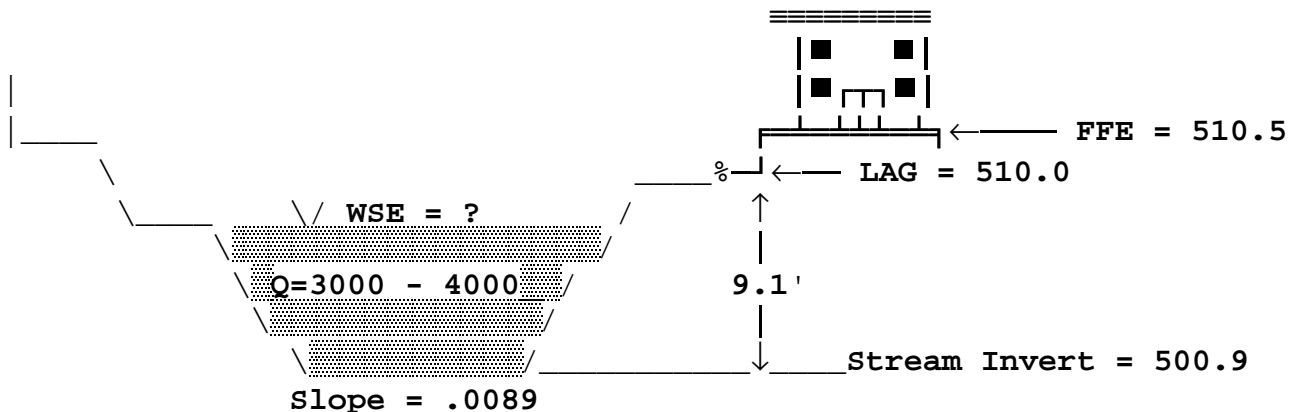
Let's assume that we know the discharge is between 3000 cfs and 4000 cfs based on our best estimates.

Let's assume our structure does not have a basement; the lowest adjacent grade (LAG) to the house is at elevation 510 NGVD; and the first floor elevation (FFE) is 510.5 NGVD.

Let's determine the maximum carrying capacity of the floodplain using a depth equal to the lowest adjacent grade (510.0) minus the minimum stream elevation (500.9). For purposes of this example we'll use a depth of 9 feet (510-501).

To perform a channel capacity calculation we also need to know the downstream slope, which in this case is easy to compute from the information on page 15. $Slope = 500.9 - 496.9 / 450 = .0089$.

The graphic below sums up our situation so far:



Follow the steps as shown on the next page to compute the rating curve

... 

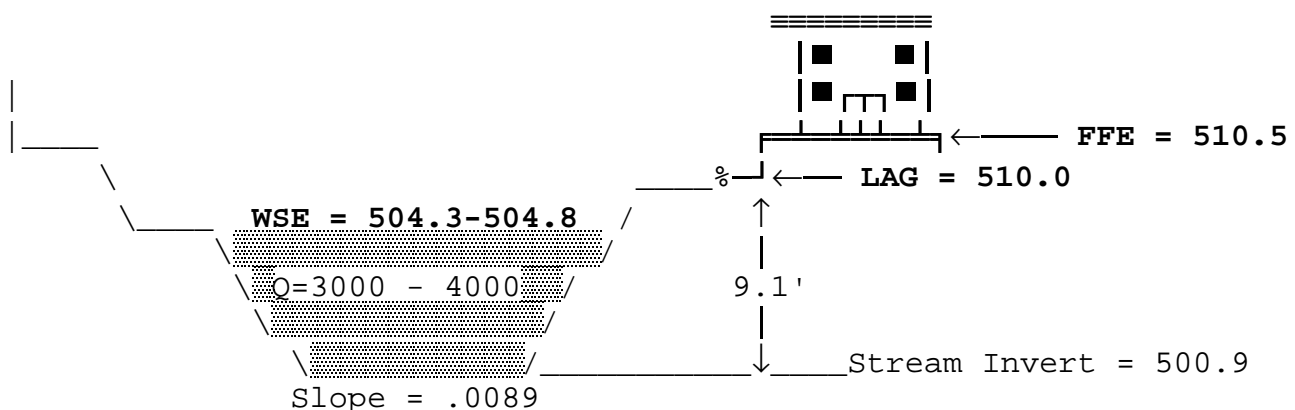
1. At the Main Menu Screen **Type 2** and Press **<Enter>**
2. At the Shape of Cross Section Screen
Type I and Press **<Enter>**
3. At the Input/Output Screen **Press <F6>**

We are using the 2nd cross-section file stored as
C:\QUICK2\DATA\T450.XSC

Type C and Press **<Enter>** when prompted for the directory
Type QUICK2\DATA & Press **<Enter>** when prompted for the subdirectory
Type T450 and Press **<Enter>** when prompted for the filename

4. Type **.0089** and Press **<Enter>** to enter the slope
5. Type **9** and Press **<Enter>** to enter the depth
6. Press **<Enter>** to Begin the Calculations
7. Press **<F4>** to Plot to screen Press **<F5>** to Print

Looking at the rating curve plot we can see that for a discharge range of between 3000cfs - 4000cfs the BFE ranges from about 504.3 to 504.8. Since our lowest adjacent grade and first floor elevation are at or above 510, it is clear that this structure is above the BFE.



8. Press **<Enter>** to continue
9. Press **<F7>** to go back to the Main Menu
10. Press **<F10>** to Exit the program

PLOT-2

In general PLOT-2 will only work on QUICK-2 files that have been converted into HEC-2 format using QUICK-2's Step-Backwater option.

Profile plots from PLOT-2 will work only if the QUICK-2 generated data file (HEC2.DAT) is also run using the HEC-2 program (see Running HEC-2 Using QUICK-2 Files, page 4-18), since a HEC2.T95 file needs to be generated by the HEC-2 program for use by PLOT-2.

PLOT-2 Cross-section plots can be generated using the QUICK-2 generated data file (HEC2.DAT) even if it is not run with HEC-2. However, the Cross-section plot will not show the computed water surface elevation (CWSEL) unless the QUICK-2 HEC2.DAT file is run with HEC-2, since the CWSEL is found on the HEC2.T95 file.

Note that the user can compute a normal depth elevation for only one cross-section and have that cross-section plotted by choosing the Step-Backwater option and the Normal Depth starting water surface elevation method. Once the computation is finished, the user simply exits (Presses <F7>), and the QUICK-2 program automatically creates the HEC2.DAT file for that one cross-section, which can be used by the PLOT-2 program.

Let's say that we want to view the water surface elevation profile and the cross-section plots from our previous tutorial on the Step-Backwater option.

_ From the QUICK-2 Title screen **Press P2**

_ You are now into the PLOT-2 program, **Press <Enter> to continue**

PROFILE PLOT {Tutorial Time: 5 to 10 minutes}

1. Let's view the profile first. **Press 1** from the PLOT-2 main menu selection

2. Cursor to the HEC2 Tape95 file name entry and **Type ?**

This will list all of the data files in the QUICK-2 directory. T95 files are designated with the 3 letter extension .T95 . Therefore cursor over to highlight that file (HEC2.T95) and **Press <Enter>**.

3. Move up to highlight the Plot profiles entry and **Press <Enter>**.

4. Your profile is now plotted. **Pressing <Enter>** moves you back to the Profile plots main menu screen. You can explore the different Profile and Plotting options and replot the profile if you wish.

5. When you are finished plotting, highlight the Return to main menu message and **Press <Enter>**

CROSS-SECTION PLOT {Tutorial Time: 5 to 10 minutes}

1. From the PLOT-2 main menu **Press 2** from the menu selection.
2. Cursor down to the HEC2 input file name entry and **Type ?**

This will list all of the data files in the QUICK-2 directory. Input files are designated with the 3 letter extension .DAT . Therefore cursor over to highlight that file (HEC2.DAT) and **Press <Enter>**. If we want to view a different data file than that of the profile we previously viewed, we would have to specify a different file here before proceeding.

3. Cursor down to the HEC2 Tape95 file name entry

Note that we do not have to re-enter this file since we have already entered it previously. If we want to view a different Tape95 file than that of the profile we previously viewed, we would have to **Type ?**, and then specify a different file here before proceeding.

4. Move up to highlight the Plot cross sections entry and **Press <Enter>**.

5. You now have the option of printing all or selected cross sections from your data file. Press Y for plotting all, or N for plotting selected cross sections.

Your first cross-section is now plotted. Pressing <Enter> moves you back to the Cross-section plots main menu screen or plots additional cross-sections depending on how many cross-section plots you have. You can explore the different Cross-section and Plotting options if you wish.

6. Highlight the Return to main menu message and **Press <Enter>**

Pressing 4 at the PLOT-2 main menu exits you from PLOT-2 and back to the QUICK-2 title screen.

Note: To use PLOT-2 and to access data files that are in another directory (i.e., they are not in the C:\QUICK2 directory), just change to that data directory (i.e., CD\dirname) and access PLOT-2 by typing C:\QUICK2\PLOT2 (or A:\PLOT2 if using the program from the floppy drive) from that data directory.

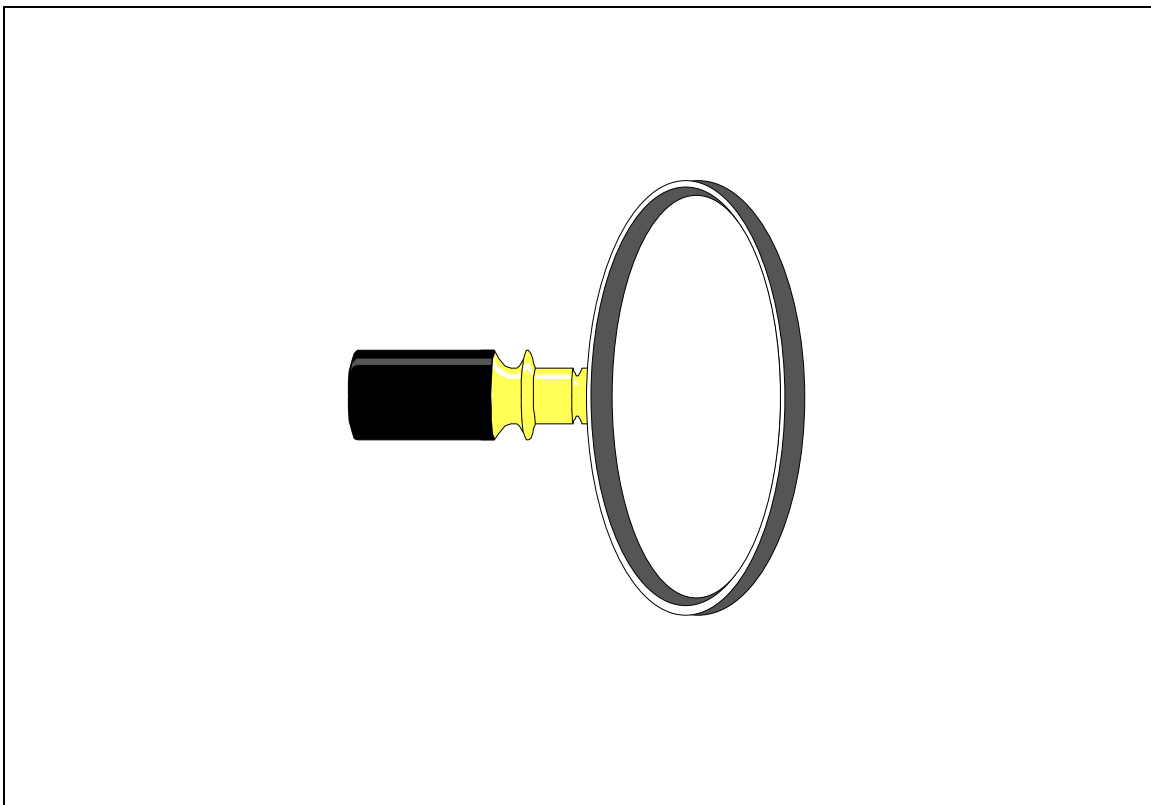
Chapter 5: FORMULAS

Critical Depth

Channel Capacity

Normal Depth

Step-Backwater



1. CRITICAL DEPTH

In every cross-section for a given discharge there exists a critical depth, where the energy grade (depth of water plus velocity head - $V^2/2G$) is at a minimum. Increasing the discharge above this given discharge will force the flow into the super-critical regime. Discharges below the given discharge will remain in the sub-critical regime. Super-critical depths will be lower than the critical depth, and sub-critical depths will be above the critical depth. Super-critical flow is characterized by small water depths with large velocity heads; while, sub-critical flow is characterized by large water depths with small velocity heads. A rule of thumb used to determine critical depth is that when the Velocity Head equals 1/2 the hydraulic depth (Area/Topwidth) critical flow is probable.

A formula which can be used to approximate critical depth (D_c) is given below.

$$Qc^2 / g = A^3 / T$$

Where Qc is the discharge (in cfs) based on critical depth, g is the gravitational constant (32.15 feet/second squared), A is the cross-section area (in square feet), and T is the top width of the water surface (in feet). Note: for rectangular channels the above equation can be reduced so that

$$D_c = (Qc/5.67 T)^{.667}.$$

The more exact way to compute critical depth (minimum specific energy) is to find a specific depth of water within a cross-section for a given discharge which produces the lowest energy grade. The following represents the process that the Critical Depth option of QUICK-2 goes through to calculate critical depth.

After the cross-section information (ground points, channel stations, etc.) has been input the program starts computing the water surface elevation (WSE) and corresponding energy grade elevation (EG) at a depth of 0.1 foot above the lowest elevation in the cross-section. It continues to calculate WSE and EG at intervals of 0.5 foot. As the depth of water in the cross-section increases the EG will decrease. At one point the EG will begin to increase. This means that between the last 0.5 foot interval there exists a minimum energy grade. Once this has occurred the program decreases the WSE in intervals of .02 foot. As the depth of water decreases in the cross-section the EG will also decrease as it approaches the minimum specific energy. At one point the EG will begin to increase again.

This means that between the last .02 foot interval critical depth exists. At this point the screen will display the actual critical water surface elevation (along with other variables) by assuming that the next to the last iteration was the critical depth.

The calculations performed by the program for a given cross-section are listed on the next page. The calculations include the iterations that the program goes through to arrive at critical depth.

ELMIN = 92.5					
WSE = 92.6	Qc= 6.026845E-02	Q= 260	EG=466080.8		EG Decreasing
WSE= 93.1	Qc= 5.314738	Q= 260	EG=452.6406	-	
WSE= 93.6	Qc= 24.18726	Q= 260	EG=125.4259	-	
WSE= 94.1	Qc= 61.71717	Q= 260	EG=101.21	-	
WSE= 94.6	Qc= 121.451	Q= 260	EG=96.99928	-	
<u>WSE= 95.1</u>	<u>Qc= 204.4488</u>	Q= 260	EG=96.14474	-	v
<u>WSE= 95.6</u>	<u>Qc= 311.15</u>	Q= 260	EG=96.14897	+	EG Increasing

Therefore Minimum Specific Energy is between WSE's of 95.1 and 95.6. Note also that the Discharge (Q = 260) is also within the computed Critical Discharge (Qc) range of 204 - 311.

WSE= 95.58	Qc= 306.5006	Q= 260	EG=96.14179	-	EG Decreasing
WSE= 95.56	Qc= 301.8821	Q= 260	EG=96.13499	-	
WSE= 95.54	Qc= 297.2962	Q= 260	EG=96.12863	-	
WSE= 95.52	Qc= 292.7447	Q= 260	EG=96.12271	-	
WSE= 95.50	Qc= 288.2256	Q= 260	EG=96.11724	-	
WSE= 95.48	Qc= 283.737	Q= 260	EG=96.11225	-	
WSE= 95.46	Qc= 279.2825	Q= 260	EG=96.10776	-	
WSE= 95.44	Qc= 274.8583	Q= 260	EG=96.1038	-	v
WSE= 95.42	Qc= 270.4678	Q= 260	EG=96.10038	-	
WSE= 95.40	Qc= 266.1075	Q= 260	EG=96.09752	-	
WSE= 95.38	Qc= 261.7806	Q= 260	EG=96.09525	-	
WSE= 95.36	Qc= 257.4854	Q= 260	EG=96.09361	-	
WSE= 95.34	Qc= 253.22	Q= 260	EG=96.09262	-	
WSE= 95.32	Qc= 248.986	Q= 260	EG=96.09199	minimum	v
WSE= 95.30	Qc= 244.76	Q= 260	EG=96.09271	+	EG Increasing

We assume that ... Critical Depth = 95.32', Minimum Specific Energy = 96.09199'

The Froude number would be, Q / Q_c , or $260 / 248.986 = 1.04$.

It is not unusual for the Froude number to not equal exactly 1.0, since the calculation of critical discharge using the formula $Q_c^2 / g = A^3 / T$, does not always yield a WSE that is exactly at the True minimum specific energy.

You should notice from the above tabulation, that as you approach critical depth (minimum specific energy), for very small changes in EG there are large jumps in the water surface elevation. The EG is only changing by .001' to .003' while the WSE changes by .02'. A 0.01' difference in EG can cause a 0.10' change in WSE.

2. CHANNEL CAPACITY

In this option, a Normal Depth elevation (see 3. *NORMAL DEPTH*) is input and the program computes the corresponding discharge. (In the Normal Depth option, the discharge is input and the program computes a normal depth elevation). The Manning's equation is used as the formula for determining the (normal) discharge.

$$Q = 1.486 A (R^{.667}) S^{.5} / N$$

Where Q is the discharge (in cfs), A is the cross-section area (in square feet), R is the hydraulic radius (in feet), S is the energy slope (in feet/feet), and N is the Manning's roughness value.

After the cross-section information (ground points, channel stations, streambed slope, normal depth elevation(s), etc.) has been input, the program simply solves for the area (A) and hydraulic radius (R) below the normal depth elevation (specified by the user) and computes the (normal) discharge directly using the Manning's equation. This is not an iterative process. The screen will display the (normal) discharge (which represents the channel capacity) along with other variables.

3. NORMAL DEPTH

The standard formula for determining normal depth in a cross-section is the Manning's formula. Water is flowing at normal depth when the energy grade and the hydraulic grade (water surface) slopes are the same as the stream bed slope. Normal depth profiles occur, in general, when the flow is uniform, steady, one-dimensional, and is not affected by downstream obstructions or flow changes. The standard Manning's equation is:

$$Q = 1.486 A (R^{.667}) S^{.5} / N$$

Where Q is the discharge (in cfs), A is the cross-section area (in square feet), R is the hydraulic radius (in feet), S is the energy slope (in feet/feet), and N is the Manning's roughness value.

The exact method for computing normal depth for a given discharge at a particular cross-section, is to assume that S is equal to the downstream streambed slope and to solve iteratively for the depth (this obviously assumes N is known). The following represents the process that the Normal Depth option of QUICK-2 goes through to calculate normal depth.

After the cross-section information (ground points, channel stations, discharge, streambed slope, etc.) has been input, the program starts computing discharge using the Manning's equation at an initial depth of 0.1 foot above the lowest point in the cross-section, and from that point in 0.5 foot intervals. At some point, the computed discharge will exceed the given target discharge. The program then uses a converging technique to compute a discharge (with a corresponding normal depth) that is within 1% of the given discharge. At this point the screen will display the actual normal depth water surface elevation (along with other variables).

The calculations performed by the program for a given cross-section are listed below. The calculations include the iterations that the program goes through to arrive at normal depth.

ELMIN= 92.5				
WSE = 92.6	Q= 260	Computed Q=	.023579	below target Q
WSE= 93.1	Q= 260	Computed Q=	2.803083	below
WSE= 93.6	Q= 260	Computed Q=	14.11313	below
WSE= 94.1	Q= 260	Computed Q=	38.33264	below
WSE= 94.6	Q= 260	Computed Q=	80.01045	below
WSE= 95.1	Q= 260	Computed Q=	146.9773	below
WSE= 95.6	Q= 260	Computed Q=	245.9516	below
WSE= 96.1	Q= 260	Computed Q=	369.2461	above target Q
WSE= 95.65697	Q= 260	Computed Q=	258.7531	within 1%

We assume that ... Normal depth = 95.66 for a Discharge (Q) of 260 cfs

4. STEP-BACKWATER

The **Energy Equation** which represents one-dimensional, uniform, and steady flow in open channels is shown below.

$$(1) \quad WSE_d + HV_d = WSE_u + HV_u + HL + OL$$

Where WSE_d is the water surface elevation at the downstream cross-section, HV_d is the velocity head at the downstream cross-section, WSE_u is the water surface elevation at the upstream cross-section, HV_u is the velocity head at the upstream cross-section, HL is the friction loss between the two cross-sections, and OL is the eddy (contraction or expansion) loss between the two cross-sections.

Velocity Head, HV, is calculated as follows:

$$HV = (\alpha) V^2 / 2g$$

Where (α) is alpha the velocity coefficient, V is velocity (Q/A), and g is the gravitational constant. Alpha (α) is calculated as follows:

$$(\alpha) = \frac{(A^2)}{(K^3)} \left| \frac{Kl^3}{Al^2} + \frac{Kc^3}{Ac^2} + \frac{Kr^3}{Ar^2} \right|$$

Where A and K are the total area and conveyance below the water surface, respectively; and Kl , Kc , Kr and Al , Ac , Ar , are the conveyance and area in the left overbank, channel, and right overbank, respectively.

Friction Loss, HL, is calculated as follows:

$$HL = Lw (Q_d + Q_u)^2 / (K_d + K_u)^2$$

Where Lw is the discharge weighted reach length between cross-sections, Q_d is the discharge at the downstream cross-section, Q_u is the discharge at the upstream cross-section, K_d is the conveyance at the downstream cross-section, and K_u is the conveyance at the upstream cross-section. This is derived from the Average Conveyance Friction slope equation.

The Discharge Weighted Reach Length, Lw, is calculated as follows:

$$Lw = \{(Ll * Ql) + (Lc * Qc) + (Lr * Qr)\} / Qa$$

Where Qa is the average total discharge between cross-sections; and, Ll , Lc , Lr , and Ql , Qc , Qr , represent the reach length and average discharge between cross-sections for the left overbank, channel, and right overbank, respectively.

Eddy Loss, OL, is calculated as follows:

$$OL = (Ce \text{ or } Cc) * ABS |HV_d - HV_u|$$

Where Ce is the expansion coefficient, Cc is the contraction coefficient, HV_d is the velocity head at the downstream cross-section, and HV_u is the velocity head at the upstream cross-section. When HV_u is greater than HV_d Ce is utilized. When HV_u is greater than or equal to HV_d Cc is utilized.

After the cross-section information for the first cross-section has been input, either a known water surface elevation is input to start the calculations or the water surface elevation could have been determined by the Normal or Critical Depth options or by another source or method. The program then computes all pertinent variables for the first cross-section that will be needed for an energy balance with the next upstream cross-section. After this the user must put in the appropriate information for the next cross-section (i.e., ground points, channel stations, reach lengths, contraction and expansion coefficients, etc.). Once this is done the program performs a series of trial iterations to make sure that the Energy Equation (1) listed previously will balance to within .014 foot. The sequence of trial elevations is listed below.

1ST TRIAL:

Uses the depth of water (DP) of the previous cross-section added to the lowest elevation (ELMIN) within the current cross-section. If DP + ELMIN is less than the previous WSE (i.e., adverse slope condition) then the program uses the previous WSE for the 1st trial at the current cross-section.

2ND TRIAL:

Uses the average of the computed WSE and the WSE assumed in Trial number 1.

3RD TRIAL AND ON ...:

Uses a formula designed to help converge quickly to balance the energy equation as shown below:

$$\text{Trial WSE} = \text{WSE} - (\text{WSE} + \text{HV} - \text{DG} - \text{HL} - \text{OL}) / (1 - ((Q/QC)^2) + ((1.5 * \text{HL}) / (\text{A}/\text{W})))$$

Where WSE, HV, HL, OL, QC, A, and W are the latest computations of water surface elevation, velocity head, friction loss, eddy loss, critical discharge, total area, and total wetted perimeter, respectively; and, DG is the computed energy grade elevation from the previous cross-section; and, Q is the discharge at the current cross-section.

For most energy balances between cross-sections that are not at or near critical flow, the program will balance the energy equation within 5 trials.

The calculations performed by the program for an energy balance between two cross-sections are listed below. The calculations include the iterations that the program goes through to arrive at the energy balance.

WSE	WSE		Trial #
Assumed	Calculated	Difference	
98.75	98.32489	+.4251099	1
98.53744	98.32472	+.2127228	2
98.32476	98.32513	-.00037	3

We assume that the correct WSE = 98.32

Note: Energy balance in this case was accurate to .00037 foot.

Appendix 1: Definition of Variables

- ACH** - Area within the specified channel below the water surface elevation
- ALOB** - Area within the specified left overbank below the water surface elevation
- AROB** - Area within the specified right overbank below the water surface elevation
- ALPHA** - Velocity head coefficient
- AREA** or **Area** - Total area within the cross-section below the water surface elevation
- AVG.VEL** or **Velocity** - Average Velocity within the entire cross-section
- Base Width** - Channel bottom width of a trapezoidal or rectangular cross-section
- Bottom Width** - Channel bottom width of a trapezoidal or rectangular cross-section
- CC** - Contraction Coefficient
- CE** - Expansion Coefficient
- CH-SLOPE** - Slope of the streambed, Channel Slope
- CHAN-VEL** or **ChanVel** - Velocity within the main channel of cross-section
- Critical Slope** - Slope of the Energy Grade line at Critical Flow
- CWSEL** - Computed water surface elevation within a cross-section
- Depth** - Max depth of water in the cross-sect as measured below the water surface elevation
- Diameter** - Width or Height of a circular pipe
- Discharge** - The rate of the flow of a volume of water within a cross-section, usually expressed in cubic feet per second (cfs)
- EG** or **EG ELEV** - Energy grade elevation, expressed as, WSE + HV
- EG-Slope** - Energy grade slope
- ELEV** - Elev of a ground pt of a cross-sect, as ref to some datum (i.e., NGVD, NAVD, etc.)
- ELMIN** - Lowest elevation in a cross section
- Flow Regime** - Type of water surface profile (Supercritical regimes are not computed)
M1: EG-Slope <= Ch-Slope and FR# < .8 **M2**: EG-Slope > Ch-Slope and FR# < .8
C1: EG-Slope <= Ch-Slope and FR# >= .8 **C3**: EG-Slope > Ch-Slope and FR# >= .8
- Flow Type** - either, Supercritical, Critical or Subcritical
- Froude#, Froude No., Froud#** or **FR#** - Froude number, used to determine the flow type (i.e., **sub-** (FR# < 1), **critical** (FR# = 1) or **super-critical** (FR# > 1) flow)
- HL** - Friction loss between cross sections
- HV** - Velocity head
- Hyd Radius** or **Hyd R** - Hydraulic Radius: equal to (Area / Wet Perimeter)

KRATIO - Ratio of upstream total conveyance to downstream total conveyance

L Side Slope - Ratio of the slope of the left side of a channel in terms of Horizontal distance in feet to 1 foot Vertical.

Manning's n - Coefficient used to account for the friction caused by earthen, vegetative, and/or man-made surfaces within a floodplain cross-section.

Max Discharge - The maximum flow possible within a circular pipe, (usually occurring at $.94 * \text{Diameter}$).

NCHL, NLOB, NROB - Manning's "N" value for the specified channel, left overbank, and right overbank, respectively.

OL - Expansion/contraction loss

Q - Total discharge in the cross-section

QC - Critical discharge within entire cross-section for a specific water surface elevation

QCH - Discharge within the specified channel of a cross-section

QIC - Critical discharge within the entire cross-section for a specific water surface elevation, assuming that critical flow is limited to the channel, even if flow is occurring in the overbanks

QLOB, QROB - Discharge within the specified left overbank, and right overbank, respectively, of a cross-section

R Side Slope - Ratio of the slope of the right side of a channel in terms of Horizontal distance in feet to 1 foot Vertical.

SECNO - Cross section number or identifier

Slope or **EG-Slope** - Energy grade slope

STAT-L, STAT-R - Station, within a cross-section, of the left edge, and right edge, respectively, of the water surface

STAT - Station of a ground point of a cross-section

STCHL, STCHR, ST-MIDCH - Station of the left bank, right bank, and mid-point, respectively, of a cross-section

Top Width or **Top Wid** - Top width of the water surface within a cross-section

Velocity - Average Velocity within the entire cross-section

Wet Perimeter or **Wet Per** - actual width of ground within a cross-section below the water surface elevation.

WS ELEV or **CWSEL** - Water surface elevation within a cross-section

XLCH, XLOB, XROB - Distance between cross-sections as measured along the channel, left overbank, and right overbank, respectively.

NOTES

Appendix 7

Hydraulic Computer Manuals

HEC-2

U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC), "Water Surface Profiles, HEC-2, User's Manual," Davis, California, 1991.

HEC-RAS

U.S. Army Corps of Engineers, Hydraulic Engineering Center (HEC), "HEC-RAS, River Analysis System, User's Manual - Draft," BETA 2 Test Version, Davis, California, February 1995.

PSUPRO

Federal Emergency Management Agency, "PSUPRO Encroachment Analysis User's Manual", Washington, D.C., 1989.

SFD

Federal Emergency Management Agency, "Simplified Floodway Determination Computer Program User's Manual", Washington, D.C., 1989.

WSPRO

U.S. Geological Survey, "Water Surface PROfiles, WSPRO, User's Manual, Reston, Virginia, 1990.

WSP2

U.S. Department of Agriculture, Natural Resources Conservation Service, "WSP2 Computer Program User's Manual", Technical Release No. 61, Washington, D.C., 1976.

Appendix 8

Normal Depth Hand Calculation

Appendix 8 - continued

Normal Depth Hand Calculation

Appendix 8 - continued

Normal Depth Hand Calculation

Appendix 9

Weir Flow Hand Calculations

Appendix 9 - continued

Weir Flow Hand Calculations

Appendix 9 - continued

Weir Flow Hand Calculations

Appendix 9 - continued

Weir Flow Hand Calculations

**Appendix 10
Worksheet**

Base Flood Elevations in Zone A Areas

Community Name: _____ State: _____

Community ID# : _____ Panel #: _____ FIRM Date: _____

Project Identifier : _____

This request is for: Existing [] Proposed [] <5 acres [] >5 acres []
 Single Lot [] Multi-Lot [] <50 lots [] >50 lots []

Other _____

-----**APPROACH USED TO DEVELOP THE BASE FLOOD ELEVATION (BFE)**-----

EXISTING DATA

Available		Not Available	Did Not Check
FEMA	[]	[]	[]
Federal	[]	[]	[]
Other	[]	[]	[]

SIMPLIFIED Contour Interpolation [] Data Extrapolation []

DETAILED

Hydraulics Normal Depth [] Weir Flow [] Culvert Flow []
 Other _____

Hydrology Regression Equations [] Rational Formula []
 Discharge-Drainage [] TR-55 []

Other _____

Topography Topographic Map [] or Field Survey []

Map Scale: 1" = _____' Contour Interval: _____'

Field Survey tied to Datum? YES NO N/A

Datum: NGVD 1929 [] Other _____

Cross-Sections [] Length of Stream _____ ft.

-----**RESULTS**-----

BFE or Depth of 100-year Flood _____

First Floor Elevation or Depth _____

Lowest Adjacent Grade to Structure _____

Lowest Grade on entire Property _____ N/A