CHAPTER II

FACTORS THAT INFLUENCE FLOODPROOFING FEASIBILITY

A. INTRODUCTION

Many factors influence the decision making process for determining the feasibility of floodproofing options. The optimum solution would be one that:

- Provides for reduction in damages for the selected or required design level and does not result in increased damages to other property.
- Is responsive to all applicable floodplain regulations.
- Provides for the safety of persons on and adjacent to the site.
- Is cost effective with regard to installation, maintenance and operation of the system.
- Is acceptable to the property owner, employees and the general public with regard to operational efficiency and impacts on the surrounding environment.

To develop a floodproofing plan that can meet these performance goals, it is necessary to conduct a systematic evaluation of physical, social, and economic factors that influence the feasibility of floodproofing. In most situations, it will be necessary to collect basic information related to each of the major categories shown in Figure II-1. This information is required to: (1) identify viable construction sites and/or floodproofing alternatives, (2) develop preliminary design concepts, and (3) select, refine, and implement an optimum floodproofing plan for a new or existing structure. This chapter identifies the specific types of information that may be required, how that information may be used, and potential data sources. The chapter has been arranged to reflect the general outline of information provided in Figure II-1. This format results in an initial discussion of the potential regulatory context of floodproofing, followed by a presentation of physical factors that impact floodproofing alternatives. The chapter concludes with a summary of factors that influence the design, use, and acceptability of floodproofing alternatives.

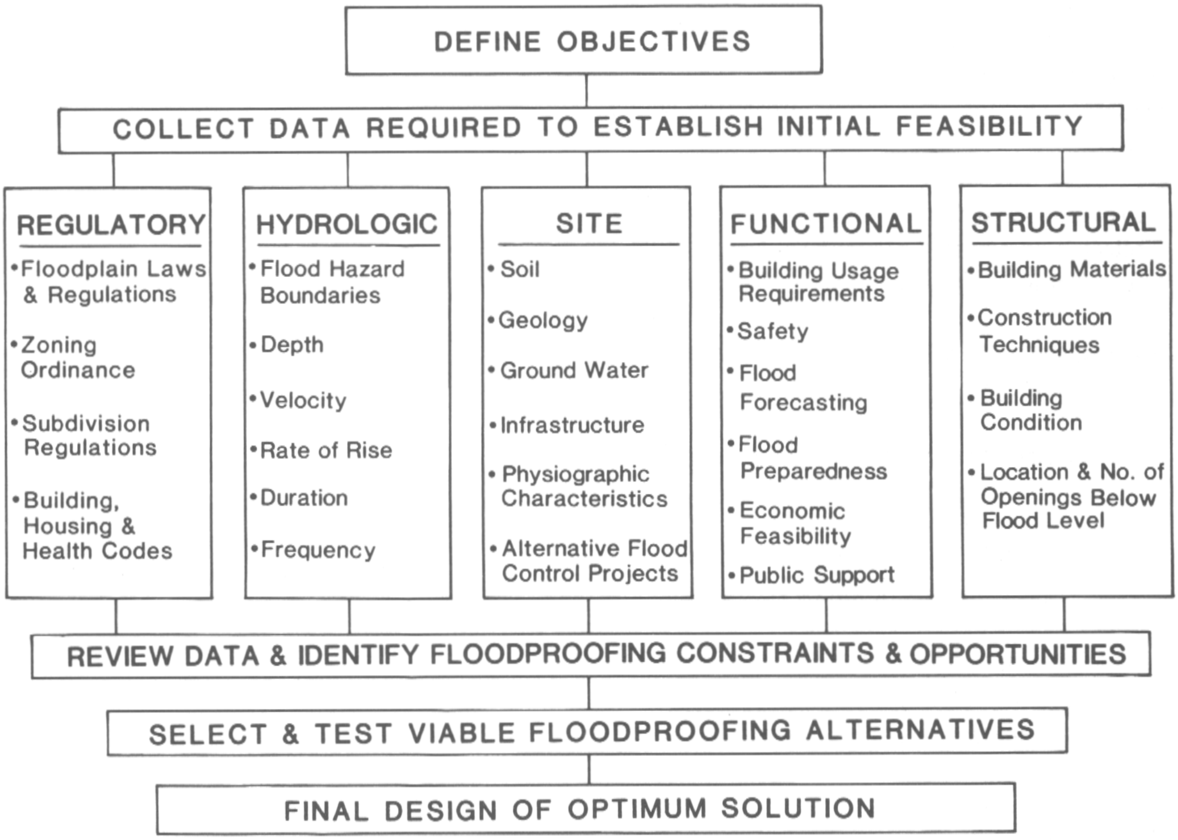


Figure II-1. General Floodproofing Design Process

B. REGULATORY CONSIDERATIONS

A variety of floodplain management programs have been developed and adopted throughout the United States as part of a long term effort to reduce flood damages. The floodproofing analysis process should begin with contacts to appropriate federal, state, regional, and local agencies to identify sources of technical assistance and to develop an understanding of floodplain regulations and other code requirements that are applicable to the proposed action. Figure II-2 provides an overview of the general range of floodplain management services that are available through various levels of government. As described below, the programs and regulations that are administered by these agencies can influence decision on where floodproofing may be applied, what techniques may be used, and the design of specific floodproofing components.

1. FEDERAL PROGRAMS. There are a variety of federal agencies that have direct or indirect involvement in flood protection issues. Several agencies support major research and program efforts in specific areas of floodproofing. For example, many of the Corps of Engineers District Offices have been involved in floodproofing projects and all of them provide flood and floodplain related technical assistance including information on floodproofing through the Flood Plain Management Services Program. The Corps of Engineers also maintains a National Advisory Committee on Floodproofing that has directed several floodproofing demonstrations and tests. Other federal agencies that support major programs related to floodproofing include the Federal Emergency Management Agency and the Soil Conservation Service.

FLOOD PLAIN AGENCIES	Floodwater Control	Floodproofing Information	Preserve Channel Capacity	Development Regulations	Land Use Controls	Public Information	Flood Fighting	Post-Flood Relief	Flood Warning System
• FEDERAL EMERGENCY MANAGEMENT AGENCY		●		●		●	●	●	
• U.S. ARMY CORPS OF ENGINEERS	●	●	●	●		●	●	●	●
• U.S. SOIL CONSERVATION SERVICE	●	●	●			●		●	
• DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT				●				●	
• NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION						●			●
• U.S. GEOLOGICAL SURVEY						●			
• FEDERAL HIGHWAY ADMINISTRATION	●		●				●		
• STATE FLOODPLAIN MANAGEMENT COORDINATING AGENCY	●	●	●	●	●	●			
• REGIONAL AUTHORITIES	●	●	●	●		●	●	●	
• LOCAL GOVERNMENT PLANNING AGENCIES				●	●	●			

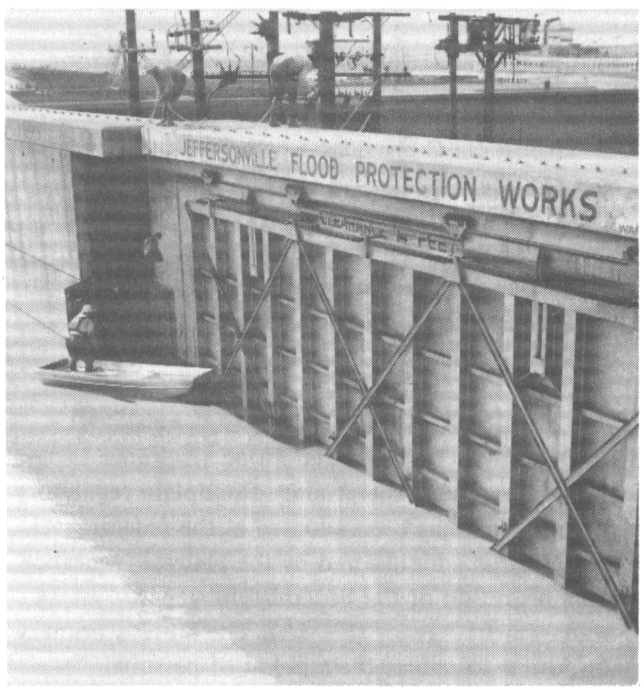
Figure II-2. Floodplain Management Services

Appendix C provides a listing of agency offices that may be contacted to obtain information information about programs and regulations that apply to a specific project. In addition, agency representatives may be able to provide technical assistance in the form of basic information and reports.

2. NATIONAL FLOOD INSURANCE PROGRAM. The National Flood Insurance Program (NFIP) represents the primary floodplain regulatory program that has been adopted at the federal level. The NFIP is administered by the Federal Insurance Administration of the Federal Emergency Management Agency (FEMA). The NFIP's primary purpose is to reduce the amount of personal hardship and property damage associated with flooding. The program makes flood insurance available to communities that implement comprehensive land use planning and management to reduce flood damage in their jurisdictions. Community response to this requirement generally involves the adoption of zoning, building code, and development regulations and strategies that feature various damage mitigation measures for new construction and substantial improvements to existing structures in identified flood hazard areas. The minimum standards for floodplain regulations, as published by FEMA, (44 CFR Part 60) require that: (1) all new or substantial improvements to *residential* buildings have the lowest floor (including the basement) elevated to or above the base flood elevation (BFE); (2) all new or substantial improvements to *non-residential* buildings must have the lowest floor (including the basement) elevated or floodproofed to or above the BFE. Under the floodproofing option, structures must be made watertight, with walls substantially impermeable to the passage of water and with structural components that are able to resist flotation, collapse, lateral movement, or other forces associated with a 100-year flood. Furthermore, specific floodproofing plans must be certified by a registered professional engineer or architect as meeting the minimum requirements of the National Flood Insurance Program.[1] Floodproofing techniques are not allowed in 'V'-zones (Coastal High Hazard Areas) as indicated on the Flood Insurance Rate Maps.

3. STATE PROGRAMS. The majority of states have adopted some form of floodplain regulations that must be considered during the planning of a floodproofed facility. Some state floodplain management laws and regulations do address floodproofing directly. State regulations also often include provisions that specify the amount of encroachment a facility may have on the floodplain, regulate the location of potentially hazardous materials, and restrict the location of such activities as schools, hospitals, and public services facilities. In addition, state building and utility permit systems may also impact the location and design of floodproofing measures. In association with the NFIP, each state has a designated State Coordinating Agency that provides assistance required to implement the program. These agencies (see Appendix C) generally represent the best place to begin an investigation of regulatory issues and to identify sources of technical assistance.

[1] Section 60.3 (c)(4) of the National Flood Insurance Program Regulations states that '...where a non-residential structure is intended to be made watertight below the base flood level, (i) a registered professional engineer or architect shall develop and/or review structural design, specifications, and plans for the construction, and shall certify that the design and methods of construction are in accordance with accepted standards of practice...and (ii) a record of such certificates which includes the specific elevation (in relation to mean sea level) to which the structures are floodproofed shall be maintained with the official designated by the community...



4. REGIONAL JURISDICTIONS. There are several regional jurisdictions within the United States that have an interest in floodplain management activities. These include several federal and state River Basin Commissions and the Tennessee Valley Authority. These agencies participate in a wide range of structural and non-structural floodplain management activities. The listing provided in Appendix C may be used to contact specific agency representatives.

5. LOCAL AGENCIES. In response to the National Flood Insurance Program and other federal and state floodplain management programs, most local jurisdictions have implemented regulatory programs through their zoning, building code, or other permit agencies. Zoning ordinances may specify allowable uses for a particular floodplain zone and various restrictions on the location and size of a structure. In addition to use of zoning ordinances, a variety of other regulatory tools such as subdivision regulations, building codes, sanitary regulations and plumbing codes are used by local jurisdictions.

C. FLOOD HAZARD CONSIDERATIONS

To develop an effective floodproofing scheme for a facility, several hydrologic factors must be properly evaluated. These factors include the regulatory floodplain boundaries and the anticipated flooding characteristics for the site such as flood velocity, duration, rate of rise, and frequency. This type of hydrologic base data may be available from several agencies as summarized in Figure II-3, or may have to be independently determined for the specific site.

AGENCIES / DATA TYPE	Coastal Surveys & Reports	Flood Control Measures	Flood Boundary Maps	Flood Insurance Rate Maps	Floodplain Information Reports	Flood Records & Probabilities	Floodplain Technical Studies	Hydrologic Atlases	National Flood Ins. Program Regulations	State Floodplain Regulations	Technical Assistance	Topographic Maps	Zoning Ordinances And Maps	Soil Maps
• Local government planning agency or municipal engineer	●	●	●	●	●	●	●		●	●	●	●	●	
• State floodplain management coordination agency	●	●	●	●		●	●		●	●	●			
• Federal Emergency Management Agency	●	●	●	●					●		●			
• National Oceanic and Atmospheric Administration (Department of Commerce)	●				●	●								
• Soil Conservation Service (U.S. Dept. of Agriculture)		●			●	●								●
• U.S. Army Corps of Engineers (Department of Defense)	●	●	●	●	●	●	●				●	●	●	
• U.S. Geological Survey (Department of the Interior)					●	●	●	●				●		
• Regional Authorities (e.g. T.V.A.)		●			●	●	●				●	●		

SOURCE: ADAPTED FROM DESIGN GUIDELINES FOR FLOOD DAMAGE REDUCTION, FEMA, 1981

Figure II-3. Summary of Hydrologic Data Sources

If a Flood Insurance Study has been developed by FEMA, the study will often offer the most current and detailed information that is available (see Figure II-4). Many such studies will include a 'Flood Boundary and Floodway Map' and supplementary stream profiles. For those areas where data is not available, hydrologic specialists can develop the necessary design information from site specific investigations. These may involve development of hydrologic relationships in some cases using knowledge of historical flood events and the physiographic conditions of the site and watershed. Detailed information regarding the specific structural loading impacts that floodwaters can exert on structures is provided in Appendix D (Floodproofing Performance Criteria). A general overview of considerations associated with other hydrologic factors is provided below.

1. FLOOD HAZARD BOUNDARIES. The proper identification of flood hazard boundaries is significant in that these boundaries define the regulatory floodplain, and the relative extent of flood hazard within various floodplain zones. Flood hazard boundary classifications must also be investigated to determine areas that may restrict the use of certain floodproofing measures such as areas identified as the regulatory floodway or areas that are subject to high flood velocities.

In accordance with the NFIP requirements, the 100-year or 'base flood', that is, the flood having a one percent change of being equalled or exceeded in any given year is used as the basis for floodproofing designs for new and substantially improved construction. Base flood elevations may be determined at any point within the 100-year floodplain by referring to the appropriate 'Flood Insurance Rate Map' (see Figure II-5). For areas that do not have a Flood Insurance Study, floodplain boundaries may be obtained from other sources such as a Flood Hazard Boundary Map, floodplain information studies, zoning maps, or through analyses performed by hydrologic/hydraulic specialists.

2. DEPTH. The depth of flooding associated with the required regulatory flood (usually the 100-year return frequency or other selected protection level) is one of the primary factors that influence floodproofing design. This factor must be determined to design against over-topping of the system (freeboard consideration) and to formulate a design that can withstand associated loading pressures.

STUDY ELEMENT	FLOODPLAIN DATA[1]	FLOOD HEIGHTS	ELEVATION REFERENCE MARKS	FLOOD PLAIN BOUNDARIES	FLOODWAY DATA	FLOOD INSURANCE ZONES
FLOOD INSURANCE STUDY REPORT	●	●				●
FLOOD BOUNDARY & FLOODWAY MAP (FBFM)			●	●	●	
FLOOD INSURANCE RATE MAP (FIRM)		●	●	●	●[2]	●

[1] Flood profiles, water velocity, floodway widths, historical flood information, etc.

[2] Some FIRM's do not depict floodway data.

Figure II-4. Summary of Key Information Provided by Flood Insurance Study Effort

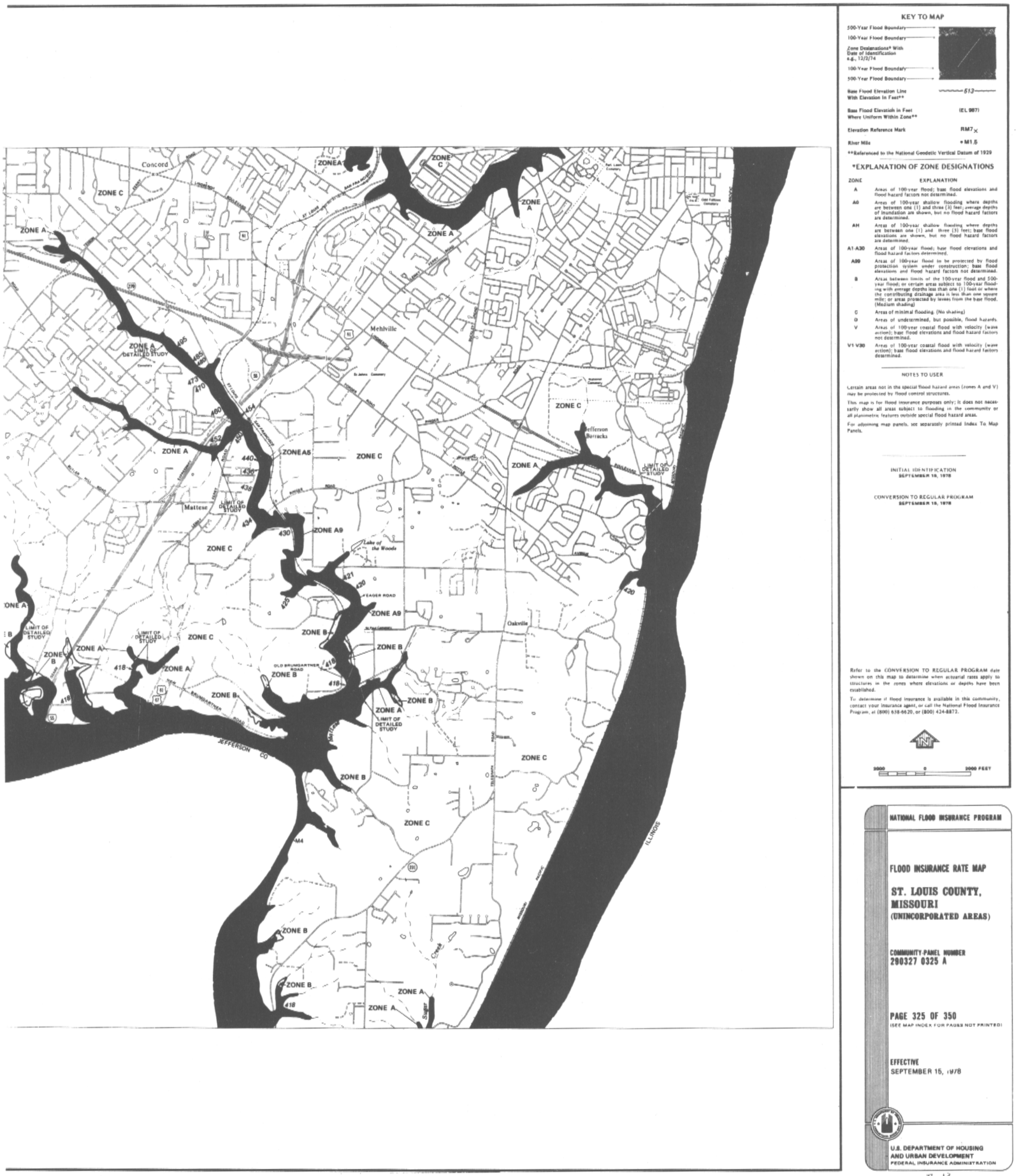


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Figure II-5. Flood Insurance Rate Map

There is considerable variation among floodproofing techniques regarding the maximum flood depth for which each method can be applied (see Figure II-6). Elevation of non-residential structures on posts, piers, or piles as high as 12 feet is not uncommon. Elevation on fill has been used to protect against flooding depths in excess of 10 feet depending upon the characteristics and availability of fill material. The upper limit of permanent and contingent closure systems is generally limited by the building's wall or floor strength and cost considerations. Existing non-residential buildings of reinforced concrete or heavy masonry construction can often resist flood loading up to depths of four to six feet, including allowance for both hydrostatic and hydrodynamic loads (see Chapter III and Appendix D).

Estimates of flood depths for a particular site can normally be inferred from flood insurance studies or similar hydrologic reports. Where a Flood Insurance Study Report is available, the elevation of various probability events (100-year, 500-year) for a particular stream channel may be obtained from a flood profile (see Figure II-7). For floodproofing purposes, the depth of flooding may be calculated by subtracting the elevation of the lowest grade adjacent to the structure to be floodproofed from the Base Flood elevation as determined from an appropriate flood profile. If a Flood Insurance Study or other floodplain studies have not been conducted, flood depths may be determined through site specific evaluations or historical information.

3. VELOCITY. In addition to depth of flooding, velocity has a direct relationship to the amount of force applied to a structure by floodwaters. Water velocity also can result in higher depths of flooding on the upstream side of a building. An allowance for freeboard, particularly on upstream side of a facility, can address this concern. The velocity of flow also determines the force which could be applied to the structure through the impact of objects being carried by the flood (see Appendix D for more detailed information on flood loads). High velocities also have an impact on the design of levees or embankments that can be subject to scour and erosion.

Experience has shown that floodproofing is generally not appropriate in areas where flood velocities exceed 10 feet per second. Information on stream velocity may be obtained from the Floodway Data Table contained in the Flood Insurance Study Report, other technical studies, or through site specific hydrologic investigations.

	DEPTH	VELOCITY	RATE OF RISE	DURATION
LEVEES	4–7′	< 10 FT/SEC	MAY NEED ADVANCE WARNING IF GATES NEED TO BE INSTALLED	NO CONSTRAINTS
FLOODWALLS	4–7′	<12′ FT/SEC		NO CONSTRAINTS
CLOSURES	4–8′	< 8 FT/SEC	NEED 5–8 HOURS ADVANCED WARNING	< 24 HOURS
FILL	10′+	< 10 FT/SEC	WILL REQUIRE EVACUATION TIME UNLESS FILL CONNECTS TO HIGH GROUND	NO CONSTRAINTS
PILES , PIERS COLUMNS	10–12′	< 8 FT/SEC	NEED ADEQUATE EVACUATION TIME	NO CONSTRAINTS

* BASED ON STATE OF THE ART REVIEW OF ACTUAL SITES, INFORMATION PRESENTED IS GENERAL AND WARRANTS CAUTION

Figure II-6. General Limits of Floodproofing Methods

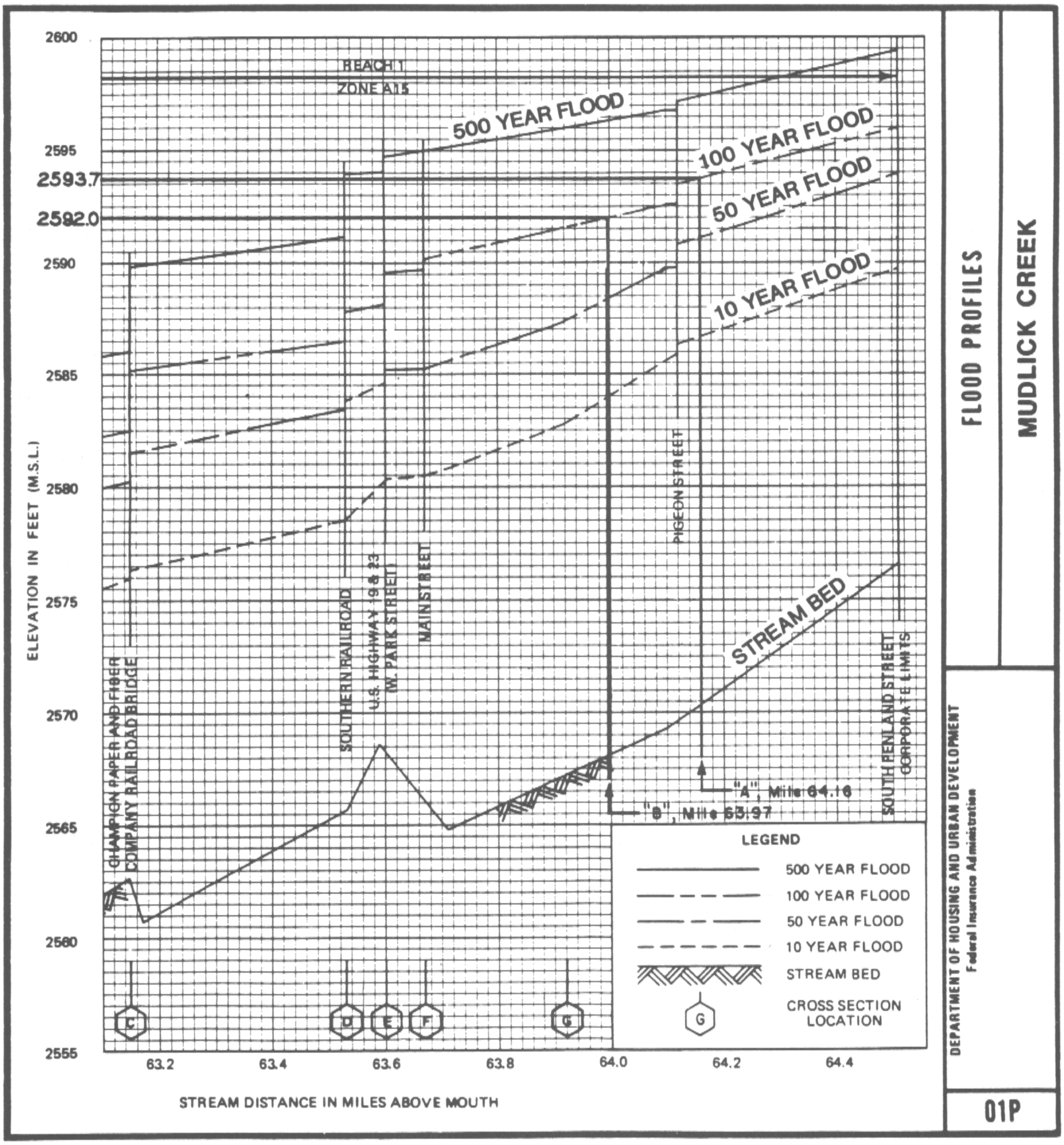
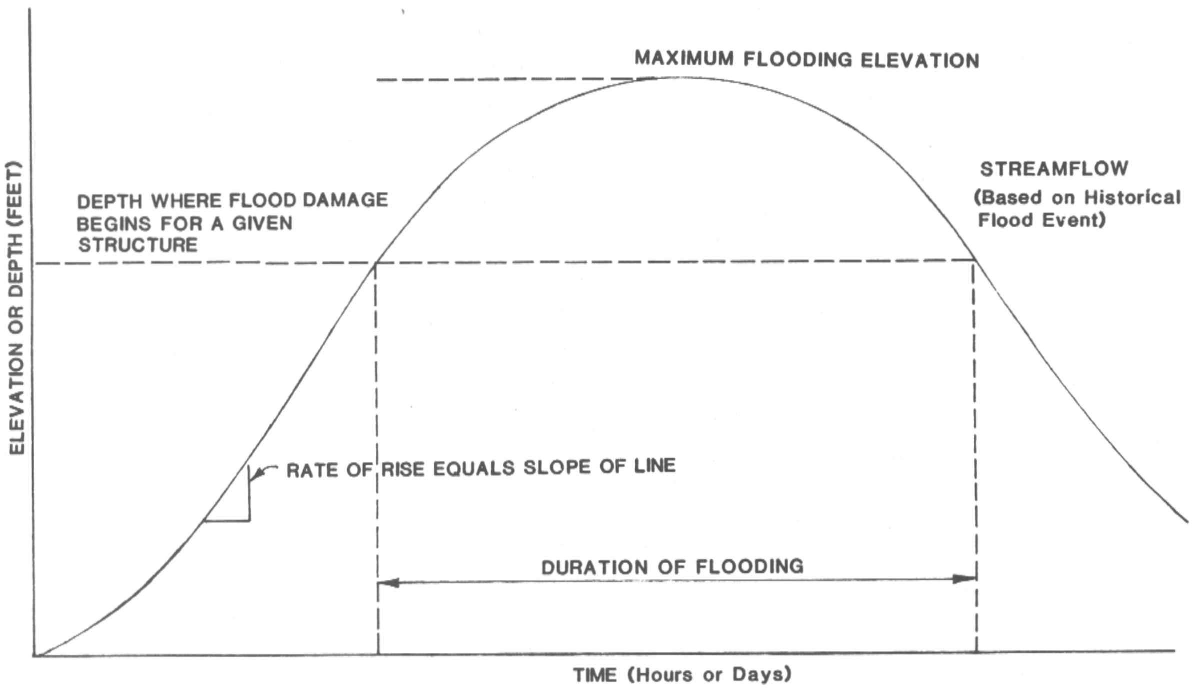


Figure II-7. Typical Flood Profile

4. RATE OF RISE. The rate of rise of a flood is an expression of how rapidly water depth increases during a flooding event. This factor is important when determining whether sufficient lead time is available to permit the use of contingent floodproofing methods; and for designing appropriate emergency evacuation plans. The rate of rise of floodwaters can be derived from a streamflow hydrograph for the area under consideration that relates flooding depth to time (see Figure II-8). The rate of rise can be determined from the hydrograph by the slope of the hydrograph at the depth and time in question.

Information required to determine rate of rise may be available from existing hydrologic studies, on-site investigations, local civil defense offices, or historical records.

5. DURATION. The duration of a flood is an important floodproofing consideration because it affects the saturation of soils and building materials, seepage rates, and the amount of time facilities might be inaccessible. Floodproofed structures that will be subjected to long periods of flooding must be carefully designed to reduce the risk of failure as a result of soil or building material saturation, internal pump system failures, or similar problems related to extended flood duration. The duration of flooding can be derived from an applicable streamflow hydrograph or, in some cases, from historical flood information. As shown on Figure II-8, the depth at which damage from flooding begins at a particular structure can be plotted on the hydrograph. The amount of time that the water level remains above this elevation indicates the duration of flooding.



*Can be used to determine the rate of rise (amount of advance warning), and the duration of flooding.

Figure II-8. Streamflow Hydrography*

6. FREQUENCY. The frequency of flooding must also be considered in determining the best method for floodproofing a structure. Frequency of flooding is defined as the probability (in percent) that a random flood event will equal or exceed a specified magnitude in a given time period, usually one year. The frequency of flooding can be statistically determined using historical records of flooding at the location under consideration.

The owner of a structure subject to a high frequency of flooding may choose to install permanent floodproofing measures instead of contingent measures to reduce operational costs and the chance for system failure resulting from an inadequate response.

D. SITE FACTORS

In addition to the collection of information that defines the extent and characteristics of floodwaters, there are several other site specific features that must be investigated as part of a pre-design analysis of floodproofing alternatives. The designer must identify floodproofing constraints and opportunities associated with geologic, ground water, and soil conditions, existing infrastructure, and physiographic characteristics of the project area.

1. GEOLOGY, GROUND WATER, AND SOIL CONDITIONS. The selection and design of most floodproofing measures requires an evaluation of geologic, groundwater, and soil conditions. Although geologic features do not generally represent a key design factor in floodproofing design, basic data should be collected to identify any major geologic constraints including presence of Karst (sink-hole) features, faults, or extremely shallow depth to bedrock. Likewise, the depth of the groundwater table in the area should be determined because a high water table in combination with flooding conditions could have a significant impact on foundation and floor system design.

Soil characteristics will often have a major effect on the selection and performance of floodproofing systems. Factors that are of primary importance include permeability, erosion potential, slope stability, and bearing capacity. Soil characteristics are particularly important in determining the feasibility of elevating structures on fill material, the construction of earth berm levees, and foundation design for floodwalls and elevated structures. General soil characteristics can be determined by referring to Soil Survey Reports published by the U. S. Department of Agriculture's Soil Conservation Service. However, final floodproofing design must be based on site specific detailed soil analyses conducted by a qualified soils engineer.

2. INFRASTRUCTURE. Existing road and utility systems can influence the selection and design of various floodproofing measures. For example, levees and floodwalls must be compatible with road, rail or water-borne transportation systems; and elevated facilities must be designed so that they are accessible to people and materials. In addition, the floodproofed facility must be designed so that it is compatible with existing utility systems. Information concerning existing and planned road and utility systems that may influence floodproofing design may be obtained from local and state planning agencies and utility companies.

3. PHYSIOGRAPHIC CHARACTERISTICS. An analysis of the various physiographic features of a proposed floodproofing site is an important step in the identification of the best location for a new building or the location of a floodwall or levee. Characteristics that should be considered include the size and shape of the land parcel, site elevations, slope, and existing drainage patterns. The physiographic characteristics of an area may have a significant impact on the feasibility of floodproofing systems that require a substantial amount of space, such as levees and fill used to elevate a structure. In addition, levees and earth fills must be carefully designed so that they do not create a significant constriction of flood flows, thereby increasing hazards for other facilities in the area. Physiographic features can be determined from topographic maps, floodplain studies, and on-site investigations.

E. FUNCTIONAL, OPERATIONAL, AND ECONOMIC FACTORS

Viable floodproofing alternatives must be responsive to the functional usage requirements of the structure, the safety of the structure's occupants, and the reactions of local officials and citizens to the proposed measures. In addition, the ultimate test of feasibility lies in the relative cost of the measure weighed against the economic benefits to be gained by taking action.

1. USAGE REQUIREMENTS. The functions that must take place in a non-residential building can have a major impact on the types of floodproofing measures which may be used. For example, if a doorway must be used for delivery of freight or personnel access, it is obviously not feasible to permanently close that opening. Likewise, critical facilities such as hospitals or fire stations cannot function properly if access is restricted by floodwalls or some other floodproofing technique. The current and future use of the structure must be carefully evaluated in deciding to what degree access can be limited and in determining how long the facility can be closed during a flood and how well the effects of the design flood being exceeded can be tolerated.

2. SAFETY. The relationship of various floodproofing options to occupant safety must be evaluated in the pre-design phase. In situations where a floodproofed facility is likely to be completely surrounded by floodwaters, provisions must be made for the evacuation of all personnel and residents before flooding affects the structure. Evacuation is essential because it is always possible that a flood may exceed the design capacity of the floodproofing measures, which could result in extreme danger to any occupants that remain at the site.

Federal Executive Order 11988 on Floodplain Management requires that all federally funded critical service non-residential facilities (such as fire stations, nursing homes and hospitals) be located outside the 500-year floodplain. These facilities should always be restricted to areas that are only exposed to low flood depths and velocities and where access to the site can be assured at all times including peak flooding conditions. These and similar safety requirements must be carefully evaluated in developing alternative floodproofing plans.

3. FLOOD FORECASTING. As mentioned in preceeding sections, contingent and emergency floodproofing methods cannot be successfully implemented without an adequate flood warning and forecasting system. The length of warning time that will be required can vary from a few hours to several days depending upon the complexity of any contingent or emergency techniques that must be implemented. Therefore, flood warnings must be issued promptly and the forecasts must be accurate if they are to be effective. This section provides a brief description of a standard flood forecasting system.

A flood forecasting system must perform two functions: first, it must determine when a flood is imminent, and second, it must predict when specific areas will be flooded. In some cases it may also be necessary to determine when and at what elevation the flood will crest.

For most major streams in the United States, this type of information is provided through the National Weather Service's river forecast centers or its river district offices. (Appendix C provides a listing of these offices.) Unfortunately, many facilities are located on smaller streams not included in a major forecasting network. In these areas, interested property owners can work with appropriate local and state agencies to develop an adequate flood forecasting system.

An organizational structure is required to implement a flood forecasting system. The typical organizational structure that has been used in many parts of the United States includes a flood coordinator, a central staff, observers, and/or a computerized gauge system to collect critical streamflow data. The size of the organization may range from a dozen members to over one hundred based on the size and complexity of the watershed to be monitored. The sequence of activities to be performed by this group during potential flood periods consists of (1) activating the system, (2) reporting observed data, (3) assembling and analyzing the data, (4) developing the forecast, and (5) disseminating the information.

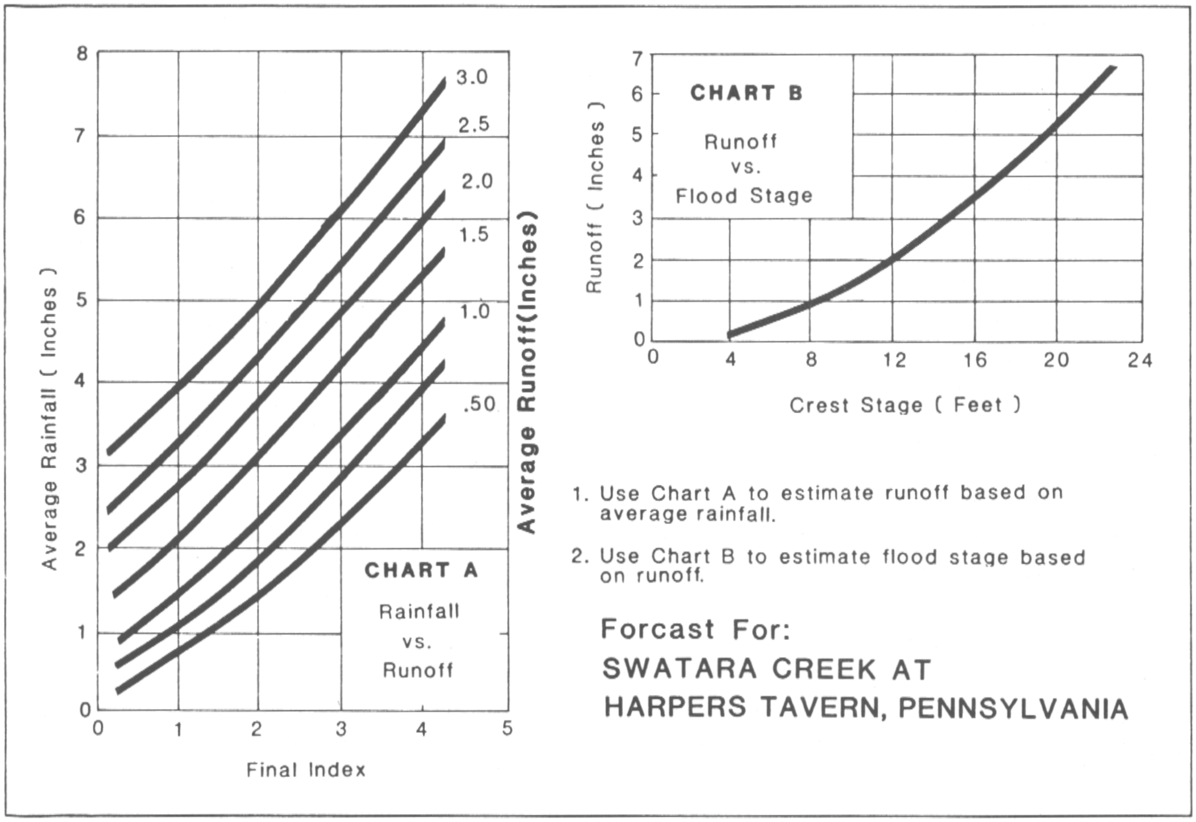


Figure II-9. Flood Forecasting Charts

Source: *Cooperative Flood Loss Reduction,* a technical manual for communities and industry, SEDA-Council of Governments, June 1981.

For a flood forecasting system to be effective, it must begin functioning immediately when conditions indicate that a flood is imminent. The system may be activated in one of two ways. First, it may be activated by the flood coordinator. The person designated for this role should always know when conditions are favorable for the development of floods. This information can be obtained from the National Weather Service or through private meteorological agencies. The flood coordinator should closely monitor the development of such conditions and activate the system as soon as it is determined that flood-producing events may occur. The system could also be activated by an observer or automatic gauge system when a predetermined stream level or amount of rainfall occurs.

Activation of the system requires the flood coordinator and the central staff to report to a prearranged location and that the system's observers, if any, begin to record and report data on a regular basis. The central staff should immediately begin to assemble and to analyze information being reported from the observers and/or automatic gauges. The method of reporting this information must be highly reliable because the accuracy of all predictions will be based on the receipt of correct and timely data.

Data analysis is normally performed by hand, using charts that have been prepared for the area. These charts are usually designed to use the average precipitation over the drainage area to develop an estimate of runoff amount (see Figure II-9). This runoff amount is then multiplied by a correction factor that is designed to adjust for antecedent moisture conditions, ground cover type, and other factors. This final step allows the forecasters to estimate the net magnitude of flood runoff, which can then be used to estimate anticipated flood elevations, rate of rise, and duration of flooding. The National Weather Service can provide assistance required to prepare these charts, or input data may be obtained from historical information (where accurate information exists) or from computer simulations of the watershed. Because it is very important that flood forecasts be as accurate as possible, the forecasting charts should be updated and modified after every flood event. The flood coordinator is generally responsible for deciding that specific areas are likely to be flooded, and for issuing a flood warning when appropriate.

4. PREPAREDNESS PLANS. Proper design of floodproofing measures for a facility, and provision of the necessary equipment and floodproofing devices represent important components of a successful floodproofing program. However, these actions alone cannot ensure success. It is still necessary for all measures to be properly installed within the limited amount of time that is available prior to flooding. The best means of ensuring that this can be done is through the preparation and implementation of a flood emergency preparedness plan.

A preparedness plan must be comprehensive and specific. The plan must cover every aspect of the floodproofing procedure ranging from the initial receipt of a flood warning to post flood cleanup requirements. Each activity must be clearly specified in its order of occurrence, with enough detail to ensure that the personnel who will be required to perform these activities will know exactly what to do and how to do it. Each task must be specifically assigned to an individual or group to minimize confusion and duplication of efforts.

The first item that the flood emergency preparedness plan must consider generally involves the evacuation of all personnel except those required to install the floodproofing measures. For those times when the structure is not occupied, the plan should include provisions for the efficient notification and assembly of personnel that are responsible for initiating all contingent and emergency floodproofing measures.

The plan must also recognize that many vital services to the facility may be disrupted during a flood. For example, if communications and electrical service must be maintained to install the floodproofing elements and to run critical equipment during the flood, it may be necessary to provide a supplemental radio system and portable electrical generators.

Hazards to persons and property on and off the site must also be identified and resolved in the preparedness plan. When flooding occurs on the site, several potential hazards may exist such as electrical wiring in or near standing water or ruptured gas lines or tanks. In addition, emergency personnel working at the site could be stranded without provisions, utilities, or water. Off site hazards might include hazardous substance spills resulting from broken fuel lines or small buildings or tanks that could float off the site and damage other property. The plan must identify these types of hazards and identify appropriate safety measures that will reduce these risks.

Two final items that the flood preparedness plan should cover are maintenance and training. The preparedness plan should include a checklist of maintenance items to be performed regularly. A completed checklist verifying that all items were inspected during specified time intervals should be maintained as part of the facility's permanent records. A regular training program should be established to ensure that those who are responsible for various steps in the floodproofing procedure can perform their tasks efficiently.

Back-up personnel should also be assigned to key positions and participate in the training program so that an adequate number of qualified personnel can be obtained at any time. The training program should include actual installations of various measures as part of impromptu preparedness drills to identify the amount of time that will be required to activate the system and to indicate problems which might occur.

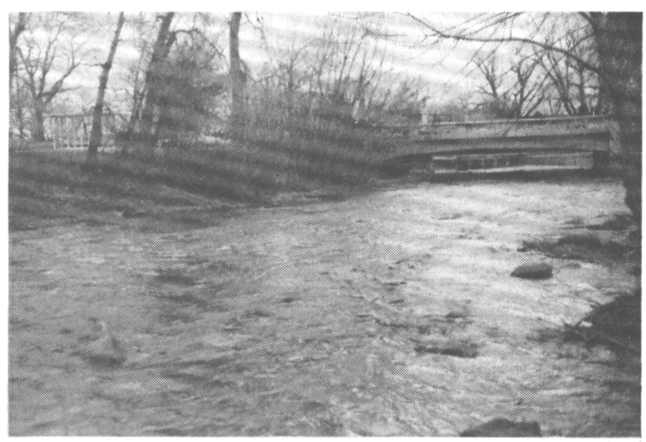
In summary, the flood emergency preparedness plan should define all of the steps involved in implementing floodproofing procedures at a facility and give a thorough explanation of how each step is to be performed. In addition, the plan should anticipate any problem that might arise during the floodproofing of the structure and develop solutions to those problems. Finally, the plan should provide for regular maintenance of all floodproofing elements and auxiliary equipment and should establish a permanent training program for personnel involved in implementing the floodproofing measures.

5. ECONOMIC FEASIBILITY. Once it has been determined that floodproofing is feasible in terms of regulatory requirements and the physical characteristics of the floodplain and the structure, it is possible to identify the floodproofing program that is most cost effective. A cost effective plan would be one where the total cost of floodproofing (installation, operation, and maintenance) is less than the amount of physical flood damages, lost earnings, and other economic impacts that are likely to occur if the structure is not floodproofed.

Damages are generally calculated on an average annual damage basis over the economic life of the structure. These average annual damages that would be incurred without floodproofing are then viewed as the average annual benefits associated with the proposed floodproofing plan. Other benefits, such as reductions in flood insurance premiums, reduction in lost production time, or the advantageous use of the space beneath an elevated structure should also be included in the calculation of annual benefits.

The total cost of implementing a floodproofing plan must also be calculated. All factors must be considered, including the cost of installation, operation, maintenance, financing, training, installation of contingent methods, and the cost of maintaining an adequate warning system. Once these variables have been identified, it is possible to amortize the total project cost over the economic life of the structure to identify an average annual cost. The average annual cost can then be directly compared with the average annual benefits (damages prevented) to determine the relative cost effectiveness of proposed floodproofing plans. Chapter V provides more detailed guidelines that can be used to estimate the costs and benefits of specific floodproofing plans.

If public opinion is not considered in the preparation of floodproofing plans, it is possible that a technically sound and cost effective program can be jeopardized. Therefore, a coordination program should be considered during the initial stages of the project to ensure program success.



F. STRUCTURE CHARACTERISTICS

The physical characteristics of a structure must also be carefully evaluated to determine appropriate floodproofing applications. For existing structures, it is important to identify the type and quality of construction techniques that were used and the present structural condition of the facility. With regard to structures that are still in the planning and design stages, it is necessary to identify how alternative designs will contribute to or detract from the ability to minimize future flood damages.

There are an infinite variety of structure types in terms of size, shape, materials, and construction techniques. However, it is possible to identify the most common non-residential building types and to illustrate the general applicability of each type to the floodproofing techniques described in this manual. The reader can refer to Figure II-10 and the following discussion as a general aid in the identification of alternative floodproofing methods that may be applicable for a given structure. These options must then be evaluated in terms of hydrologic and site constraints, functional acceptability, and cost effectiveness based on guidance provided in other sections of this manual.

The matrix illustrated in Figure II-10 begins by making a distinction between structures that have basements and those that do not and between proposed and existing structures. After these distinctions have been made, the reader can refer to the matrix and the following narrative to determine the general applicability of various floodproofing options to particular building types. The following discussion is organized to reflect the three general floodproofing options shown in Figure II-10 including elevation on columns or fill, protection by floodwalls and levees, and floodshield/closure systems.

1. ELEVATION. As indicated by the matrix, elevation of existing buildings is generally limited to structurally sound frame structures with wood or metal siding. In addition, elevation is easiest for existing structures that have a unified floor system that remains intact and can support the structure walls when it is raised from an existing crawl space or basement foundation. This technique is most applicable to structures that: (l) are small enough to be lifted as a single unit, (2) are light enough to be elevated with standard equipment; and (3) have sufficient space below the first floor to place supporting beams and jacks. Elevation of slab-on-grade structures is possible but more difficult. Elevation of existing masonry, masonry veneer, or concrete structures is also possible. However, elevation of these structure types is generally not cost effective because of the weight of the structures and their general lack of tolerance to the stresses imposed by elevation.

Existing structures that are suitable for elevation may be placed on supporting columns in their present location or they may be physically moved to a new site and placed on a new foundation system or compacted fill. The use of fill material under a structure that is to be elevated in its current location is not feasible because the cost of placing and compacting the fill material under the structure is generally prohibitive. If an existing structure with a basement is elevated, the cost associated with the loss of use of the basement must be considered in the feasibility of this approach.

With regard to new construction, the matrix demonstrates that all structure types may be elevated on columns or fill if this factor is included as an initial design objective.

2. FLOODWALLS AND LEVEES. As shown in Figure II-10, floodwalls and levees could be used to protect virtually any existing or proposed structure regardless of materials, condition, or other structure characteristics. Therefore, the various hydrologic, site, and functional parameters of a particular area must be investigated to determine the feasibility of floodwalls or levees.

GENERAL STRUCTURE TYPE			ELEVATE ON COLUMNS OR FILL 2	FLOODWALL OR LEVEE	FLOOD SHIELDS & CLOSURES 3
			FLOODPROOFING OPTION		
WITH BASEMENT	PROPOSED STRUCTURE	WOOD OR METAL SIDING	X	O	X
WITH BASEMENT	PROPOSED STRUCTURE	MASONRY (CONCRETE BLOCK OR BRICK VENEER)	X	O	O
WITH BASEMENT	PROPOSED STRUCTURE	CONCRETE (CAST-IN-PLACE OR PRE-CAST	X	O	O
WITH BASEMENT	EXISTING STRUCTURE	WOOD OR METAL SIDING	O	O	X
WITH BASEMENT	EXISTING STRUCTURE	MASONRY (CONCRETE BLOCK OR BRICK VENEER)	X	O	O
WITH BASEMENT	EXISTING STRUCTURE	CONCRETE (CAST-IN-PLACE OR PRE-CAST	X	O	O
WITHOUT BASEMENT	PROPOSED STRUCTURE	WOOD OR METAL SIDING	O	O	X
WITHOUT BASEMENT	PROPOSED STRUCTURE	MASONRY (CONCRETE BLOCK OR BRICK VENEER)	O	O	O
WITHOUT BASEMENT	PROPOSED STRUCTURE	CONCRETE (CAST-IN-PLACE OR PRE-CAST	O	O	O
WITHOUT BASEMENT	EXISTING STRUCTURE	WOOD OR METAL SIDING (WITH UNIFIED FLOOR SYSTEM)	O	O	X
WITHOUT BASEMENT	EXISTING STRUCTURE	WOOD OR METAL SIDING (SLAB ON GRADE)	O	O	X
WITHOUT BASEMENT	EXISTING STRUCTURE	MASONRY (CONCRETE BLOCK OR BRICK VENEER)	X	O	O
WITHOUT BASEMENT	EXISTING STRUCTURE	CONCRETE (CAST-IN-PLACE OR BRICK VENEER	X	O	O

O-MAY BE APPLICABLE X-GENERALLY NOT APPLICABLE

1. Table assumes that goal is to prevent water from entering basement (i.e. dry floodproofing)
2. Elevation of existing structure on fill may be feasible if structure can be physically moved to a new site that has been properly filled and compacted.
3. Flood shields may not be applicable in areas subject to flash flooding conditions; and shields and closures can only be used in structures that have a floor system that can prevent water entry.

Figure II-10. Relationship of Floodproofing Options to Structure Type

3. FLOOD SHIELDS AND CLOSURES. Assuming flood conditions that reach the first floor elevation of a structure with a basement, and recognizing that the surrounding soil may become saturated, the hydrostatic pressure imposed on the basement walls and floor may exceed the resistance of standard basement construction techniques. This must be considered prior to the use of flood shields and closures to protect existing structures with basements. Flood shields and closures may be used to floodproof new masonry or concrete structures with basements, assuming that the design includes provisions to resist flood forces.

For structures without basements, flood shields and closures may be similarly used when the walls and floor of the facility are impermeable and strong enough to resist loads produced by the design flood. These requirements generally limit the use of flood shields and closures to masonry and concrete structures that are built on a slab-on-grade concrete foundation. Most existing masonry construction is reinforced and its ability to resist extensive hydrostatic forces is usually questionable. Unless construction plans are available indicating reinforced masonry, the walls should be assumed to be reinforced.

Steel or wood frame structures with wood or metal siding are not watertight and have low resistance to flood forces. Therefore, these type of structures are not suitable for flood shields and closures. Other considerations that must be made in the use of floodshields for a structure include the size, location and number of window and door openings to be closed, and the strength of the frames around these openings.