# A Levee Policy for the National Flood Insurance Program (1982)

Pages
121

Size
8.5 x 10

ISBN
0309328748

Committee on a Levee Policy for the National Flood Insurance Program; Water Technologies Board; Commission on Engineering and Technical Systems; National Research Council

# A LEVEE POLICY FOR THE NATIONAL FLOOD INSURANCE PROGRAM

Committee on a Levee Policy for the
National Flood Insurance Program

Water Technologies Board

Commission on Engineering and
Technical Systems

National Research Council



NATIONAL ACADEMY PRESS
Washington, D.C. 1982

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This report represents work supported by Contract Number EMW-C-0606 between the Federal Emergency Management Agency and the National Academy of Sciences

COMMITTEE ON A LEVEE POLICY FOR THE NATIONAL FLOOD INSURANCE PROGRAM

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Earl Jones
Department of Housing and Urban Development

Walter Ochs
USDA Soil Conservation Service

Frank H. Thomas
U.S. Water Resources Council

Technical Consultant

George W. Brazier, Jr.
Consulting Civil Engineer
Luray, Virginia

## Workshop Participants

Gregory Baecher
Massachusetts Institute of Technology
Cambridge, Massachusetts

Duane Baumann
Southern Illinois University
Carbondale, Illinois

Richard Buncie
U.S. Army Corps of Engineers
St. Louis, Missouri

Joel Crawford
Scott Company
Hilton Head, South Carolina

Lucien Duckstein
University of Arizona
Tucson, Arizona

Gary Dyehouse
U.S. Army Corps of Engineers
St. Louis, Missouri

Burrell Fair
Saint Francis Levee Board of Arkansas
West Memphis, Arkansas

John Graham
Susquahanna River Basin Commission
Harrisburg, Pennsylvania

R. G. Kazman
Louisiana State University
Baton Rouge, Louisiana

John Koeper
Metro St. Louis Sewer District
St. Louis, Missouri

Richard L. Konsella
New York State Department of Conservation
Albany, New York

Paul Lanferman
Alameda County Flood Control and Water Conservation District
Hayward, California

Guy F. LeMieux
J. J. Krebs & Sons
Metairie, Louisiana

James Lewin
New Orleans East Incorp.
New Orleans, Louisiana

Earle Magner
Orleans Levee Board
New Orleans, Louisiana

William Remmert
U.S. Army Corps of Engineers
St. Louis, Missouri

Everett W. Rowland
Texas Department of Water Resources
Austin, Texas

Harold Vance
Los Angeles County Flood Control District
Los Angeles, California

Robert Watson
Department of Natural Resources
Madison, Wisconsin

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Booker Associates
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## PREFACE

Levees provide a viable structural approach for reducing average annual flood damages, but it is an approach that should be used with care. Levee tops that are higher than flood crests bar movement of flood waters onto lands behind them, but levees must be carefully engineered and maintained so as not to fail structurally during events too small for their overtopping. Furthermore, levees often lead to more intense land development behind them and are subject to sudden failures that can add to damage totals during extreme events. It is because levees reduce average annual flood damages that FEMA is being pressured to reduce flood insurance premiums for buildings behind levees, the logic being that protected property owners should not both pay for the levee and then be required to pay insurance premiums based on full damage exposure. It is because of the need for care in using levees that FEMA has an obligation to recognize only levees that are properly engineered and structurally sound. Riverine levees extend for thousands of miles along water courses from the nation's largest rivers to some very small streams, making levee inventory, inspection, evaluation, and acceptance or rejection a formidable process.

The committee reviewed technical considerations for application in evaluating the great number of existing and proposed levees for hydraulic and geotechnical soundness. This document formulates principles for a levee policy that will provide equity for protected parties in terms of recognition for efforts spent in reducing their risk without encumbering program administration with an unwieldy number of variations in levels of recognition of levee efficacy. The details will need to be developed from these principles by FEMA.

The committee defined six dimensions of levee recognition. The design protection level appropriate for recognition depends on whether the application is for 1) reduction in insurance rates, 2) easing land occupancy regulations, 3) eliminating flood insurance purchase requirements, 4) permitting siting of critical facilities, 5) removing requirements for notifying occupants of the hazard, or 6) eliminating warning and evacuation programs. Each recommended levee recognition distinction was based on the experience and judgment of the committee members integrating technical considerations with economic and

administrative factors. Each recommendation is reasoned and presented in the body of the report, and all of them are listed for convenience in a final summary chapter. Table 1 in Chapter 2 condenses the levee-recognition policy recommendations and mapping suggestions on one page. Appendix A defines technical terms used in the context of the report.

As when any group of people assemble to discuss a complex and controversial issue, differences of opinion arose. A few of the 35 recommendations made by this committee were not unanimous, and the cases made by committee members with contrary viewpoints are given in Appendix D to complete the record. As this report is advisory, the complete record provides the Federal Emergency Management Agency more information for weighing in formulating policy. The discussion coalescing in these minority opinions caused the committee to give these issues particular attention throughout the study and review processes. Consequently, speaking as an author of one of them, a lack of unanimity should be taken as an indication that there is legitimate room for debate, and the choice of the majority suggests that the balence of existing evidence supports the positions articulated in the committee recommendations.

In the opinion of the chairman, the focus of the committee recommendations is on recognition of levees along rivers where flows, depths, and velocities are large enough to pose threat to life. In small watersheds, levees are often used to augment channel capacity or provide freeboard at locations where channels, flows, and flood volumes are small. FEMA should not automatically extrapolate committee procedural recommendations (such as those on design, maintenance, and evacuation plan detail) to smaller streams without being able to justify reasonableness in terms of maintaining, but not exceeding, the level of protection presented in principle in the body of this report. The consideration of reasonableness is particularly important in setting program priorities.

The chairmanship of this committee has been an interesting and enriching experience. The committee members, agency liaisons, and workshop participants gave willingly of their time and counsel and deserve credit for the substance and recommendations found in this report. The committee is grateful to the staffs of the National Research Council and the Federal Emergency Management Agency for support that enabled the committee to focus quickly and efficiently on the assigned task and to complete it on time.

L. Douglas James
Chairman

October 12, 1982

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# INTRODUCTION

## BACKGROUND

Prior to the 1960's, the national thrust in flood damage mitigation and relief was to provide structural flood protection works, such as dams, levees, and seawalls, and disaster assistance to remaining flood victims. Unfortunately in many instances, flood protection works generated a false sense of security and magnified the impacts of future disasters by encouraging floodplain development. The National Flood Insurance Program (NFIP) was established by the National Flood Insurance Act of 1968 in response to a continued increase in annual flood losses. This act formally realigned the federal flood control program toward an emphasis on nonstructural approaches to flood hazard mitigation. The act established a program to provide flood insurance coverage within communities willing to implement a floodplain management program featuring (1) land use regulations to guide development away from flood-prone locations and (2) minimum building construction standards to reduce future flood losses to structures in inundated areas.

Section 1360 of the act required the identification of all areas having special flood hazards within 5 years. The act also required determinations of flood risk probabilities throughout all flood-prone areas within 15 years of enactment. The Federal Emergency Management Agency (FEMA) has adopted the 1 percent annual chance of exceedance (100-year) flood as the standard for identifying special flood hazard areas, and it is within the 100-year floodplain that floodplain management programs are required and provisions for lender notification and mandatory insurance are enforced. FEMA has chosen maps as the mechanism for identification and publication of floodplain and risk information. Flood Hazard Boundary Maps (FHBMs) are used initially to identify special flood hazard areas from approximate information. From priorities set according to a community's existing floodplain development and future development potential, a detailed engineering study is made to establish 100-year flood elevations and assemble risk information necessary for floodplain management and the determination of actuarial flood insurance rates. This information is published on Flood Insurance Rate Maps (FIRMs), which fulfills the second requirement of the act.

Because of the large number of communities (approximately 20,000) identified as having some areas of special flood hazard, the FHBM

program was accelerated to meet statutory deadlines. For the conduct of this mapping effort, FEMA did not provide guidance for evaluation and acceptance of local flood protection works, such as levees, as sufficient for removal of special flood hazard designations. The assessment of a particular protection work was left to the judgment of the agency or consultant who produced the map. In most instances, because of time and cost constraints, levees with crown elevations exceeding estimated 100-year flood levels were credited with providing protection against the 100-year flood. Little or no consideration was given to freeboard requirements, structural stability, or maintenance.

As a result of the Flood Disaster Protection Act of 1973, the mapping to define flood risk zones, called flood insurance studies, was also accelerated. The lack of a specific policy for treating leveed areas carried over into the rate mapping program, and the study contractor's evaluations were made primarily on the basis of a field reconnaissance and a comparison between levee crown elevations and computed 100-year flood levels.

In 1975, following the initiation of a significant number of rate studies, the need for a formal levee policy became more apparent. The Federal Insurance Administration (FIA) began receiving requests from study contractors for guidance in the evaluation of levees. Land developers began requesting FIA to provide standards that levees must meet in order for the special flood hazard designation to be removed from an area. Various groups were constructing 100-year design levees for the sole purpose of freeing property from the floodplain management, lender notification, and insurance purchase requirements under the NFIP. Thus, by crediting levee systems for providing protection against the 100-year flood, FEMA may be indirectly encouraging levee construction to no more than this minimum top elevation standard, with essentially no control on design, construction, operation, inspection, and maintenance.

This situation has generated concern within FEMA for the following significant reasons, as indicated by FEMA:

1. It is estimated that levee overtopping or failure is involved in approximately one-third of all flood disasters.
2. The 100-year flood is generally found to be a low design standard for structures protecting densely populated areas because of the relatively low cost of raising or upgrading the levee compared to the damages that can be prevented.
3. Only a fraction of all earthen levees built with crown elevations at the computed 100-year flood elevation can be expected to provide protection to the true 1 percent event because of (1) the uncertainty involved in establishing flood elevations, (2) changing hydrologic conditions, and (3) the possibility of structural failure before overtopping.
4. The degree of protection to be expected from a 100-year design levee is less than that obtained by elevating individual buildings to the 100-year flood elevation because of the possibility of levee failure during smaller floods and the greater depths of

flooding experienced in unelevated structures upon levee overtopping or failure.

5. Crediting a levee system with protection against the 100-year flood would, under present interim procedures, remove essentially all floodplain management requirements, lender notification requirements, and insurance purchase requirements within the leveed area (provided that flooding from interior drainage did not trigger such requirements). This could violate the spirit of the National Flood Insurance Act by encouraging development in areas subject to major flood damage. It could be financially burdening for the program should the people in the area purchase flood insurance at rates that apply outside special flood hazard areas.

6. Results of the U.S. Army Corps of Engineers nonfederal dam inspection program suggest that a large percentage of private or locally built levees as well as dams are or can be expected to be poorly designed and maintained.

Because of these concerns, FEMA contracted with the National Research Council to recommend provisions for a comprehensive levee policy for use in administering floodplain management, insurance, and risk mapping aspects of the National Flood Insurance Program (NFIP).

## NATIONAL RESEARCH COUNCIL APPROACH AND OBJECTIVES

The Commission on Engineering and Technical Systems of the National Research Council established a committee of recognized experts with experience in hydrologic, hydraulic, and geotechnical engineering; levee and dam design; construction and operation of flood control works; flood plain management; insurance; emergency planning and management; and law. Representatives from federal, state, and local agencies involved in the above areas were also consulted and kept aware of the study's progress as liaison representatives to the committee.

A workshop, held in St. Louis, Missouri, on January 20-23, 1982, brought together the committee and other individuals interested in FEMA's levee policy program. These invited individuals gave their time and experience to assist the committee in sorting out its tasks and gathering additional information. Invitees included persons with varying expertise as regards levees such as emergency preparedness planners, hydrologists, hydraulic engineers, geotechnical engineers, environmental engineers, engineers familiar with Corps of Engineers' practices regarding levee design and construction, and public administrators representing viewpoints of various geographical areas where levees exist. This report was developed from the experience of the committee and the deliberations at the workshop.

The study was structured to address the following five specific task areas identified by FEMA as critical to a levee policy:

1. Minimum design standards (covering level of protection, structural integrity, interior drainage, etc.), for recognition of the levee in the program.

2. The nature and extent of the inspection and evaluation to be conducted by or for FEMA to assure conformance with the minimum design standards at the time a levee is accepted (recognized) in the program.

3. Requirements FEMA should place on communities with recognized levees as to (1) levee system operation, inspection, testing, and maintenance; (2) floodplain management in the protected area; and (3) contingency planning. The first requirement pertains to the agency responsible for the levee; the second and third pertain to communities enrolled in the NFIP.

4. Estimation of risk in areas protected by levees for use in setting insurance rates.

5. Floodplain mapping of levee protected areas to portray special hazard areas, degree of flood risk, and evacuation routes.

## INTERIM FEMA POLICY ON LEVEES

In February 1981 FEMA established an interim policy on levees for the NFIP. This policy and subsequently developed policy criteria are included in Appendix B.

## 2

## COMMITTEE APPROACH TO LEVEE POLICY

In approaching the assignment of formulating recommendations to FEMA on when and how to recognize levees in the National Flood Insurance Program (NFIP), the committee quickly concluded that different answers would be needed for the various measures used by FEMA to reduce flood damages. The process required defining the program components, establishing a levee recognition policy for each one, and justifying the resulting recommendations.

### DIMENSIONS OF LEVEE RECOGNITION

Flood loss mitigation is promoted through the following six basic measures or dimensions that are either direct requirements of or closely associated with the NFIP:

1. Provision of flood insurance at rates guided by actuarial risk
2. Land development and building construction regulation
3. Mandating the purchase of flood insurance in high risk areas
4. Regulation restricting the placement of critical facilities in hazardous locations
5. Notification of flood hazard to occupants of property at risk
6. Contingency planning, including warning and evacuation during floods

While all six measures apply in mitigating flood losses to properties in the 100-year floodplain, none pertain to areas outside the 500-year floodplain. Recognition of a levee by the NFIP is recommended when the levee reduces flood risk to properties behind it to the extent where one or more of these measures would no longer be used. The applicability of the several measures logically varies with level of protection provided by a levee, the structural integrity of the levee, and the property elevation. For example, the recognition of a levee by the NFIP for purposes of reducing insurance rates (from what they would be without levee protection) is logical, but it certainly does not appear advisable to abandon warning and evacuation programs for major floods in levee-protected areas. Once the principle of recognizing a levee for purposes of individually

modifying NFIP activities is established, multiple dimensions of levee recognition are created.

Any levee runs the risk of overtopping and structural failure during floods. Accordingly (based on a reasonable risk before requiring a given activity), a levee may be recognized with respect to none, all, or only selected ones of the above listed measures. The risk of levee failure varies with many characteristics, but the primary variable for purposes of levee recognition must be the flood frequency associated with overtopping. Other levee properties can logically be specified as minimum requirements for reducing structural levee failure to acceptably low levels.

Given overtopping frequency as the primary variable, the frequency to which a levee reduces flooding must be determined before that levee is recognized. Once it has been determined that the levee achieves a minimum required level of protection and should in fact be recognized to some extent, then each of the dimensions can be addressed. The committee concludes that:

1. The dimension in which a levee would logically first be recognized would be that of reducing insurance rates. In selecting the minimum acceptable overtopping exceedance frequency for this purpose, it can be argued that even small levees reduce actuarial risk. At some point, the reduction in actuarial risk becomes large enough to make rate reduction worthwhile.

2. The dimension of land development and building construction regulation should logically be continued to a rarer overtopping frequency. Areas defined by the 100-year floodplain are subject to these regulations where no levees exist. It would be hard to justify dropping this requirement for lands in the 100-year floodplain where they receive a lesser level of protection from levees. One could more logically argue for a rarer frequency criteria behind levees, since levee failures often cause greater damage than equivalent-frequency floods cause to property on the floodplain fringe (where levees don't exist).

3. The dimension of mandatory insurance purchase may logically be continued to an even rarer overtopping frequency (than the annual 1 percent chance flood), because the risk of flooding over a typical home mortgage period (25 to 30 years) can be significant and there is the threat to public funds of having to rescue and financially assist property owners heavily damaged by levee failure.

4. The dimension of prohibiting location of critical facilities may be tied to a still rarer overtopping frequency due to the consequence of disruptions and risks to the community from flooding of these facilities. However, many communities have no reasonable alternate site for the location of such facilities and require provision for exceptions.

5. The dimensions of notification of hazard and of warning-evacuation programs can logically be argued to be continued behind all levees, however rare their overtopping frequency. These minimal cost programs can achieve major benefits by increasing flood hazard awareness--an important NFIP objective.

Based on the above considerations, level of protection criteria need to be set at equal or progressively higher minimum levee sizes for:

1. Reducing insurance rates
2. Dropping land development and building construction regulations
3. Removing mandatory insurance purchase
4. Permitting critical facilities
5. Dropping hazard notification
6. Warning and evacuation planning

Some of the latter dimensions may be desirable behind all levees regardless of size. Engineering criteria need to ensure structural integrity sufficient to keep failure risks other than by overtopping to an acceptably low level.

## RECOGNITION BY PROGRAM DIMENSION

The committee recommendations on level of protection for levee recognition by program dimension are summarized on Table 1 for convenient reference. This tabulation facilitates comparison among the recommendations and assessment of their impact as a whole. Explanations of the recommendations and their justifications are presented in subsequent chapters.

On Table 1, the committee recommendations vary according to the level of protection provided by the levee and frequency of flooding that the land behind the levee would experience without the levee. Recommendations are specified for each element of the NFIP and associated with flood hazard mapping designations. For example, a 25-year levee is required before protected property becomes eligible for reduced insurance rates, whereas a 100-year levee is recognized as sufficient to lift requirements for elevation of residential structures and flood proofing of industrial and commercial structures. A levee must be designed to contain the 500-year flood to remove requirements for flood insurance purchase in the natural 100-year floodplain. Critical facilities should not be allowed in areas behind any levees without demonstrating that there is no practical alternate location.

All occupants of levee protected areas are to be notified of their hazard should the levee fail. Contingency planning, including warning and evacuation, should even consider those outside the natural 500-year floodplain but subject to flooding or isolation by levee failure. The plans should cover warning of impending failure and directing evacuees to safe areas that are not on islands.

## TECHNICAL GUIDANCE FOR SETTING LEVEE POLICY

This report integrates technical considerations with economic and administrative factors in recommending a practical levee-recognition

TABLE 1 DIMENSIONS OF LEVEE RECOGNITION--SUMMARY

| Levee protection level | 0-24 year | 25-99 year* | 100-500 year** | | 500 year** | |
|---|---|---|---|---|---|---|
| Ground elevation compared to flood level | < 100 year | < 100 year | < 100 year | > 100 year | < 100 year | >100 year |
| Zone Designation | A1-A30 | AL | ALP | BLP | BLP | BLP |
| NFIP Action | | | | | | |
| 1 Insurance rates disregard levee | Yes | No | No | No | No | N/A |
| 2 New buildings elevated or floodproofed to 100-year flood level | Yes | Yes | No | N/A | No | N/A |
| 3 Insurance purchase required | Yes | Yes | Yes | No | No | No |
| 4 Critical facilities regulated | - | Yes | Yes | Yes | Yes | Yes |
| 5 Notify residents | - | Yes | Yes | Yes | Yes | Yes |
| 6 Emergency management measures required | - | Yes | Yes | Yes | Yes | Yes |

*New levees constructed to less than the 100-year flood level should not be recognized in the NFIP. Therefore these required/allowed actions are not applicable to new levees.

**Or Standard Project Flood (SPF); a levee designed to pass either the 500-year flood or SPF reflects a conservative design standard. For purposes of this report, no distinction is made.

policy to FEMA. Administrative factors favor the convenience of having very few differentiations by degree of hazard. Economic factors suggest a variation in optimal programs that would require a large number of differentiations according to site hazard characteristics. Technical factors help define a middle ground. It is technical differences in the degree of flood risk which determine whether lumping areas of differing hazard for administrative convenience violates concepts of equity. It is the degree of reliability in technical estimation that determines whether differences along the hazard continuum are significant before applying economic principles to formulate different policies. The goals in the recommendations in this report are to propose policy distinctions when hazard differences can be defended technically but not to encumber the FEMA program with an unwieldy number of different policies that are not based on real technical differences in hazard.

# 3

# ENGINEERING CRITERIA FOR LEVEE RECOGNITION

## GENERAL

This chapter recommends minimum engineering criteria to be used in the evaluation of new or existing levee systems for recognition by the National Flood Insurance Program (NFIP). These criteria will enable FEMA to determine the acceptability of a levee system for recognition as achieving NFIP purposes. In order to be recognized, a levee should be (1) hydraulically able to contain an acceptably large flood and (2) structurally sound when that flood occurs.

The committee considered both causes of failure and a number of factors affecting probabilities for failures of each type. Major among the engineering factors were: level of protection and the hydrologic and hydraulic analyses required to support this level, embankment geometry, seepage control, slope protection, freeboard, closure devices, and interior drainage facilities. Additionally, the committee recognized that a number of institutional and social realities need to be considered in setting levee criteria. Examples are restrictions and requirements of the NFIP statutes, FEMA's fiscal and administrative limitations, socioeconomic implications on affected communities, and the past performances of existing levees during floods.

In general, a levee project can be said to have failed when the area that the project was intended to protect is flooded as a result of water passage across the line of the levee. This failure can occur due to overtopping of flood waters from the riverward side of the levee or from structural failure of the levee owing to piping, erosion, or structural instability. Additionally, a project should be considered to have failed (but with lesser damage) when accessorial facilities (i.e., pipes, pumps, ponds, and valves) fail to prevent flooding from interior drainage. It is believed that the committee's guideline-level criteria encompasses all modes of levee failure.

Since early 1981, FEMA has had an interim policy concerning treatment of levees in the NFIP (see Appendix B). An important feature of this interim policy is a requirement that, to be recognized in the NFIP, a levee must provide protection equal to or exceeding the 1-percent chance of exceedence on an annual basis (100-year) flood with an additional height for freeboard, essentially 3 feet. From the point of view of levee evaluation, the policy is directed at obvious structural deficiencies. The committee reviewed this interim policy

and believes that the interim policy may be overly rigid in some cases and not rigid enough in others.

For the purposes of this report, the committee considered that floodwalls are substitutes for levees and that the criteria applied to levees should, as appropriate, be applied to floodwalls.

## RECOGNITION OF LEVEES IN THE NATIONAL FLOOD INSURANCE PROGRAM

Prior to developing design criteria, one very basic issue had to be addressed by the committee: what levees, if any, should be recognized for purposes of modifying NFIP requirements currently applied to the area protected or to be protected by the levee.

### Existing Levees

Many existing levees have, for a great number of years, provided varying degrees of protection to the occupants of the floodplains behind them. This proven history of successful performance commends these levees for some consideration in the implementation of the NFIP. This recognition should reflect, as nearly as possible, actual degrees of protection provided by the levees. While it is possible that recognition of these levees in the NFIP might encourage additional development, such development would take place in compliance with the provisions of the NFIP.

In the opinion of the committee, existing levees at the 25-year level or higher, plus freeboard, provide, to facilities behind them, sufficient protection to be credited in setting insurance rates within the NFIP. Typically these levees represent substantial engineered construction efforts designed for reasonable structural safety. Often levees built to less than the 25-year level are poorly constructed and have been developed, over time, on an ad hoc basis, with little or no attention having been given to acceptable design criteria. Review of the large number of levees below the 25-year level would involve a major administrative problem for FEMA in handling both the sheer volume and the difficult engineering analyses that would be encountered in evaluating the smaller and, typically, less well engineered levees. The economic and safety returns from bringing such levees into the program would be minimal. Limiting recognition to levees providing a greater degree of protection (e.g., 50 years) would, in the opinion of the committee, be an unnecessary financial burden on communities that have and must continue to pay for carefully engineered levee projects that substantially reduce the average annual flood damages experienced.

The committee recommends:

- Existing levees should be recognized for the purpose of reducing insurance rates where they provide protection against 25-year or larger

floods and where they meet specified structural design criteria, including requisite freeboard.

## New Levees

About 16 percent of the nation's urban land area is located in floodplains susceptible to 100-year floods. Many communities, in fact some entire counties, lie within the floodplains of major rivers, and it would be unreasonable to halt all future development in these areas. When use of the floodplain is necessary to ensure the continued vitality of an area, a feasible and prudent approach may be the use of levees to protect the floodplain areas. Under circumstances where the community lies both within and outside the floodplain, economics will frequently dictate which approach--wise use of the floodplain or construction on higher ground--is more prudent. The NFIP now permits construction in the floodplain when lowest floor elevations are above 100-year flood levels, or, in the case of nonresidential structures, where flood proofing provides for watertight, stable, and nonbouyant buildings. Recognition of new levees provides consistency with this key tenet of the NFIP and permits growth behind appropriately constructed levees.

The 100-year flood has become a widely accepted, applied, and institutionalized standard, and the establishment of the 100-year minimum degree of protection as a standard for new levees would be consistent with the base flood level of the National Flood Insurance Program guidelines. Requiring buildings in the floodplain to have their base elevations at or above the 100-year level is part of the NFIP, and the committee supports this policy. If such a level of protection is appropriate for new buildings, then at least that amount is appropriate as a minimum level of protection for new levees that protect many buildings. A recent survey of state floodplain managers indicates that they generally share this view. Provision of less than 100-year protection would be inconsistent with the thrust of Executive Order 11988 and the NFIP. On the other hand, under certain circumstances, for example in densely urbanized areas containing critical facilities, considerations for loss of life and economics might dictate more than the 100-year level of protection.

The committee recommends:

- New levees should be recognized for the purpose of reducing insurance rates where they provide protection against 100-year or larger floods and where they meet specified structural design criteria including freeboard. All levees on which construction begins after a date to be determined by FEMA should be considered new levees.

A counter argument to this recommendation is contained in Appendix D.

## STRUCTURAL CRITERIA

Once a determination has been made that an existing or proposed levee is eligible, from a level of protection standpoint, for recognition by the NFIP, the structural characteristics of the levee must be evaluated. This section discusses the important considerations, but not the engineering details, in light of the committee's opinion that it is inadvisable in this report to specify engineering criteria in depth. Standard references cover each of the design aspects in extensive detail and should be consulted. Evaluations of the suitability of the engineering of a specific levee must be based on sound technical analyses made by professional engineers skilled in structural, geotechnical, hydrologic, and hydraulic engineering, with specific experience in levee design. Exceptions to the general design criteria discussed below should be permitted only when information presented by professional engineers shows that the risk of flooding will not increase as a result of the exceptions.

The committee recommends:

- All levees (existing and new) to be given credit for reducing flood risk in the NFIP must meet standard minimum engineering criteria with respect to geometric parameters, freeboard, soils and foundations, interior drainage, closure devices, and rights of way.

### Geometric Criteria

Height. The height of a levee or floodwall is the difference between its top elevation and the land surface elevation upon which it is built. The top elevation must be at the design high water level plus an allowance for freeboard.

Top width. The top width of a levee must be capable of supporting one way vehicular (truck) traffic. Appropriate provision must be made for turnarounds.

The top width criteria is necessary to ensure that heavy equipment and personnel can be brought to all parts of the levee during flood fights.

Slopes. The specific slopes used for the embankment on the land and water sides of levees must be determined safe by stability analyses but should not normally be steeper than 1 vertical on 3 horizontal.

Side slopes for earth-fill levees should ordinarily not be steeper than one vertical on three horizontal. In cross section, access ramps should be constructed in addition to, rather than infringing upon, minimum levee side slopes. Some levees with steeper side slopes can satisfy stability analyses and perform satisfactorily. However, experience has shown that flatter side slopes (i.e., less than 1 on 3) are more amenable to proper maintenance.

## Freeboard

Freeboard provides a margin of safety for those situations that cannot be rationally quantified in design flood profile computations. Freeboard requirements should apply equally to floodwalls and levees, since the lack of precision associated with flow line calculations pertains to both floodwalls and levees.

> Both existing and new levees and floodwalls must have a freeboard of 3 feet, or 1 foot plus wave height plus runup, whichever is greater. At bridges and other hydraulic obstructions, additional freeboard may be required. With the presentation of detailed information substantiating the accuracy of the forecast water surface level (e.g., levee next to a lined channel) or where the 3-foot requirement represents a substantial percentage of the levee height, freeboard requirements may be reduced. But, for new construction, in no case should freeboard be less than 2 feet.

The 3 foot freeboard is consistent with that specified by the Corps of Engineers in Engineering Manuals 1110-2-1913 (Design and Construction of Levees) and 1110-2-1601 (Hydraulic Design of Flood Control Structures). These guidelines are only slightly more stringent than those specified for type I structures by the Soil Conservation Service (SCS National Engineering Standard 356-1).

## Soils and Foundations

> Design or construction of any levee or floodwall must be based on use of recognized soil mechanics analyses and techniques. In evaluation of existing levees or floodwalls, site conditions must be investigated by a professional engineer. In determination of the acceptability of plans for new levees, appropriate seepage analyses must be conducted, provisions should be made to accommodate any seepage problems, subsidence should be fully accounted for in design where applicable, and margins of safety should be identified. Designs must provide for adequate vegetative cover or other protection to prevent erosion. All justified penetrations of a levee must be made so as to maintain the

integrity of the levee; however, penetrations should be avoided if at all possible. Appropriate design and construction techniques must be followed to prevent adverse effects of seepage along penetrations through or beneath the levee.

### Interior Drainage

Provisions must be made for interior drainage, i.e., the discharge of runoff from the area on the land side of the levee. If interior drainage flooding can result in loss of life or extensive property damage, protection should be provided against 100-year interior flood conditions. This flood level should be determined based on the joint probability of interior and exterior flooding as estimated by considering the interior hydrograph (including baseflow and seepage through and beneath the levee), the river stage, and the hydraulics of facilities for evacuating the water. The interior drainage system may include storage areas, gravity outlets, pumping plants, or combinations thereof.

These provisions are necessary in view of the high potential for damage created by flooding behind levees during periods when the river stages do not permit gravity flow and the flow into the leveed area exceed what can be discharged through pumps. In many situations interior flooding may be as damaging as flooding from outside the levee.

### Closure Devices

All openings in floodwalls must be provided with appropriately engineered closure devices. Sand bagging of openings should not be allowed.

### Rights of Way

Sufficient rights of way and easements must be provided to accomplish maintenance of the levee and to insure the proper functioning of landside seepage collection or pressure relief systems. Activities on the riverside of the levee must be monitored and appropriate controls must be taken to preclude all activity riverside of the levee that would increase the design high water flow in the area of the levee.

## OTHER FACTORS TO BE CONSIDERED

### Coastal Levee Systems

This document does not provide specific guidance on coastal levee recognition or design. There may be important differences in engineering requirements for coastal levees as compared with riverine levees. For example, differences might be made in the allowance for waves and seepage requirements between a riverine levee, where the water level may remain high for extended periods and the water flows parallel to the levee, as opposed to a coastal levee, where the duration of high waters is limited but the full dynamic impact of waves from the sea strikes the levee perpendicularly. In the design of coastal levees, the engineering criteria should be documented by a professional engineer with justifications for any departures from the engineering criteria for riverine levees.

### Floodwall Design

The design of floodwalls should adhere generally to the applicable criteria provided for levees. In those cases where levee criteria are not applicable (e.g. slope, width, etc.), the design of the floodwall should be in accordance with recognized professional engineering standards for reinforced concrete structures.

### Hydrologic and Hydraulic Analyses

For evaluation of the plans for new levees and the continued soundness of existing levees, FEMA must require the application of standard, scientifically acceptable methodologies accounting for the relevant factors in the computation of discharge frequencies and water surface profiles (as an example with many applications, the HEC-2 "Water Surface Profiles" computer program). It is especially important to consider the possibilities of ice and debris causing higher flood peaks. Further, where circumstances dictate, regional hydraulic analyses of the cumulative effects of construction of several levees on flood flows and stages should be required in order to determine the impacts of the total system of existing levees and/or proposed new levees on levee flow lines. In cases where the 10-, 50-, 100-, and 500-year flood levels have already been determined in the NFIP study for communities, where levees already exist, the committee suggests that FEMA recognize a practical and economical alternative method of determining the level of protection. The existence of these four flood profiles constitutes an adequate base for the development of elevation-frequency curves, and levels of protection can be determined adequately therefrom.

Flood stages for a given flow can change over time due to a variety of factors, and any change will alter the hydrologic risk. FEMA must

be cognizant of these factors as they may drastically affect design levels and the NFIP as a whole. Four cases of change are:

1. Increased land use change that results in increased runoff volumes, shorter times of concentration, and greater peak discharges for events having the same meteorological characteristics.
2. Removal of natural valley storage and conveyance due to excess encroachment in floodplains, including construction of levee systems, resulting in higher stages and discharges.
3. Construction of reservoirs that modify the flows so that historical records cannot be used for current risk assessment without hydrologic reanalysis.
4. Changes to river bed or bank geomorphology or vegetative cover that significantly alter stage-discharge relationships and flood elevations.

An obvious impact of such changes is that levels of protection may change to greater or lesser levels.

The committee recommends:

- FEMA should monitor watershed and channel changes where hydrologic risk is increasing and respond to significant changes with restudies and subsequent map and rate revisions.

Such surveillance can be accomplished as part of FEMA's periodic restudy process, as part of a national monitoring program, perhaps using advanced remote sensing systems, or through reports from federal, state, or local agencies and NFIP participants.

## EXCEPTIONS

In the application of the principles presented in this report, levee proponents may, because of unusual circumstances or advances in technologies or construction techniques, request exceptions to the criteria and guidelines. As with any specifications, there must be cutoff points, and the committee carefully considered each criterion and guideline to ensure that the chosen cutoff points (elevation, slope, etc.) were dictated by sound engineering practice and represented, in the opinion of the committee, the "bottom-line." Since each exception granted becomes a precedent, extreme care must be taken to ensure that all requests are fully documented and well justified and that the precedent-setting impacts of each decision are carefully analysed prior to the decision by FEMA to grant a waiver.

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# LEVEE INSPECTION AND EVALUATION

## CONSIDERATIONS AND RELATIONSHIP TO DESIGN CRITERIA

In order to confirm that a given proposed or existing levee satisfies the requirements for level of protection and structural integrity and should be recognized by the NFIP, FEMA must verify that its criteria have been met. Such a verification process can contribute to reducing the probability of levee failure. However, the committee recognizes that no levee evaluation procedure can be developed that assures that a given levee, new or old, will not fail at less than the stated level of protection. This chapter recommends procedures for reviewing designs, inspecting and evaluating the construction of new levees, and evaluating the effectiveness of existing levees.

In developing its recommendations concerning the initial levee inspection and evaluation the committee took the position that such evaluations should be (1) technically adequate, (2) made with a cost conscious perspective, and (3) administratively and politically realistic. Concerning the first point, the committee does not believe it necessary or desirable for FEMA to develop an engineering organization for assessing technical adequacy. There are adequate professional capabilities within the private sector, civil engineering-oriented agencies of the federal government, and the governments of many states. Concerning the second point, the committee realizes that since many existing levees were built without the application of much, if any, engineering talent, the temptation may exist to exhaustively evaluate them. Although in some critical instances exhaustive subsurface evaluations may be necessary, the committee notes that such evaluations may be difficult to obtain if for no other reason than the high costs involved. In such instances primary reliance will necessarily be placed on prudent engineering judgement. Obviously, no set rule can be made; each site will present unique problems that must be addressed specifically.

Several state-level water resources agencies already have programs for the inspection and evaluation of water resources structures. Where such programs apply also to levees and require procedures at least as restrictive as those recommended in this report, the committee proposes that the states' standards be given precedence.

The interim FEMA policy (Appendix B) on existing levees requires map development contractors to determine that design standards have been met and that a field inspection or "suitable alternative" be performed to verify that levees appear structurally sound and adequately maintained. Certification from a federal or state agency or a professional engineer that these standards are met may be acceptable in lieu of an actual site-specific inspection by the

contractor. The committee concurs in principle with this interim policy, but feels that more detailed guidance is required and that procedures for existing and new levees should differ markedly, particularly since the committee is recommending a lower credible design level for existing levees than is allowed under current policy. Development of a detailed inspection manual may be required.

## INSPECTION AND EVALUATION PROCEDURES FOR NEW LEVEES

The evaluation of design and construction quality in conformance with the standards delineated in Chapter 3 requires the services of a professional engineer competent in hydrologic, hydraulic, structural, and geotechnical engineering and with specific experience in levee design. Designs must be prepared to meet or exceed NFIP standards. During construction, on-site inspections must confirm that the levee is built according to the approved plans and specifications.

Since many levees with which this report is concerned exist or would be built along waterways where the federal government already has major responsibilities for levees, it would appear prudent for FEMA to investigate the possibility of using the expertise of the agencies involved to assure that FEMA's design evaluation and construction quality standards are met. Consideration should also be given to state involvement where water resources agencies are capable of undertaking the work. Should these options not be practical, it is appropriate for FEMA to use private engineering firms for evaluation of both design and construction conformance.

The committee deliberated at great length on the question of engineer qualifications. The committee believes that no verification of qualifications is necessary should federal or state agencies accept the work. Where private sector firms are involved, however, the committee concluded that the best results could be obtained if first priority were given to the use of firms having experience in levee work. Although some local political entities responsible for levees have engineers on their staffs, the committee does not believe it generally desirable for those engineers to be responsible for the review of their own work.

The committee recommends:

- In its administration of design evaluations and construction conformance inspections, FEMA should first pursue the possibility of using the services of federal agencies having water resources experience. Where federal participation can not be arranged, FEMA must use state agencies and private sector capabilities.

## INSPECTION AND EVALUATION PROCEDURES FOR EXISTING LEVEES

Many existing federal and state levees have been built consistent with the recommended design and construction criteria. The agencies

that designed and constructed those levees also periodically inspect the condition of the ones still under their control. In some instances, however, responsibility for the completed levees was assigned to local authorities for operation and maintenance; and there is much less assurance they have been acceptably maintained.

Concerning levees that have been continuously maintained by the federal or state agency that designed and constructed them, the committee sees no need for independent evaluations. A statement from the agency concerned attesting to the adequacy of those levees should suffice. For levees that were built by federal or state forces and assigned to local entities for operation and maintenance, however, the committee believes independent evaluations are necessary as project conditions may have changed considerably since the assignment.

Individuals needing information concerning levees may wish to check with state floodplain agencies. Those agencies may have data answering some of the evaluation questions. They must be checked before FEMA approves plans for a levee to ensure that any state requirements more restrictive than FEMA's have been met.

The committee recommends:

- Where responsible federal or state agencies have had continuous maintenance responsibilities on levees they designed and constructed, and will attest to their adequacy under FEMA standards, independent evaluations should not usually be required. Evaluations should be required, however, on levees that were designed and constructed by federal agencies but are currently being operated and maintained by others.
- Where a federal or state agency does not evaluate a levee, levee evaluations should be done by "levee evaluation contractors" (LECs), private consulting firms designated by FEMA.

LECs could be selected from a list of firms that have submitted evidence that they are competent and capable of performing the required work, according to appropriate contract selection rules. The number of LECs on hand would, of course, be determined by work load, but at least one would be available per FEMA (standard federal) region; contracts could change periodically. FEMA may want to establish an interagency LEC evaluation panel to facilitate the LEC selection process and to plan training for new LECs.

The committee recommends:

- While FEMA should designate qualified private consulting firms to be LECs, the firms should work under contract to an applicant interested in having a levee evaluated for recognition by FEMA. All costs of the LECs' work should be borne by the applicant.

In most cases it will be to the applicant's financial benefit to have a levee recognized by FEMA. Therefore, the cost of the levee evaluation should be borne by the applicant and not by the general taxpayer through FEMA. This process is similar to NFIP procedures for changing flood insurance maps to reflect new data or the impacts of new flood control structures.

In the case of existing levees, the Flood Insurance Study process may or may not have already given a levee credit as providing protection from the 100-year flood. The two cases need to be handled differently.

## Previously Unrecognized Levees

The committee's recommendation that existing levees providing protection against a flood at or exceeding the 25-year level (plus freeboard) be credited for the purpose of reducing insurance rates departs from current FEMA policy. In these situations the beneficiaries have an economic incentive to have their levee recognized and should have the responsibility to initiate and pay for the inspection and evaluation, including the retention of engineering services.

The committee recommends:

- Since recognition of 25-year levees for the purpose of reducing insurance rates would represent an important change in federal policy, FEMA should publicize the benefits, costs, and procedural details for levee recognition.

The inspection and evaluation for existing levees is complicated by the fact that conditions within levees are concealed from view, the levees may have been in place for decades, and construction may have had many raising and repair stages. It is important that the original plans, as built drawings, boring logs, profiles, and records of operation and maintenance and past experiences in floods be reviewed. There are no substitute optical or visual means for looking beneath the earth surface into the interior or beneath the bottom of a levee. Test drilling and other new methods can sample subsurface conditions, but the percentage of area actually covered, at best, is generally far less than a fraction of 1 percent of the totals. Test drilling, sampling, and evaluation are valuable for investigating subsurface conditions and are important tools for evaluating existing conditions. Soil borings should be made sufficiently close together to provide a reasonable representation of subsurface conditions.

Following completion of the inspection, the LEC (or other responsible entity) would submit a report to the applicant, who then would have the option of submitting the report to FEMA for zone designation and map amendments. All costs would be borne by the applicant. Once the completed report is submitted, FEMA would finance

the review of the report and the costs of publishing and distributing a revised map. This procedure is essentially the same as the current map revision procedure.

### Previously Recognized Levees

The committee recommends:

- FEMA should inventory all levees previously credited as providing protection from the 100-year flood, set priorities, and schedule communities for restudy to reevaluate the levees.

Communities with levees credited with removing areas from the 100-year floodplain should have those levees restudied to ensure that the levees meet adopted hydrologic and engineering criteria. Because most levees (particularly those built by federal agencies to protect large urban areas) are expected to still prove adequate and because there are limited funds for restudies, a priority list should be developed.

The following criteria should be used in setting priorities for communities to be restudied:

1. If the levee was designed, built, or maintained by a private organization.
2. If there has been significant tributary catchment urbanization, floodplain encroachment, or other development that would increase flood heights along the levee since the original study.
3. If the levee protects a large population or critical facilities.

The committee recommends:

- FEMA should develop a short and simple checklist that can be used to make a quick assessment of whether a levee meets recommended criteria.

Such a checklist would be used by a flood insurance restudy contractor paid by FEMA to make a quick check of each levee's condition. The checklist should cover slope, maintenance, and top elevation (to determine settling). It would not include subsurface exploration or other time consuming investigations. The restudy contractor would separate those communities with levees that appear to be clearly in good shape from those in bad or doubtful shape.

When the restudy contractor finds a levee in doubtful or bad shape, he will inform FEMA who will notify the community that the levee cannot be considered adequate for protecting against the 100-year flood. The community may either contract and pay for a thorough

evaluation, as described in the previous section, or accept the fact that the levee will no longer be recognized by FEMA. If the community cannot show that the levee is still adequate, the area behind it will be mapped as 100-year floodplain (A1-A30 Zone).

This expedites review of previously recognized levees. Levees requiring the greatest and earliest attention should be studied first, and FEMA would finance the preliminary studies to determine if an earlier FEMA decision should be changed. The community would not be required to pay for this preliminary study unless an on-site check gave FEMA reasonable belief that the levee should no longer be considered adequate. Community officials would, of course, be given the usual opportunities for review, consultation, and appeal of the restudy conclusions.

## OPERATION AND MAINTENANCE EVALUATION

The evaluator should review the current operation and maintenance plan and actual activity in the context of the operation and maintenance needs of the levee. Criteria for operation and maintenance should be consistent with those (see Chapter 5) required of levee owners for continued levee recognition. The same evaluator certifying the levee's design and construction would ordinarily also evaluate the operation and maintenance practices of the levee owner. FEMA should not recognize any levee unless it is properly operated and maintained. Failure to do so would be cause for redesignating the area behind the levee as not protected.

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# REQUIREMENTS OF LEVEE OWNERS

## GENERAL

Most riverine levees are operated by a levee district or some other special or general local government. Often levees protect two or more communities and are the responsibility of jurisdictions other than the protected communities. This chapter recommends operation and maintenance criteria that FEMA should require of levee owners for continued NFIP levee recognition. These requirements are aimed at assuring that the levees continue to provide their credited level of protection by having a top elevation higher than the crest of the flood of credited exceedance frequency (plus the required freeboard) and by being able to structurally withstand that flood.

## OPERATION AND MAINTENANCE GOALS

In formulating operation and maintenance (O&M) recommendations, the committee considered inspection procedures and intervals, operating plans, maintenance plans, assignment of responsibilities, and the nature and frequency of reporting on compliance and testing. The starting points were FEMA's interim policy on O&M and a detailed critique and evaluation of the appropriateness of Federal Code 208.10, Title 33, "Local flood protection works; maintenance and operation of structures and facilities," as a guide for NFIP requirements on this subject.

Quality operation and maintenance are as necessary to good performance as proper design and construction. In the case of flood protection projects, maintenance is particularly important, because these structures are subject to deterioration between flood events and may go many years without experiencing floods anywhere near the magnitude of that for which they are designed. In floodplain areas protected by levees, two possibly independent causes of flooding exist--(1) external or riverine flooding and (2) flooding from interior drainage behind the levee. Typically, a levee system has, in addition to its distinctive earth embankment or concrete floodwall, street-gate closures, pumping and gravity drainage facilities, subsurface pressure relief well systems, and internal ponding areas. The earth embankment and all its design features require maintenance to minimize settlement and deterioration and to assure the integrity

of its mass, internal materials, its foundation, and vegetated and/or rock-protected surfaces against the forces of seepage or flowing water. Closure and drainage facilities require service, testing, and competent operating personnel to assure their proper operation in flood situations. Well-documented operating plans and frequent operating practice drills are of great importance, considering personnel turnovers that occur over the years between major floods and the fact that real operations will occur during periods of adverse weather fraught with poor communication and transportation situations. The failure of a single street-gate mechanism or pumping station or a single weak, eroded, or gullied spot in an embankment may render an entire levee system ineffective. Engineers and managers of public works programs are generally conscious of the importance of proper operation and maintenance. Budget officials responsible for public works appropriations must be kept continually aware of the importance of proper levee system operation and maintenance for levee design levels to be realized in flood situations.

FEMA's interim policy on levees (Appendix B) addresses maintenance in general terms, in that a credited levee must be adequately maintained. The interim policy is quite specific on the subject of human intervention and operation of closures. FEMA does not and should not recognize human intervention (sandbagging, emergency earth fill, etc.) during a flood event for the purpose of increasing a levee's design level of protection. Human intervention is recognized where closure structures, such as street gates and stop logs, are integral parts of the system design, where locally mandated by a formal operating plan, and where flood warning times are sufficient to permit placement. FEMA further requires annual testing of closure structures and regular training of operating personnel. Finally, compliance with these requirements must be demonstrated and accepted by FEMA.

The committee recommends:

- FEMA should confirm its interim policy that does not recognize sand bags on top of levees and other types of human intervention, except for structural closures which are legitimate parts of planned levee systems, as augmenting a levee system's design level of protection.

This recommendation should not, of course, be interpreted to mean that human intervention should not be encouraged in fighting floods that exceed a levee's design level of protection.

## RECOMMENDED OPERATION AND MAINTENANCE GUIDELINES

Construction of levee systems has been a significant component of the Corps of Engineers Civil Works Program for many years. The Corps has constructed about 10,500 miles of levees and floodwalls, most of which have been assigned to nonfederal sponsors following construction

for operation and maintenance. A few of these systems have failed during floods--mostly from overtopping. Failures of Corps-built levees attributable to operation and maintenance deficiencies have been minimal. Communities responsible for Corps-constructed levee systems use Federal Code 208.10, Title 33, as a guideline for operation and maintenance; and, owing to the apparent successful results of its application, the committee began by reviewing this document but recommends modifications of those regulations for NFIP application. These guidelines, as modified by the committee, are presented as Appendix C.

The committee recommends:

- Federal Code 208.10, Title 33, "Local flood protection works; maintenance and operation of facilities," should be modified where not well suited, supplemented for interior drainage, and adopted by FEMA as a guideline for operation and maintenance of levee systems.
- A specific operation and maintenance plan, tailored to local needs, must be formally adopted by the levee owner for a levee to be credited and continue to be credited in the NFIP.

## OPERATION AND MAINTENANCE INSPECTION

Both property owners and the federal government, if it is insuring the property, have the right to assurance from the levee owners that the structural systems protecting flood-prone property will be inspected, maintained, and operated in the way intended at the time they were accepted into the National Flood Insurance Program.

The committee recommends:

- The operation and maintenance plan must provide for periodic inspections. The plan should be completed within a designated time period, meet the requirements of, and be acceptable to FEMA. Each inspection must be by a professional engineer retained by the levee owner and registered in the state in which the levee is located. A written report to the levee owner must be promptly prepared and certified by the professional engineer making the inspection. The report should specifically describe items found deficient and emerging potential future problem areas. Copies of the certified report should be sent by the certifying professional engineer to the regional FEMA office. Also, a copy should be provided to the local political entities which

have responsibilities to FEMA for the levee-protected area. FEMA should follow up to assure corrections are made within a reasonable length of time. In instances where corrections are not made to critical deficiencies, FEMA should withdraw recognition of the levee.

# 6

# REQUIREMENTS OF LOCAL COMMUNITIES

Floodplain regulation, notification of residents, predisaster warning, and evacuation planning are responsibilities of local communities, generally cities and counties. This chapter recommends management and planning activities that FEMA should require of those communities to be eligible for the recommended recognitions for levee-protected areas.

## FLOODPLAIN REGULATIONS

Levee construction supports urban development in the floodplain by reducing average annual damages to highways, airports, shopping centers, industrial plants, and single- and multifamily housing. However, it is short-sighted and foolish to regard even the most reliable levee system as fail-safe. Floods exceeding the design stage will occur periodically. Structural failure or overtopping can also be associated with poor maintenance, temporary damming caused by debris accumulation at a downstream bridge opening, or human error in the operation of pumps and levee closures. Consequently, developments in levee-protected areas are still vulnerable to flood damages. Therefore, it is important that FEMA's policy on levees include requirements for floodplain regulations commensurate with the residual risk. It is also important that actual implementation of the programs be compatible with the objectives of the National Flood Insurance Program. Specifically, with respect to floodplain management formal agreements between the political entity (community) having responsibility for local land use control and the FEMA may be desirable.

Floodplain regulation includes certain land-use management and building construction provisions which FEMA may require of communities to minimize the exposure of occupants of levee-protected areas to the probability of flooding. The committee's recommendations are made in a broad sense and do not address details such as construction methods, flood-proofing techniques, etc. that have been developed and generally adopted for flood-prone lands not protected by levees. Numerous documents are available on this general topic.

Section 60.3C of the NFIP Rules and Regulations (44 CFR, Parts 59 and 60) lists current requirements for protecting new construction from flood damage. Residential buildings must be elevated above the 100-year flood level, and nonresidential buildings must be elevated above or flood-proofed to the 100-year flood level. These rules should be enforced in all areas behind levees that are not judged adequate for containing the 100-year flood (A1-A30 and AL zones). A minority opinion on this topic is in Appendix D.

The committee recommends:

- FEMA should require the elevation of new residential structures and the elevation or flood-proofing of other new buildings in all areas protected by levees unable to contain the 100-year flood (see Table 1).

On the other hand, the committee believes that buildings protected by 100-year or greater levees need not be elevated, other than as necessary to be above the 100-year flood associated with interior drainage flooding and ponding. The majority of the committee feels that levees meeting the engineering criteria (including freeboard) delineated in Chapter 3 and the operation and maintenance criteria of Chapter 5 provide sufficient protection so that building elevation or flood-proofing need not be mandatory. To require elevating these buildings (some places by as much as 20 feet) would be too severe, given the fact that FEMA does not require protection of new buildings in other areas not subject to the 100-year flood level. Such a new requirement may pose a financial burden to individuals and communities, would in many cases cause communities to withdraw from the NFIP and could thus be counterproductive to flood loss reduction goals. Implementation of initiatives by FEMA to effect insurance rates that reflect actuarial risk to all properties, including those in levee-protected areas, would reduce the financial burden to the general taxpayer, and required contingency planning should provide occupant safety. However, it is critical, before accepting an area behind such a levee as indeed secure at the 100-year level of protection, that checks be made of the entire levee system with respect to design standards, and adequate operation and maintenance and that the 100-year flood stage has not changed so as to threaten levee safety. Appendix D contains a counter argument for elevating or flood-proofing buildings in these areas but considered by the majority of the committee as less persuasive.

## FLOOD INSURANCE PURCHASE

The committee recommends:

- FEMA should require purchase of flood insurance in all areas where the ground is lower than the unconfined 100-year flood level

except where protected by a levee built to contain the 500-year flood (see Table 1).

Areas within the natural floodplain behind a greater-than-100-year levee are presently designated Zone B under the FEMA Interim Levee Policy. This classification removes such areas from mandatory-flood insurance purchase under Section 102 of the Flood Disaster Protection Act of 1973. Zone B designation also removes such areas from application of floodplain management restriction under NFIP (although state and local authorities may regulate such areas independently of NFIP). However, the commitee views all levees as potentially subject to failure, due to floods exceeding their design capacities, inherent uncertainties in design and construction, undetected deterioration, or human error in operation. Consequently it is recommended that flood insurance purchase be mandatory in the 100-year natural floodplain in areas behind levees unable to contain the 500-year flood. This would reinforce public recognition that such areas are only artificially removed from natural floodplains. This position is further based on the following considerations:

1. For levee systems the combined risk from hydrologic and geotechnical factors can not be quantified with the precision common to other familiar engineered structures and therefore is not entirely accounted for in the stated level of protection.
2. In event of overtopping or other levee failure, substantial loss will result. Insurance coverage for the damaged property will reduce disaster relief and tax write-off costs to the federal government.
3. Mandatory purchase and renewal of insurance serve as an annual notification to property owners that their property is in a natural floodplain and subject to catastrophic flooding.
4. Actuarial rates in areas behind a 100-year-plus levee would be low, because of the infrequency of flooding, thus not posing an unreasonable burden on the property owners.

The committee's recommendation for mandatory purchase of flood insurance contrasts with its position on floodplain regulations in these areas. The committee believes that some restriction or reminder of danger is advisable for such lands because the risk of major damage over the life of a typical mortgage is considerable. Less economic burden is imposed in requiring insurance purchase than in requiring elevating residences and flood proofing other buildings. Additionally, floodplain restrictions can be imposed by state and local governments, whereas insurance purchase requirements cannot.

Since property on ground higher than the 100-year flood level and property protected by a 500-year flood levee are safe from the 100-year flood, an insurance purchase requirement for buildings in such areas would exceed established NFIP policy. Furthermore, with implementation of the recommendations of this report, residents of those areas will still be notified that they could be flooded in the

event of levee failure, and insurance is always available for them. Counter arguments on this subject are in Appendix D.

## CRITICAL FACILITIES

Executive Order 11988 limits approval of critical facilities in 500-year floodplains to situations in which certain steps have been followed to assure that there is no practical alternative. A "critical facility" is defined as any facility, from a hospital to a natural gas terminal, whose flooding and discontinuity of service would create untoward hardship and/or danger for the community as a whole. FEMA, as a federal agency, should seek to amend Section 60.3 to comply with the Executive Order. FEMA should require regulation of critical facilities in areas protected by levees where the ground is lower than the 500-year flood level. These regulations should prohibit critical facilities (not already regulated by some higher level of government) unless there is no practical alternative and should clearly delineate that the assurances required to demonstrate that there is no practical alternative (placement outside the 500-year floodplain would be prohibitively costly or even greater hardship for the community being served) and the flood-proofing provisions made.

The committee recommends:

- Communities should regulate the placement of critical facilities (not regulated by some higher level of government) in all leveed areas in accordance with the procedures of Executive Order 11988 (see Table 1).

## NOTICE TO RESIDENTS

Areas protected from flooding by levees should be displayed on the various NFIP maps and designated as such using procedures set forth in Chapter 9.

The committee recommends:

- Owners, tenants, and lenders occupying areas designated as protected by levees should be notified periodically by responsible local officials that their land in the levee-protected area is still subject to flooding in the event of levee failure (see Table 1).

It is believed that this would be a good policy with even the safest of levees. The notification should contain information on the availability and cost of flood insurance, floodplain management regulations, and evacuation routes.

There is currently no procedure to tell residents that they are in a floodplain. The current procedure for advising people of a property's flood hazard is implemented by lending agencies only at the time of a mortgage, home improvement loan, or federal disaster assistance. This procedure does not help renters or people who have lived in the area for a long time. NFIP maps must designate the areas as "A Zones" for the lenders to become involved. Therefore, the above new procedure is recommended.

When FEMA informs a community that its maps are being reevaluated with respect to recognition of levee protection levels according to the new criteria, FEMA should also advise the community of the requirement for notification to residents. Compliance would be checked as part of the annual O&M certification. Communities should be given reasonable flexibility in timing and designing their notification program. Regional FEMA offices and state NFIP coordinators are urged to cooperate in preparing model programs.

## ADOPTION OF A PREDISASTER WARNING AND EVACUATION PLAN

The committee recommends:

- Local officials of any NFIP participating community protected by a levee, regardless of its size and reliability, should prepare and promulgate an action plan for warning and evacuation in the event of levee failure.

The warning and evacuation plan to satisfy this recommended FEMA requirement must alert a community's populace that conditions which could cause levee failure are developing, provide warning to people in the area behind the levee should failure become imminent, identify evacuation routes and police procedures for expediting evacuation, arrange temporary shelter and food for evacuees, and assure the maintenance of law and order in the flooded area. The plan should reflect local conditions and needs; it is particularly important that the right audience be identified and that information be communicated in a clear and credible fashion. The program should be designed to encourage social reinforcement at the local level.

Warning and evacuation plans should provide information at various levels of danger, for example: when water surfaces reach levee base elevations, when overtopping appears inevitable, and when overtopping/breaching has occurred. The probable potential rate of levee failure and water movement through the floodplain are important and should be estimated because they have a bearing on the development of alternate evacuation routes.

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# LIABILITY OF LOCAL GOVERNMENTS AND LEVEE DISTRICTS CONCERNING LEVEE MAINTENANCE AND FLOODPLAIN MANAGEMENT

## DISCUSSION

Chapters 5 and 6 recommend requirements to be placed on levee owners and protected communities for levee operation and maintenance and for floodplain management, respectively. It is obviously very difficult for FEMA to "police" the performance of levee districts and local governments in fulfilling these responsibilities. In the event a levee is overtopped or breached, however, potential liability may be imposed by victims against responsible local authorities who neglected to perform duties with respect to levee maintenance or floodplain management. This chapter reviews relevant legal doctrines and issues pertaining to the liability of nonfederal flood control agencies for flood-related losses. It is suggested that minimizing the possibility of liability awards to floodplain occupants or to FEMA itself to recoup flood costs is a potentially useful tool for promoting national flood loss reduction objectives within the local communities.

Adoption by municipal governments of a program of constructing flood control levees raises questions of potential liability for any flood damages that result from improper design or maintenance of such systems. Where local government implements flood control measures, they become potentially liable for "misfeasance" or negligence in the design or upkeep of installed facilities. While the probability of being held liable is somewhat less, they also become potentially liable for "nonfeasance" in shirking their assumed damage reduction responsibilities by not providing needed facilities. They are also potentially liable should flooding result from a specific public project such as water ponded behind an undersized or blocked culvert beneath a new highway.

In the past, the liability of municipal corporations for harm resulting from the negligence of their employees was limited by the doctrine of sovereign immunity. Under this doctrine, municipal governments were frequently shielded from liability on the ground that they were agents of the state and as such could not be sued in the state's courts without giving their permission. As the activities of municipal governments increased in complexity during the early twentieth century, this doctrine became viewed as inflicting hardship upon victims of municipal negligence. A major qualification evolved under which municipal functions were viewed as being either "governmental" or "proprietary" according to their nature. Matters

that were viewed as strictly governmental, in which the municipality acted strictly as an agent of the state, were held to be still subject to the protection of sovereign immunity. Other functions that the municipality undertook in its corporate capacity and on a discretionary basis were considered not to be covered by the sovereign immunity doctrine. 18 McQuillin, Municipal Corporations, Section 53.23 (3rd ed. 1971).

The governmental-proprietary distinction naturally requires clarification as to the status of particular activities. Police and fire protection generally qualified as governmental, while such activities as garbage collection, recreation programs, and libraries have usually been viewed as proprietary. The status of flood control and drainage activities has also been held to be proprietary in certain jurisdictions. In Krantz v. City of Hutchinson, 196 P.2d 227 (Kans., 1948), the construction of an emergency flood control dike by the defendant outside its corporate limits was held to be proprietary:

> Having regard to the fundamental basis upon which the distinction between governmental and proprietary functions is based, we are unable to say that the acts of the city officials here complained of were in furtherance of a governmental function. They were not acts performed as an agency of the state, expressive of its sovereignty. They were not performed in promotion of the public welfare generally. They were performed for the special financial benefit of the city and its property, and of its property owners. That was the controlling consideration. The acts were essentially transactions by and for the city in its individual corporate capacity.

Plaintiffs accordingly recovered damages for flooding of their land attributable to the emergency dike. This case, it should be noted, could well have been decided to the contrary, that emergency flood control is a governmental power and that the municipality should not be liable. Strictly speaking, Krantz did not involve negligence, but rather a "taking" of a flood drainage easement without payment of compensation. Ponding of flood waters upon private land through artificial devices gives rise to liability as a "taking" of private land for public use without just compensation in violation of the Fifth Amendment to the U.S. Constitution. Baker v. Planning Board of Framingham, 228 N.E.2d 831 (Mass., 1967).

The governmental-proprietary distinction has been eroded in practice due to the irrational and unjust results of its strict application in many cases. Many states by statute or case law have abrogated the doctrine in favor of a broader scope of municipal liability to those suffering harm as a result of public actions. Recent decisions involving flood and drainage considerations do not generally discuss the distinction but turn immediately to the question of "proximate cause" of the harm, e.g., did the action of the municipality cause the harm suffered by the plaintiff. In Ingram v. City of Redondo Beach, 119 Cal. Rptr. 688 (1975), plaintiffs suffered

flood damage as a result of the collapse of "an earthen retaining wall of a drainage sump" constructed and maintained by the defendant city. The defendant maintained that the cause of the damage was an extraordinary rainstorm that exceeded the design capacity of the facility in question. The court held that "in the absence of some other reason, inverse condemnation liability should normally follow" from the failure of defendant's structure, citing Sheffet v. County of Los Angeles, 84 Cal. Rptr. 11 (1970). The matter was remanded to the trial court to determine "the proximate cause" of the damage.

Another recent California decision, Carlotto Ltd. v. County of Ventura, 121 Cal. Rptr. 171 (1975), involved the failure of defendant's "debris dam" during a heavy rainstorm. The defendant county had failed to maintain its debris basin behind the dam with the result that only 2.5 acre feet of its original 12.7 acre feet of water storage capacity remained at the time of the storm. The trial court held the county liable for negligence to the extent of 12.1 percent of the plaintiff's proven damages, according to the court's estimate of the increased flooding due to clogging of the debris basin. The liability of the county was upheld on appeal but the trial court's formula for apportionment was reversed with the case remanded for further findings on the degree of fault on the part of the county.

A Colorado case, Barr v. Game Fish and Parks Commissioner of Colorado, 497 P.2d 340 (1972), rejected the defense that failure of a dam was due to an "act of God" in the form of extraordinary rainfall. The court held that the dam was improperly designed for the "maximum probable flood," which the defendant should have foreseen. Quoting Baum v. County of Scotts Bluff, 109 N.W.2d 295 (1964):

> In order for a flood to come within the term act of God, it must have been so unusual and extraordinary a manifestation of nature as could not under normal conditions have been reasonably anticipated or expected. . . . An act of God does not necessarily mean an operation of natural forces so violent and unexpected that no human foresight or skill could possibly have prevented its effect. It is enough that the flooding should be such as human foresight could not be reasonably expected to anticipate and whether it comes within this description is ordinarily a question of fact. (Emphasis supplied by the Barr court)

Improper maintenance of levees was specifically addressed in a recent federal decision, Florida East Coast Railway Company v. U.S. v. Central and Southern Florida Flood Control District et al., 519 F.2d 1184 (U.S. Court of Appeals, 5th Circuit, 1975). This case involved flood damage to plaintiff's railroad right of way on two occasions due to failure of a flood control levee designed and constructed by the Corps of Engineers and owned and operated by the defendant flood control district. The court held the federal government to be immune to liability under Section 702c of the Flood Control Act of 1928, which states:

> No liability of any kind shall attach to or rest upon the United States for any damage from or by floods or flood waters at any place.

Citing Stover v. U.S., 332 F.2D 204 (9th Circuit, 1968), cert. den. 85 S. Ct. 276 (1964), the court-rejected the contention that the immunity exempted surface water artificially collected and impounded as distinct from natural flow.

Despite the immunity of the federal government, the flood control district was held liable for its participation in the project:

> Although the Corps had primary responsibility for the design of the project, the trial judge found that the Flood Control District worked closely with the Corps in the planning stages. The Flood Control District, . . . "reviewed in detail, and commented on the General Design Memorandum . . . , the Detailed Design Memorandum . . . and the Project Plans and Specifications. It was responsible for alignment of the project. The Flood Control District also provided advice and assistance to the Corps with regard to the actual construction of the project." In addition the Flood Control District furnished 15 percent of the funds for completing the undertaking.

It was further found that after an initial washout in 1969, " . . . neither the Flood Control District nor the Corps warned the railroad or took steps necessary to correct the defects." A second washout in 1970 caused $438,000 of damage to the plantiff. The flood control district was accordingly found liable:

> . . . for permitting the construction of a nuisance on its land and for trespass by reason of the rapid runoff of water it had caused. It was also held liable for negligence as owner of failure to assure that the project was properly designed, constructed and operated, and vicariously as a joint venturer with the Corps. These grounds of liability were upheld on appeal.

The preceding cases have each involved liability to flood victims arising from improper design or maintenance of local flood control facilities. A potential new specter of liability has appeared in a suit filed in 1981 by the Federal Emergency Management Agency (FEMA) in the Federal District Court for the Eastern District of Louisiana against two parishes, four levee districts, and several private developers. The purpose of the suit is to recover some $91 million in flood insurance payments by FEMA to persons suffering flood damage allegedly as a result of the collective negligence of the defendants in operating and maintaining flood control and drainage facilities. As of March, 1982, this suit is still in its early stages with no results to date.

A final question to be discussed here involves the potential liability of a municipal body for approving and/or participating in private development, which causes increased flooding. Until recently, municipalities were generally not held liable for wrongfully issuing building permits, failing to enforce an ordinance, or approving defective subdivision plans that led to subsequent flood damage. Breiner v. C and P Home Builders, Inc., 536 F.2d 27 (3rd Circuit, 1976). However, two recent state decisions have held local governments liable where they closely participated in or encouraged the private development process that altered natural flooding patterns. In County of Clark v. Powers, 611 P.2d 1072 (Nev., 1980), a county and a flood control district were held liable for flood damages resulting from private development that caused greater surface runoff across defendant's land. Although no local flood control project was involved, the court found that:

> The County participated actively in the development of these lands, both by its own planning, design, engineering, and construction activities and by its adoption of the similar activities of various private developers as part of the County's master plan for the drainage and flood control of the area.

The court went on to find that:

> . . . the economic costs incident to the expulsion of surface waters in the transformation of rural and semi-rural areas into urban and suburban communities should not be borne solely by adjoining land owners.

A similar conclusion was reached by the Ohio Court of Appeals in Myotte v. Village of Mayfield, 375 N.E.2d 816 (1977). In this case, the plaintiff homeowner experienced increased flooding as a result of an inadequate sewer pipe crossing her property conveying surface runoff from a newly constructed industrial park. The village was held liable for its role in approving the industrial park and for failure to expand the drainage pipe. The court found specifically that:

> The Village of Mayfield had repeatedly been made aware of the recurring flooding of the Myotte property, and it even took limited measures towards improving the flood situation by approving the additional 42-inch pipes for the storm sewer system. However, the Village failed to implement a real solution to the flooding problem, such as widening the existing water course on the Myotte property so that the increased flow of water from the industrial park would be accommodated. Such a solution would represent a relatively small cost to the Village, especially in light of the tax income which it receives from the industrial park, and in contrast to the serious harm caused to the market value of Mrs. Myotte's land if the flooding persists.

## CONCLUSION

The foregoing cases suggest that courts are (1) becoming more sophisticated in their handling of flood and drainage problems, and (2) displaying greater sympathy for the plight of land owners subjected to increased flooding by virtue of municipal negligence. Some of these cases turn on the question of actual operation and maintenance of a drainage or flood control structure (Ingram, Carlotto Ltd., and Florida East Coast Railway Company). Others involve "taking" of plaintiff's land for a drainage easement without compensation (Krantz, Baker, and Myotte). In at least two cases, the courts rejected defendant's claim that the blame should be attributed to other parties, e.g., the federal government (Florida East Coast Railway Company) or private developers (County of Clark). Furthermore, courts have rejected that defense that damage arose due to "an act of God" (Barr) or that the defendant's actions were not the "proximate cause" of the damage (Ingram and Carlotto Ltd.).

It is therefore apparent that civil liability for flood damages is becoming increasingly important as a tool by which local governments and special districts may be compelled to design and operate flood control and drainage facilities properly and to administer their other corporate powers in accordance with hydrologic realities.

The committee recommends:

- FEMA should help make local governments and special districts aware of the possibility of liability for actions or nonactions that aggravate flood hazards.
- FEMA should, in appropriate cases, seek to recoup federal flood-related costs (including flood insurance payments, disaster assistance, etc.) from levee owners/operators when such costs arise from improper operation and maintenance of levee and associated interior drainage facilities.

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# TREATMENT OF LEVEES IN THE INSURANCE ASPECTS OF THE NFIP

## DISCUSSION AND RECOMMENDED APPROACH

Currently, the crediting of levees for setting flood insurance premiums is based strictly on the level of protection provided, with the 100-year flood level being the dividing line between "all or nothing" credit. For properties behind a levee equal to or higher than the crest of the 100-year flood, no premium is added (accounting for hydrologic uncertainties or the possibility of structural failure during lesser events) to the basic rate charged insurees outside a marked floodplain. Conversely, insurees behind levees failing to meet the benchmark level of protection are given no reduction in their insurance premiums that recognizes the levee's presence.

The committee recommends:

- Regardless of the level of protection provided, the levee-protected area should be disaggregated into flood risk zones and an actuarial rate be established for each zone that reflects the degree of protection actually provided by the levees.

This ideal would entail the development of a practical procedure for estimating the probability of failure on an annual basis, the actuarial chance of loss, for properties protected by specific groupings of levees.

Premiums based on actuarial risk would require individuals who own existing or who construct new buildings in areas protected by levees to make equitable contributions to the cost of the loss-sharing mechanism arranged on their behalf by FEMA. Each policyholder for property behind a levee would pay a premium determined by a reasonable estimate of the probable residual flood damage, recognizing the inherent uncertainty in the estimate. Precedent for a rating scheme based on approximate average group risk is found in the fire insurance industry in which assignment of property to 1 of 10 fire risk rating zones is according to a determined degree of exposure. Windstorm insurance rates are regionalized, sometimes by state or by proximity to the South Atlantic or Gulf Coast. Properties in "tornado alley" are called upon to pay higher premiums than those elsewhere.

It is in the best interest of the public and FEMA to encourage communities and individuals to take actions that mitigate flood damage to the extent practical. One workable incentive is to reduce the insurance rates paid by residents whose communities provide levee protection. The reduction provides residents a tangible incentive to pressure their communities to provide levee protection. Later, should a levee owner fail to maintain a levee to the degree required for continued FEMA recognition, the residents would be notified that their flood insurance rates would be set to higher levels. Many would respond by applying pressure to their communities to correct the situation. Such local pressures tend to be much more effective than those applied directly by the federal government.

The committee recommends:

- Consistent with the design levels of protection recommended in Chapter 3, NFIP policyholders in areas behind existing levees that offer more than 25-year protection or new levees affording 100-year protection or greater should pay lower rates that reflect the reduced risk of property damage.

In order to estimate appropriate insurance rates, levees would be classified by a set of factors carefully prepared by FEMA intended to reflect the probability of failure; that is, the likelihood of failure would be estimated based on correlation with such factors as levee geometry, levee maintenance, and adequacy of internal drainage. Preliminary estimates of the rates of failure for various classifications can be based on historical data from the Corps of Engineers, SCS, FEMA, and such state agencies as the California Department of Water Resources.

The committee recommends that all property owners pay full premiums for flood insurance with no credit given for reduced risk because of any levee until the affected community <u>makes application</u> to FEMA. Subsequent to the process of levee inspection, evaluation, and acceptance by FEMA, as described in Chapter 4 and based on factors affecting levee effectiveness, credit for risk reduction would be given as guided by the correlation discussed in the previous paragraph by adjusting the insurance rate accordingly. The community, levee owner, or property owners behind the levee would be expected to pay for the inspection and for having the evaluation. Reports on inspection of maintenance, subject to FEMA verification, should be periodically submitted for approval at the community or levee owner's expense. Failure to demonstrate adequate maintenance would automatically increase insurance rates to a higher classification.

The committee recommends:

- The levee flood risk zones should match the existing flood risk zones established for the regular Flood Insurance Program.

- FEMA should continue its efforts to establish an actuarial rate basis for the Flood Insurance Program and, as far as practical, convert its present rate schedule to actuarial rates. The actuarial rates, as is done by the private insurance industry, would be updated annually to reflect experience, claims paid, and the cost of doing business.

A solvent NFIP requires that policyholders be assessed at actuarial rates. The desirability of an actuarial-based rate structure has been stated repeatedly and is endorsed here. FEMA indicates that its current policy is to implement actuarial rates over the next few years. The actuarial rate schedule proposed by FEMA would be designed to make the total program financially self-sufficient, thereby obviating the need for federal subsidy. It is recognized that subsidized rates may have to be phased out over a period of time--for example 10 years--or under condition of change in property title. Nevertheless, with a policy of reducing federal expenditures, the current subsidized costs should be transferred to those under risk.

The actuarial rate schedule adopted by FEMA should be based on the level of risk associated with floodplain development and not be designed solely to make the program financially sound. That is, the rates paid by each policyholder should be a reasonable reflection of the potential risk associated with the individual existing or proposed floodplain development.

It is realized that: (1) existing construction (built prior to the time when the first flood insurance rate map became effective) is by statute subsidized to provide for affordable rates, and (2) FEMA or FIA is not free to eliminate this subsidy. Congressional consideration of eliminating this subsidy over time would be appropriate.

## HAZARD RATING PROCEDURE

### Background

The use of actuarial risk for setting insurance rates requires that a procedure be developed which can differentiate the failure hazard associated with individual levees and assign numerical assessments of hazard. This procedure must relate hazard to identifiable conditions of the levee and the maintenance performed on it. Further, the procedure must, to the extent possible, be based on objective evaluation criteria and be publicly defensible. Given the current state of hydrologic and geotechnical risk assessment, the procedure must be simple in concept, and, given the scale of a levee evaluation program, it must also be simple in execution and administratively feasible.

The development of risk assessment procedures for levees is limited by the inherent difficulties in probabilistic risk analysis for

earthen structures and their foundations. While methodologies for evaluation exist, data requirements are extensive and the results, with incomplete or approximate information, may be questionable. Presently, risk assessments can best be based on statistical analysis of the historical record, on expert opinion, or some combination of these. Risk estimates must be based on measurements of levee conditions that have been related to the probability of failure, either by empirical evaluation of the historical record or by engineering analysis.

The major problem in employing statistical analysis of empirical data is that so few failures have been recorded. The failures that have been recorded come from a wide range of levee types. When data are disaggregated to estimate the effects of levee design, physical characteristics, soil and hydrological conditions, maintenance history, and other relevant factors, the number of failures in any one category is quite small for reliable statistical analysis.

On the other hand, the problem of assigning risk ratings to levees is not unlike many other insurance rating problems, e.g., fire safety ratings. Indicators of levee conditions and probable performance can be identified, and these indicators can be ranked in approximate order of importance. After grouping indicators in a limited number of classes, the probability of structural levee failure associated with various combinations of indicator values can be estimated from failure statistics and expert opinions. An overall risk rating is obtained by combining the estimate of structural risk from indicator information with hydrologic forecasts, and the risk ratings are then related to other risk classifications currently used by FEMA.

A rating scheme for areas behind levees is proposed below which incorporates consideration of hydrologic and geotechnical risk and uncertainty. It is suggested that hydrologic risk and uncertainty (depth, duration and frequency of flooding) for areas behind levees be handled by the existing NFIP procedures and rate zones. Hydrologic risk and uncertainty must also be incorporated into new procedures for evaluating geotechnical risk and uncertainty.

Geotechnical risk and uncertainty can be considered by providing for lower premiums for owners of floodplain property protected by levees that are adequately designed, constructed, and maintained. This premium reduction would not result if the levee were not properly designed, constructed, and maintained and if a properly designed and maintained interior drainage system did not exist.

The following rating scheme is presented as an example. Development of the specific procedures for the geotechnical rating scheme would be the responsibility of a future contractor and is beyond the committee's capability.

## Rating Scheme

The probability of levee failure under flood conditions depends on both hydrologic and geotechnical risk and uncertainties.

The conceptual approach to estimating hydrologic risk is theoretically clear and well established in practice even though hydrologists recognize that a variety of uncertainties constrain our ability to do so precisely. The reasonable way to estimate the hydrologic component of risk to lands behind levees is to employ these methods as done in existing NFIP procedures, while recognizing the inherent imprecision in the results.

The conceptual approach to estimating geotechnical risk at this time is theoretically incomplete and therefore not generally applied in practice. Nevertheless, it seems clear that the primary piece of hydrologic information determining risk for a given levee is the probable distribution of duration that water levels can be expected to continue at elevations lower than levee crest.

The aggregate probability of structural failure could be found by integrating the conditional probability at given differential heads and duration multiplied by the probability distribution of water level and duration. While probabilistic methods have been developed for some geotechnical risks, and are being developed for others, the geotechnical engineering community has not universally embraced the concept that reasonable quantification of the probability of failure is practical.

Certainly, the state-of-art is far from a highly sophisticated quantification scheme. In this situation the committee recommends developing a scoring procedure for evaluating geotechnical hazard from simple indicators that correlate to levee performance. These indicators could include observable items such as design and construction features, embankment geometry, obvious signs of distress, adequacy of maintenance programs, and similar easily identifiable properties. For each indicator, scoring criteria could be developed which assign a score of 0, 1, or 2 to each possible condition, depending on whether the condition is inadequate, requires remedial work, or is satisfactory. These numbers can then be aggregated to yield a risk score. If a levee is judged to be unsatisfactory in a key category, then the levee would be unacceptable for reduced insurance rates until the condition is corrected to a satisfactory standard.

From a practical view, the list of indicators used will have to be limited to a reasonably small number and amenable to evaluation. This should facilitate evaluation of individual levees and help organize a statistical data base to form a basis for improved estimation.

The suggested beginning for a procedure for incorporating geotechnical risk and uncertainty into the rating procedure (Tables 2 and 3) would result in a score, $\underline{S}$, which would determine whether a reduction would be made to the insurance premium as a result of geotechnical risk and uncertainty. If the estimated value of $\underline{S}$ exceeds various values, then various reductions would be subtracted from the premium. The premium from which the reduction is subtracted is that premium established by NFIP procedures for the conditions of hydrologic risk in existence for the levee protected area.

The committee recommends:

- FEMA should contract for the development of a list of key categories concerning the physical condition of a levee that would be used to evaluate the levee's ability to function effectively and concerning use of those factors to estimate geotechnical risk. An unsatisfactory rating would result in increased insurance premiums.

TABLE 2 EXAMPLE LEVEE RATING PROCEDURE

1. Indicators are estimated on a 3-point scale (3 grade levels) for factors grouped by categories. Criteria for each grade level are explicitly detailed. An inspector visits site and reviews the physical condition of the levee and related facilities, and following the criteria, completes the check list detailed in Table 3. Each factor in the check list is then rated as unsatisfactory, work needed, or satisfactory, and a score of 0, 1, or 2 is awarded as indicated in Table 3.

2. Grading sheet data are combined through a specified formula to assign a grade ($\underline{G}$) for each category.

3. The grades ($\underline{G}$) for each of the categories are combined in a weighted overall score

$$\underline{S} = f\ (\underline{W_i G_i},\ \ldots,\ \underline{W_n G_n})$$

where $\underline{W_i}$ is the weight given to the first category and $\underline{G_i}$ is the actual numerical value for the first category, for example.

4. Depending on the score ($\underline{S}$), property owners will either receive, or be denied, a reduction in insurance rates. This reduction would be deducted from the premium paid by a property owner behind a levee that has an adequate rating.

TABLE 3 RATING CHECK LIST: AN EXAMPLE

| Factors | | Grading | | |
|---|---|---|---|---|
| | | Unsatisfactory | Work needed | Satisfactory |
| | | 0 | 1 | 2 |
| I. | Levee Design (Physical Features) | | | |
| | I.1 Homogeneous cross-section | - | - | - |
| | I.2 Absence of settlement | - | - | - |
| | I.3 Etc. | - | - | - |
| II. | Maintenance Program | | | |
| | II.1 Absence of erosion | - | - | - |
| | II.2 Absence of animal burrows | - | - | - |
| | II.3 Etc. | - | - | - |
| III. | Closures | | | |
| | III.1 Functional operating mechanisms | - | - | - |
| | III.2 Etc. | - | - | - |
| IV. | Etc. | - | - | - |

Note: Specific ratings by factor are marked by checking as appropriate.

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# FLOODPLAIN MAPPING APPROACHES IN LEVEE-PROTECTED AREAS

## PURPOSE AND DISCUSSION

This chapter makes recommendations concerning the display on maps of flood risks and evacuation routes in levee-protected areas. The information requiring display is the set of lines bounding zones between the dimensions of levee recognition shown in Table 1. As a beginning example, the committee has recommended that FEMA recognize through reduced premiums to protected properties (1) existing levees that provide protection to a 25-year flood level (plus freeboard) and (2) areas protected by new levees that provide protection to a 100-year flood level (plus freeboard). Currently areas inundated by floods more frequent than the 100-year flood and areas protected by levees rated as providing protection against larger floods are not delineated on maps prepared by FEMA. The dimensions of levee recognition recommended in Table 1 would thus require that FEMA mapping practices be expanded in scope.

It is important that people be aware when they live, work, or are considering the acquisition of property located in an area protected by a levee and that a levee can fail structurally or be overtopped during floods exceeding the levee height. Such awareness would work to reduce the false sense of security that levee systems tend to generate. However, flood insurance maps alone are not sufficient because the public seldom sees them. Even though the maps must be supplemented by other means (such as mailed annual notices, newspaper articles, and T.V. presentations) they serve as basic information documents. Flood insurance maps are read and studied by local government officials, realtors, insurance people, developers, and bankers whose businesses may be affected by floodplains. Without levee-protected areas being identified on flood insurance maps, there might not be an information base that would permit any other means of notification to be used.

The committee's recommendations focus on credited levees providing 100-year flood protection and on crediting existing levees not providing 100-year flood protection. A credited levee is a levee recognized as meeting the minimum guidelines set forth in previous chapters. Before the recommendations are presented, however, a discussion of flood insurance maps is provided to lay a groundwork understanding on the types of flood insurance maps currently produced by FEMA and what they are intended to do.

## FLOOD INSURANCE MAPS PREPARED BY FEMA

The Flood Hazard Boundary Map (FHBM) is prepared by FEMA for each community having special hazards. It shows the boundaries of the flood, mudslide, and/or related erosion hazard areas designated as Zone A, M, and/or E as illustrated on Figure 1. A FHBM is generally the first map prepared to meet the flood hazard area identification requirements of the National Flood Insurance Act of 1968, as amended. It can be issued before or after a community decides to participate. It is preliminary and contains little more information than the identification of special hazard areas, which in the case of flooding are A Zones as shown in Figure 1. The FHBM shows the location of any existing levee, but it does not delineate or identify the area that the levee protects.

A Flood Insurance Rate Map (FIRM) is prepared following completion of a detailed flood insurance study. The FIRM is an official map of the community on which the special hazard areas and the risk premium zones applicable to the community are delineated. The FIRM is distributed upon completion to the community, lending institutions, insurance agents, and others who request the map and any subsequent revisions. The type of information shown on a FIRM is depicted in Figure 2, which includes a portion of the area shown in Figure 1. Note the location of Corrales Road crossing of the Rio Grande on both maps. It is significant that no reference is made on the FIRM to the levee that is located on the east side of the Rio Grande as shown in the FHBM. The levee-protected area is shown on the FIRM as Zone B (see lower right corner of the map).

The primary purposes of the FIRM are to provide the information necessary to determine if insurance is needed on a property, to define the level of risk so a premium can be determined, and to provide flood elevation information for floodplain management purposes. If a property is located in Zone B or C, no insurance is required, and the property owner is more likely to assume there is little or no flood risk. Zone B can currently mean:

> (1) Areas between limits of the 100-year flood and 500-year flood; (2) Certain areas subject to 100-year flooding with average depths less than one foot or where the contributing drainage area is less than one square mile; or (3) Areas protected by levees from the base flood (Medium shading).

Thus, a property in Zone B may be located in a levee-protected area, but there is no information on FIRM maps to distinguish this fact from the other two possibilities.

The third basic map prepared by FEMA is the Flood Boundary and Floodway Map (Floodway Map). Figure 3 shows the same area covered by Figure 2, but the information presented is slightly different. A Flood Insurance Study report is prepared in conjunction with the Flood Boundary and Floodway Map and describes the area studied, the engineering methods used, a summary of discharges, floodway data, flood insurance zone data,

and flood profiles. The map and report provide the information needed to regulate the floodplain. Distribution of the Floodway Map and Flood Insurance Study is limited, being sent basically to the community, FEMA regional office, state coordinators, and other agencies with a direct involvement in floodplain management.

The location of the levee is not noted on the Floodway Map of Figure 3, nor is the levee-protected area identified as such. The area protected by the levee is shaded as referenced in the "Key to Map" as between the 100-year flood boundary and the 500-year flood boundary.

The three maps discussed and presented as Figures 1, 2, and 3 are of the same area in Albuquerque, New Mexico. The comments contained herein are not intended as a review of these particular maps, and the mention of these maps is strictly for the purpose of illustrating map content.

## MAPPING FOR CREDITED LEVEES PROVIDING 100-YEAR PROTECTION

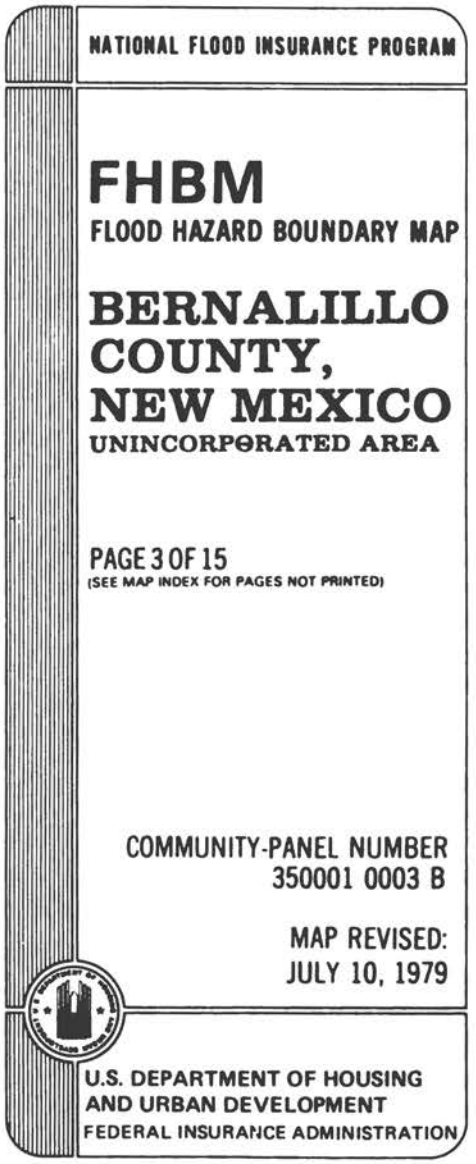
Recommendations are made in this section on how best to add information recommended in this report to each of the three categories of maps previously discussed.

### FHBM

The "Special Flood Hazard Area" is shown on a FHBM as a "Zone A" (see Figure 1), and no attempt is made to delineate or designate the levee-protected area. Most communities with identified flood hazards have been provided with FHBMs, and the FHBMs of many communities have been replaced by FIRMs. Consequently, very few new FHBMs will be prepared, and any recommendation pertaining to FHBMs will have limited effect. Also, a FEMA emphasis at this time is to convert communities from the emergency program to the regular program, which means the replacement of FHBMs with FIRMs.

In the context of the progress being made in converting communities from the emergency program to the regular program, it is not desirable to revise policies on the various dimensions of levee recognition while communities remain with the emergency program. Major efforts spent in revising the emergency program would only detract from the more important effort of converting communities to the regular program. This policy, however, should be revised if communities are unduly extending the duration of their participation through the emergency program, particularly if such extension avoids compliance with the policies for dealing with levees in the regular program.

In this spirit, FEMA should not revise FHBMs solely for the purpose of defining levee-protected zones; but, if for any reason a new or revised FHBM is prepared that involves a levee-protected area, the committee recommends:



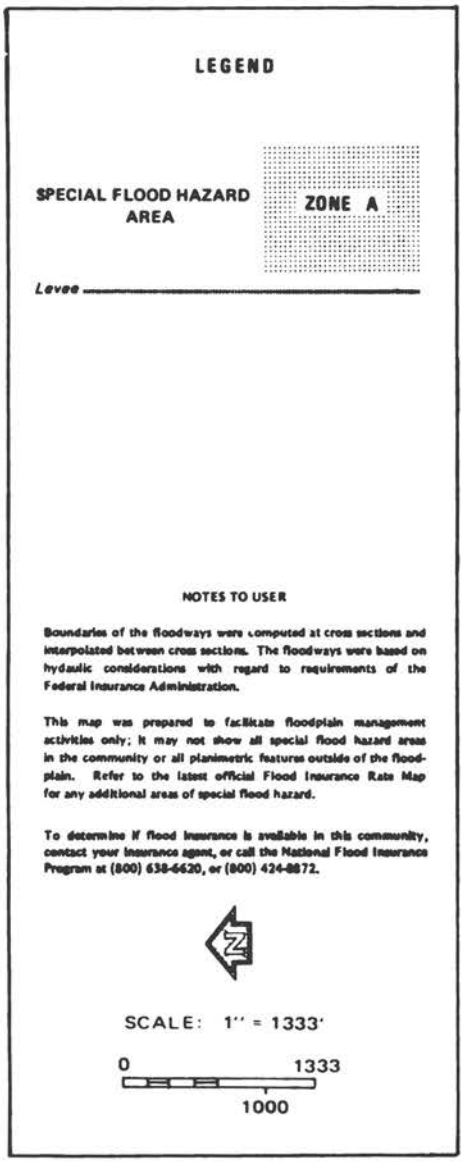
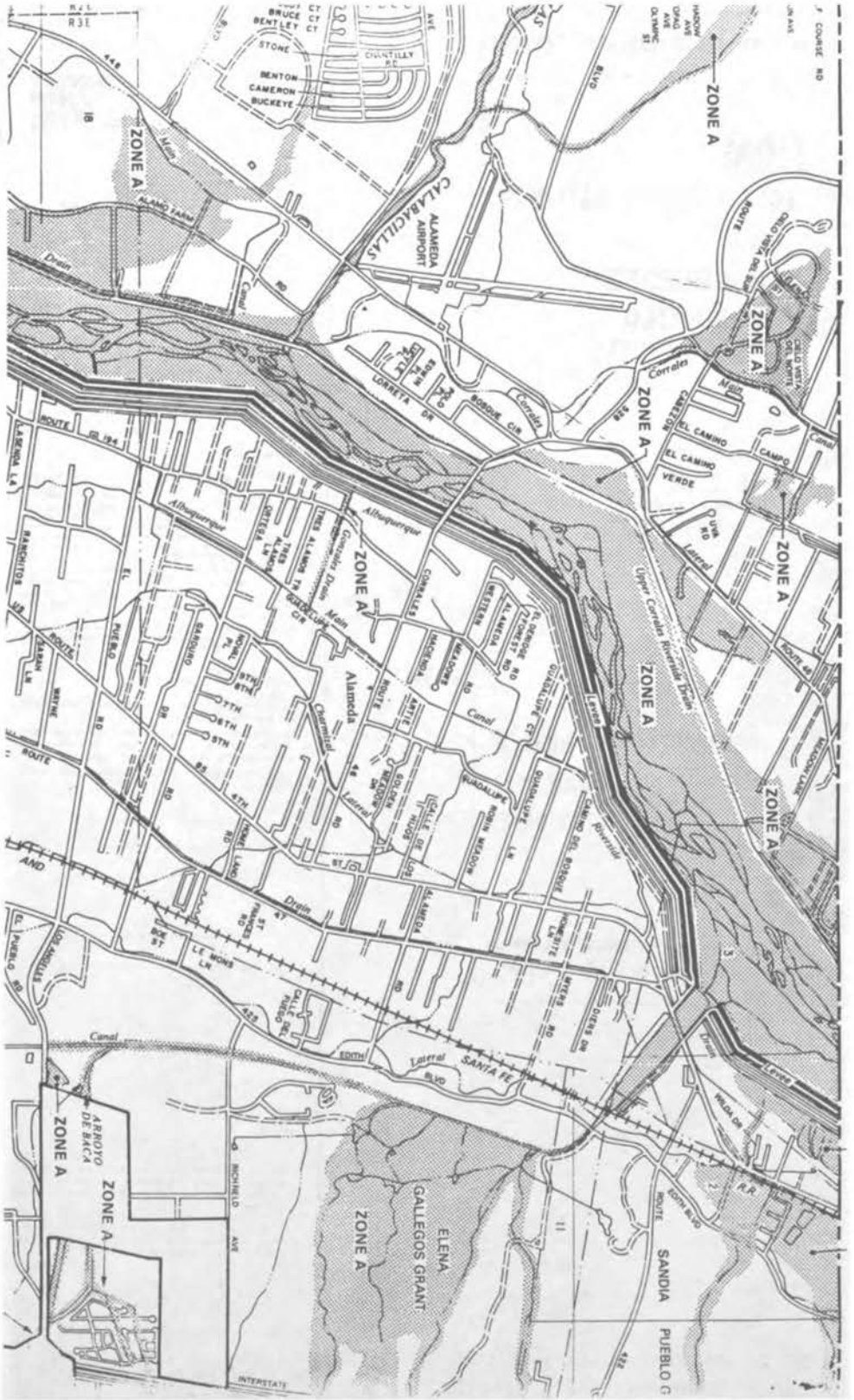




FIGURE 1 Representative Flood Hazard Boundary Map (Bernalillo County, New Mexico)



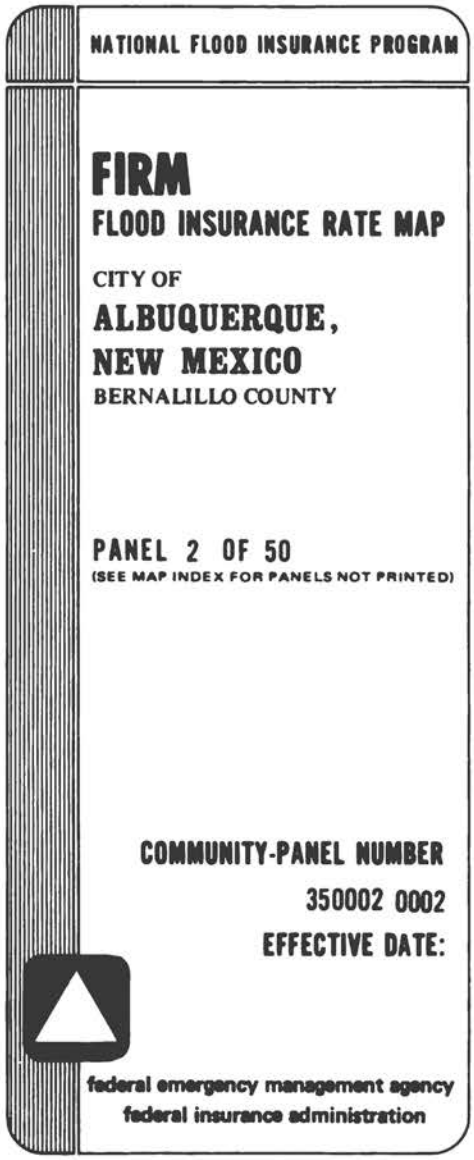
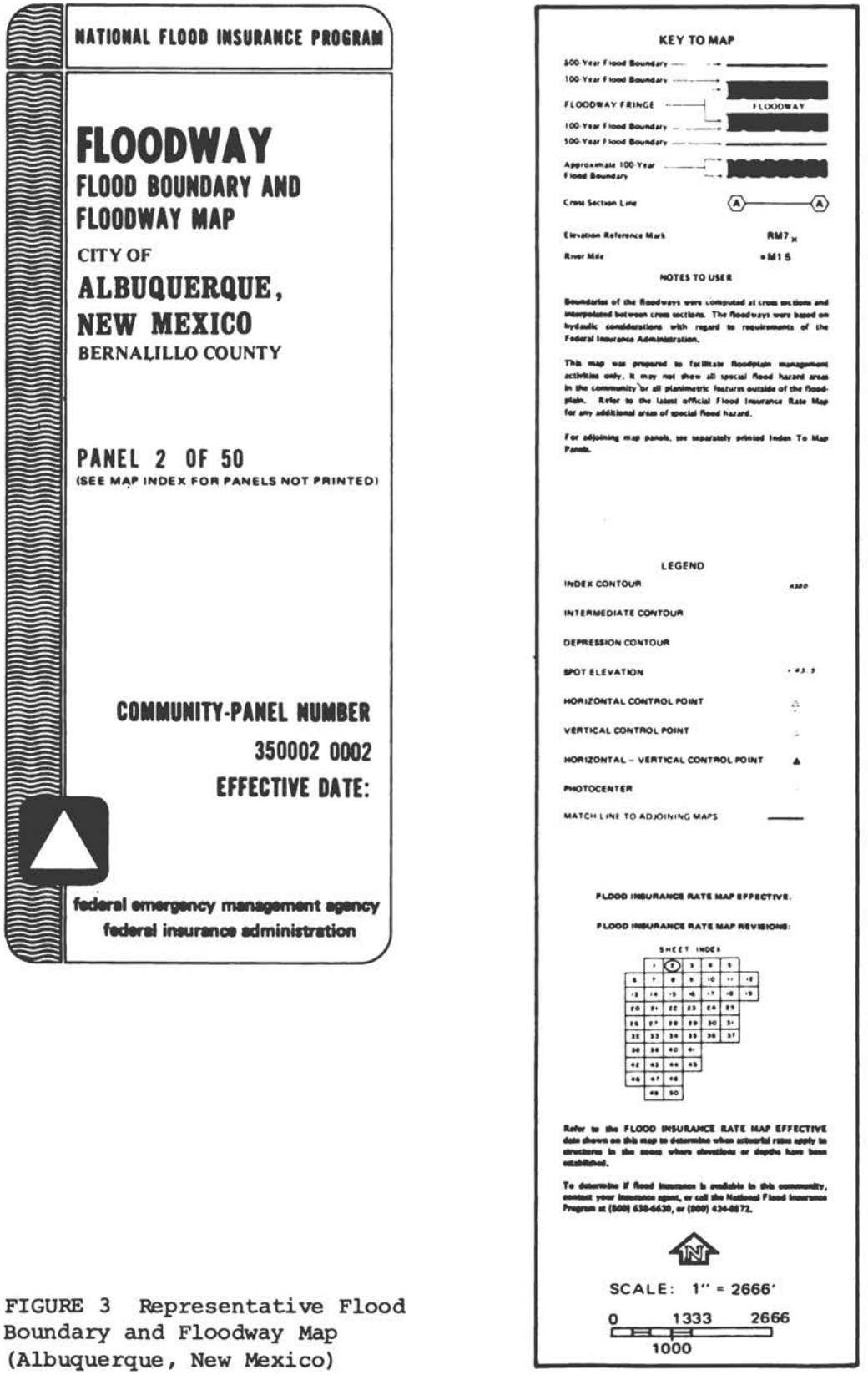




FIGURE 2 Representative Flood Insurance Rate Map (Albuquerque, New Mexico)



NATIONAL FLOOD INSURANCE PROGRAM

# FLOODWAY
## FLOOD BOUNDARY AND FLOODWAY MAP

CITY OF
**ALBUQUERQUE, NEW MEXICO**
BERNALILLO COUNTY

**PANEL 2 OF 50**
(SEE MAP INDEX FOR PANELS NOT PRINTED)

**COMMUNITY-PANEL NUMBER**
**350002 0002**
**EFFECTIVE DATE:**

federal emergency management agency
federal insurance administration

KEY TO MAP

500-Year Flood Boundary
100-Year Flood Boundary
FLOODWAY FRINGE
FLOODWAY
100-Year Flood Boundary
500-Year Flood Boundary
Approximate 100-Year Flood Boundary
Cross Section Line (A — A)
Elevation Reference Mark RM7 ×
River Mile •M15

NOTES TO USER

Boundaries of the floodways were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the Federal Insurance Administration.

This map was prepared to facilitate floodplain management activities only. It may not show all special flood hazard areas in the community or all planimetric features outside of the floodplain. Refer to the latest official Flood Insurance Rate Map for any additional areas of special flood hazard.

For adjoining map panels, see separately printed Index To Map Panels.

LEGEND

INDEX CONTOUR
INTERMEDIATE CONTOUR
DEPRESSION CONTOUR
SPOT ELEVATION
HORIZONTAL CONTROL POINT
VERTICAL CONTROL POINT
HORIZONTAL – VERTICAL CONTROL POINT
PHOTOCENTER
MATCH LINE TO ADJOINING MAPS

FLOOD INSURANCE RATE MAP EFFECTIVE:

FLOOD INSURANCE RATE MAP REVISIONS:

SHEET INDEX

Refer to the FLOOD INSURANCE RATE MAP EFFECTIVE date shown on this map to determine when actuarial rates apply to structures in the zones where elevations or depths have been established.

To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program at (800) 638-6620, or (800) 424-8872.

SCALE: 1" = 2666'

0 1333 2666
1000

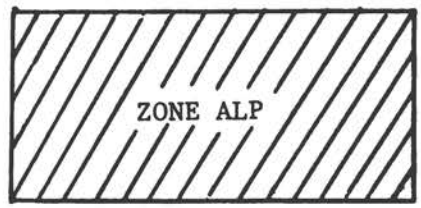
FIGURE 3 Representative Flood Boundary and Floodway Map (Albuquerque, New Mexico)

- All levees, dikes, and floodwalls should be labeled as such on any new or revised FHBM. Also, the areas protected by levees providing 100-year or greater protection should be delineated on the new or revised FHBMs as Zone ALP. Areas protected by levees not meeting this standard would continue to be mapped as Zone A.

The ALP zone could be delineated on the new or revised FHBM by cross-hatching. The legend would have to be expanded to include this additional designation. The primary purpose of including this information on any new or revised FHBM is to make it a matter of public record that an area is located behind a levee and is subject to flooding if the levee is overtopped or otherwise breeched. Therefore, the legend should include language similar to the following:

Levee-Protected Area (Levees protecting ALP Zones are designed to provide protection against the 100-year flood or greater, but they are subject to structural failure during lesser floods and overtopping during larger floods.)

(example)




One way to map the ALP Zone would be to make its outer boundary the line where the ground level matches the elevation of the top of levee minus freeboard. Though there are more detailed approaches, it is felt that this would generally be adequate because of the approximate nature of the FHBM. Also, as previously discussed, there will probably be very few new or revised FHBMs prepared.

## FIRM

The FIRM is for flood insurance purposes and is used to determine actuarial rates that apply to structures in the zones where flood elevations or depths have been established. It shows important physical features and should include the location of levees, dikes, or floodwalls. The FIRM illustrated in Figure 2 is based on orthophotography provided by local agencies. Most FIRMs do not have this type of base mapping, and a more typical mapping base is illustrated by Figure 4, a FIRM of a section of the city of St. Louis, Missouri. The location of an existing levee is not noted on the FIRM in Figure 2, but one is noted on the FIRM in Figure 4.

The committee recommends:

- The location of all levees, dikes, and floodwalls credited as providing 100-year

protection or more should be clearly denoted on all future FIRMs.

This is apparently done on some but not all FIRMs, so implementation of this recommendation would involve an effort by FEMA to be consistent and would not involve policy or procedural changes.

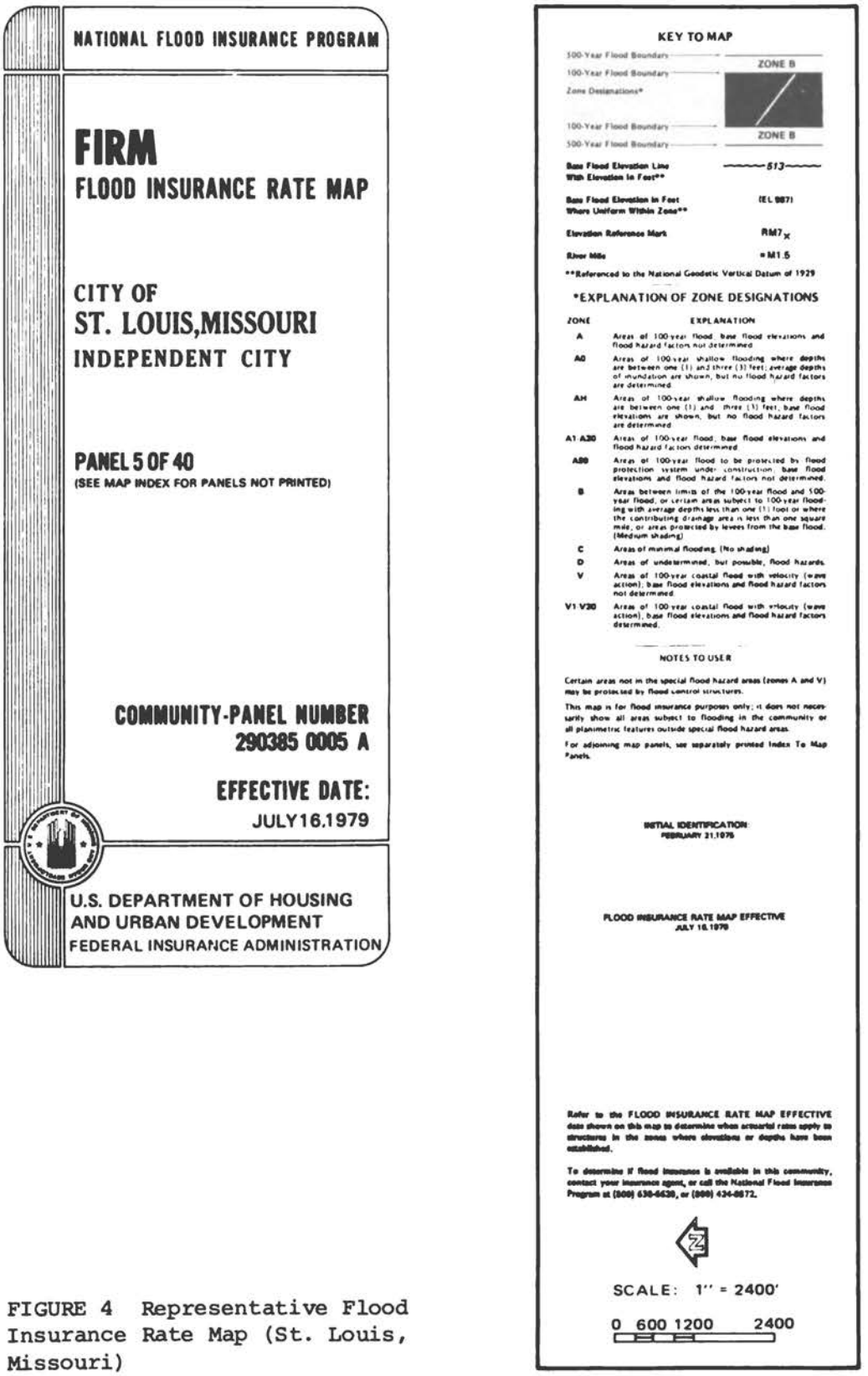
The areas behind currently credited levees are now denoted as Zone B on the FIRMs. Behind levees where insurance purchase will be required (see Table 1) the levee protected areas must be so designated on the FIRM and supplemented with information to determine insurance rates. Where insurance is to be required, the committee recommends:

- Areas behind recognized 100-year levees that would be flooded (assuming no levee) by a 100-year flood should be designated as Zone ALP. Areas between the natural 100-year flood boundary and 500-year flood boundary should be designated as Zone BLP.

The level of risk in Zone ALP may be minimal because of the levee, and the insurance rate would be very likely some fraction of the existing subsidized rates. However, this may not be the case, and specific risk should be determined by the type analysis advanced in Chapter 8. Since no insurance would be required in Zone BLP, the purpose of the BLP designation is to document that an area is protected by a levee but above the level of the base flood (100-year). Section 64.3(b) of the FEMA regulations will have to be modified to make the purchase of insurance mandatory in Zone ALP.

The current procedure for determining whether insurance is to be required involves locating a property on a FIRM. If it is in Zone B or C, no insurance is required, the matter is dropped, and the property owner is most likely not aware that the check was even made. If an area is reclassified as Zone ALP, then insurance on buildings would be required and the property owners would be made aware of the hazard. If the properties are in an area reclassified as Zone BLP, insurance would not be required (but the property owner should be made aware of the levee). Explanations of Zone ALP and Zone BLP would have to be added to the "Explanation of Zone Designation" on the FIRM.

There is an apparent inconsistency between the FIRM in Figure 2 and the FIRM in Figure 4. In Figure 2 the area behind the levee, lower right-hand corner, is shown as Zone B. In Figure 4 the area behind the levee, southern or right reach of Mississippi on west side of river, is designated mostly as Zone C with some isolated spots as Zone B. The reason for this apparent discrepancy is not known. It could be because the levee on the Mississippi, Figure 4, contains a 500-year flood, or it could be because FEMA's approach has changed since the FIRM in Figure 4 was prepared in July 1979. This issue is not critical, however, as the policy now used by FEMA to define Zone B's behind levees could continue to be used. The important change would be the designation of these areas as levee-protected zones.



NATIONAL FLOOD INSURANCE PROGRAM

# FIRM
## FLOOD INSURANCE RATE MAP

CITY OF
ST. LOUIS, MISSOURI
INDEPENDENT CITY

PANEL 5 OF 40
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
290385 0005 A

EFFECTIVE DATE:
JULY 16, 1979

U.S. DEPARTMENT OF HOUSING
AND URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION

KEY TO MAP

500-Year Flood Boundary
100-Year Flood Boundary
Zone Designations*
100-Year Flood Boundary
500-Year Flood Boundary
ZONE B
ZONE B

Base Flood Elevation Line With Elevation in Feet** — 513

Base Flood Elevation in Feet Where Uniform Within Zone** (EL 987)

Elevation Reference Mark RM7$_X$

River Mile • M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

| ZONE | EXPLANATION |
|---|---|
| A | Areas of 100-year flood; base flood elevations and flood hazard factors not determined. |
| AO | Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined. |
| AH | Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined. |
| A1-A30 | Areas of 100-year flood; base flood elevations and flood hazard factors determined. |
| A99 | Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined. |
| B | Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading) |
| C | Areas of minimal flooding. (No shading) |
| D | Areas of undetermined, but possible, flood hazards. |
| V | Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined. |
| V1-V30 | Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined. |

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

For adjoining map panels, see separately printed Index To Map Panels.

INITIAL IDENTIFICATION:
FEBRUARY 21, 1975

FLOOD INSURANCE RATE MAP EFFECTIVE
JULY 16, 1979

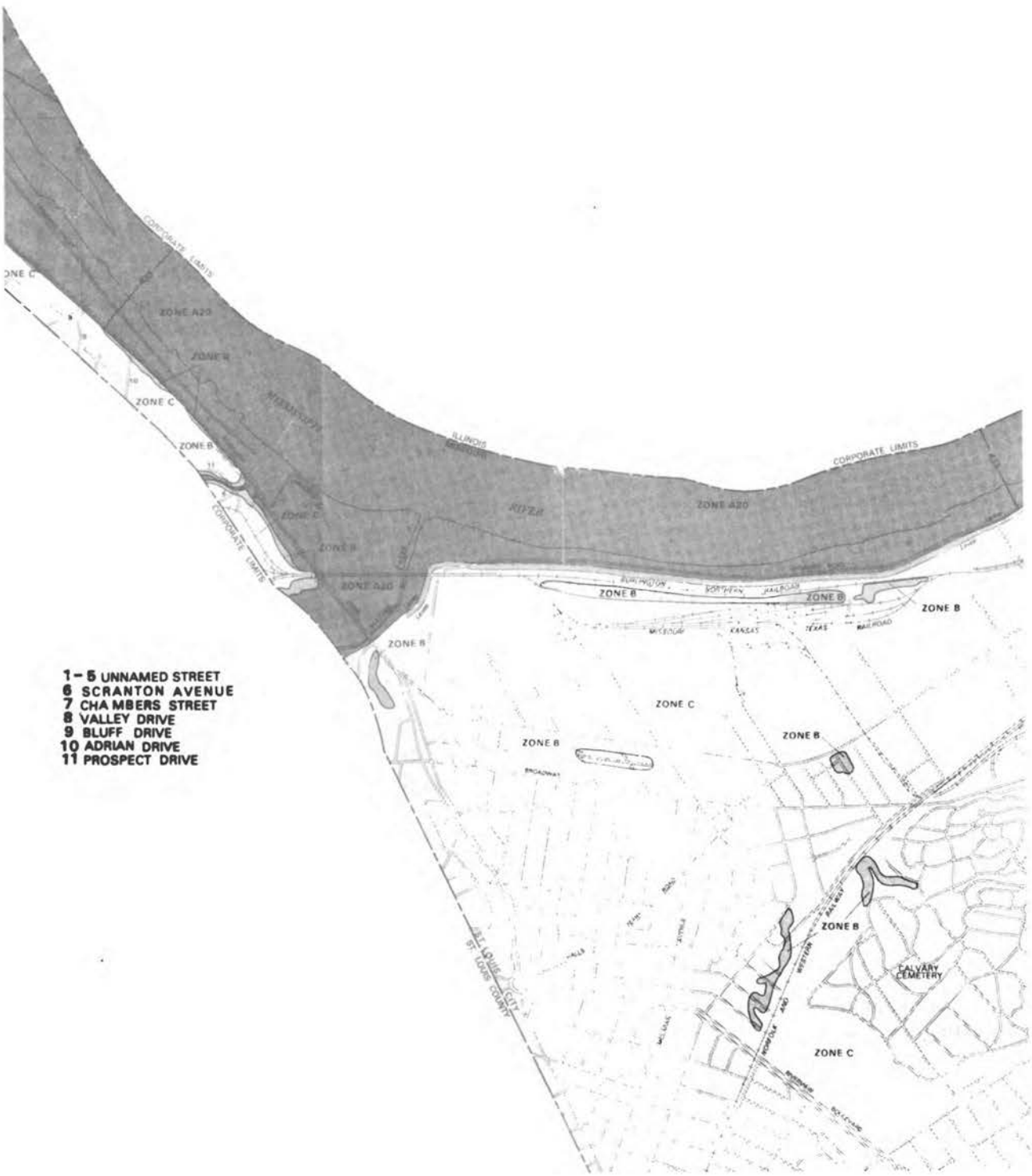
Refer to the FLOOD INSURANCE RATE MAP EFFECTIVE date shown on this map to determine when actuarial rates apply to structures in the zones where elevations or depths have been established.

To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program at (800) 638-6620, or (800) 424-8872.

SCALE: 1" = 2400'

0 600 1200 2400

FIGURE 4 Representative Flood Insurance Rate Map (St. Louis, Missouri)


1 – 5 UNNAMED STREET
6 SCRANTON AVENUE
7 CHAMBERS STREET
8 VALLEY DRIVE
9 BLUFF DRIVE
10 ADRIAN DRIVE
11 PROSPECT DRIVE
CORPORATE LIMITS
ZONE A20
ZONE B
ZONE C
MISSISSIPPI
ILLINOIS
RIVER
BURLINGTON NORTHERN RAILROAD
MISSOURI KANSAS TEXAS RAILROAD
ST. LOUIS CITY
ST. LOUIS COUNTY
CALVARY CEMETERY
NORFOLK AND WESTERN RAILWAY
BROADWAY
MILL CREEK VALLEY
BROADWAY BOULEVARD

## Floodway Map

The third map prepared by FEMA, the "Flood Boundary and Floodway Map" or "Floodway Map," is prepared to facilitate floodplain management activities only. The Floodway Map shown in Figure 3 has a levee located on the southeast bank of the Rio Grande, lower right-hand corner of map, but it is not designated. Regardless of whether floodplain management actions will be required in areas protected by levees (see Table 1), a levee is a major and significant feature and should be shown on the map. This should not present any difficulties from a cost or policy standpoint.

The area behind a credited levee is currently shown on Floodway Maps with medium shading, see lower right corner of Figure 3. This area is identified in the "Key to Map" as the area between the 100-year and 500-year flood boundary and is equivalent to the Zone B area of the FIRM in Figure 2. No special floodplain management measures are required under present FEMA regulations. If any floodplain management measures are to be required in areas protected by credited levees providing 100-year protection, then these levee-protected areas must be differentiated on the Floodway Map as well as on the associated FIRM. On the FIRM, it is recommended that the area behind the levee that would be flooded by a 100-year flood assuming no levee (unconfined 100-year flood) be called Zone ALP and that the area between the 100-year flood boundary and 500-year flood boundary be designated as Zone BLP. Since the entire area protected by a credited levee up to the 500-year flood boundary should be subject to some floodplain management measures, such as preparation of warning and evacuation plans, this entire area should be designated by a distinguishing symbol on the Floodway Map.

The committee recommends:

- The locations of all credited levees, dikes, and floodwalls should be clearly denoted on all Floodway Maps.
- Areas behind credited levees providing 100-year protection that would be flooded during a 500-year flood should be shown on Floodway Maps.

This recommendation will require another form of cross-hatching on the Floodway Map. In the Floodway Map of Figure 3, the medium-shaded area east of the Rio Grande would have to be illustrated in a different way. The manner of illustration would have to be added to the "Key to Map" on the Floodway Map.

## MAPPING FOR CREDITED EXISTING LEVEES NOT PROVIDING 100-YEAR FLOOD PROTECTION

Current FEMA mapping does not recognize any levee not providing a 100-year level of protection as having any effect on reducing insurance premiums and determines the 100-year floodplain based on unconfined flows. Where 25- to 100-year levees are given recognition,

FEMA will have to modify its mapping policy. The following discussion presents specifics.

## FHBM

Little change would be required with regard to the FHBM. Currently, Zone A adequately designates areas where insurance is mandatory and certain floodplain management measures are required as set forth in paragraph 60.3(b) of the FEMA National Flood Insurance Program regulations. A false sense of security is not developed because property owners are required to purchase insurance, and new construction and substantial improvements located in A Zones must be elevated or flood-proofed.

## FIRM

Since the FIRM is used for setting flood insurance premiums by indicating actuarial rates, flood risks behind all levees providing at least 25-year protection need to be indicated. The FIRM must carry information that will allow the rates to be determined for the properties affected.

The committee recommends:

- FEMA should create an AL(No.) Zone that would designate an area protected by a levee with a frequency of protection defined by the (No.). For example, if the levee had an elevation equal to the 40-year flood (plus required freeboard), then the Zone would be AL(40).

A schematic illustration is shown in Figure 5. Zone A is subdivided into Zone AL(40) and Zone A13 (one of the current Zones A1 to A30). The insurance rate charged in Zone AL(40) would reflect the fact that the area is "flood-free" for floods up to the 40-year event. Zone A13 is unaffected by the levee and the insurance rates in this zone would be the same as if the levee were not recognized, as currently is the case. An explanation of Zone AL(40) would have to be added to the "Explanation of Zone Designations" on the FIRM.

## Floodway Map

Since the Floodway Map is to facilitate floodplain management activities it needs to indicate areas where changes in floodplain management policy are recommended. Specifically, changes would involve insurance purchase requirements behind levees up to a 500-year flood design and which would, without the levee, be flooded by a 100-year flood and areas behind all levees for critical facilities regulation and emergency measure planning. Current practice is to not

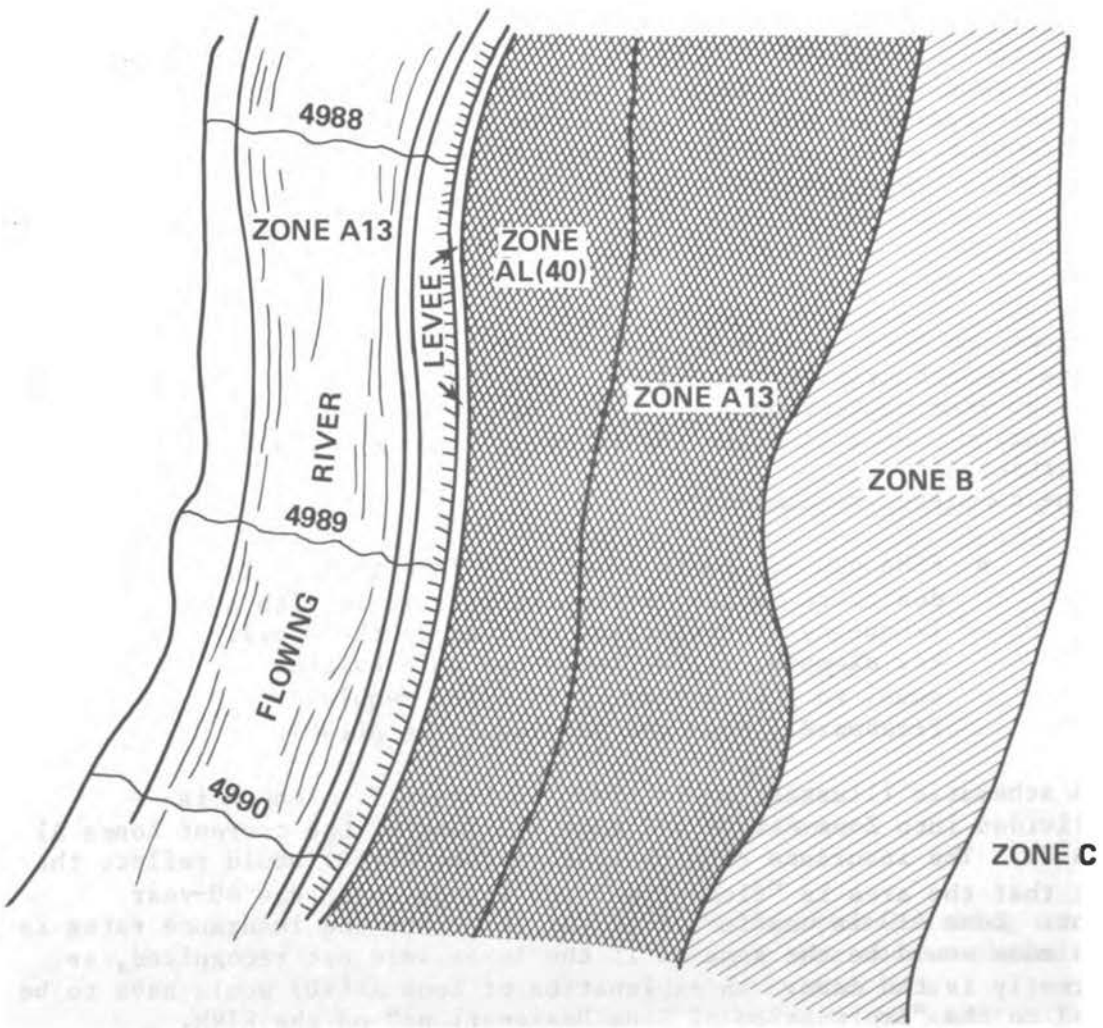



FIGURE 5 Flood Insurance Rate Map Showing--Levee Protected Areas

recognize the existence of levees with levels of protection less than 100 years, and 100-year floodplain areas are shown on Floodway Maps as heavily shaded areas ("Floodway Fringe"). It is recommended that the FEMA practice of requiring floodplain management measures as set forth in paragraph 60.3 of their regulations be continued for areas in the 100-year floodplain behind less than 100-year levees. Therefore, no change is recommended for portraying the hazard areas on the Floodway Map.

## EVACUATION ROUTES

Consideration was given to showing evacuation routes on FEMA maps. One problem is that the maps are prepared on a community basis. In urban areas where there are multiple jurisdictions, the maps stop at community boundaries; it would not be very useful to show evacuation routes just up to corporate or county limits that fall short of reaching safety. Even where community boundaries are not involved FEMA maps cover relatively small areas. Often, several maps must be pieced together to show the way out of the hazard area. A new map showing complete evacuation routes would be needed.

Evacuation routes must be coordinated with flood warning and evacuation plans. Both plans and routes must be prepared by the local communities, where the greatest expertise and familiarity with traffic and emergency personnel planning is likely to exist. If the routes are known when the FIRM and Floodway Map are being prepared and if an entire evacuation route can be shown on a simple map, there is a direct advantage to showing it on the FIRM or Floodway Map.

An advantage of having evacuation routes on the FEMA maps would be to make the FEMA maps complete as basic reference documents. Citizens, companies, or citizen groups could piece the information together and transfer it to maps of their choosing. Since the FEMA maps are generally available, completeness would make the information more accessible.

The committee recommends:

- FEMA should not make a mandatory requirement to include evacuation routes on maps. If the information is available when the maps are being prepared and if it makes sense from a community-to-community mapping standpoint, then the evacuation routes could be included on the maps. In other cases, it may be expeditious for communities to develop their own special evacuation route maps.

## INTERIOR DRAINAGE

Areas behind levees subject to flooding by interior drainage need to be delineated. It would appear from examination of present FEMA maps that the current intent is to map such areas. For example, the FIRM in Figure 2 includes the two following Zone designations, which may not necessarily have been developed for levee-protected areas but which seem to be appropriate:

AO--Areas of 100-year shallow flooding when depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.

AH--Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.

Depths greater than 3 feet are included in the A1-A30 Zone designation.

These areas of shallow flooding are already being mapped and include areas inundated by interior drainage. Special attention should be placed on linking operation of the interior drainage system with stages on the river side of the levee. An interior drainage situation may not be a problem when the river is below flood stage and consequently may not be included on a FEMA map, but it may become a problem when the river is in flood stage. For this reason FEMA should make sure that interior drainage evaluation is coordinated with evaluation of river-related flooding.

The committee recommends:

- Interior drainage situations on the landside of levees should be analyzed in conjunction with the riverine flood analysis, and the areas flooded by interior drainage should be shown on FEMA maps in accordance with current practice. Appropriate consideration should be given to correlation of the event on the river and the event causing the interior drainage problem.

If an interior drainage situation is a problem only when the river is in flood stage, then a joint probability appraisal can be made. If there is reasonable correlation between the events that cause the river to flood and the events that cause the interior drainage problem, then the area should be mapped as one of the A Zones. This certainly is the case during a hurricane, when heavy rainfall usually occurs at the same time as high stages. Also, it is usually possible to have heavy local storms at the same time river stages are high.

10

## SUMMARY OF RECOMMENDATIONS

### Engineering Criteria for Levee Recognition

In order to encourage communities to continue the operation and maintenance of existing levees that have been soundly engineered and are adequately maintained and in recognition of the fact that such levees do reduce actuarial flood risk, FEMA can legitimately recognize structurally sound levees that contain at least the 25-year flood for purposes of adjusting flood insurance rates. Specifically:

- Existing levees should be recognized for the purpose of reducing insurance rates where they provide protection against 25-year or larger floods and where they meet specified structural design criteria, including requisite freeboard.

However, since the basic objective of the NFIP is to mitigate flood damages and the basic program prohibits construction below the 100-year level, FEMA should require construction of new levees to the 100-year level. Further, the additional cost required to build a levee to contain the 100-year flood can often be justified at the time of initial levee construction. Therefore:

- New levees should be recognized for the purpose of reducing insurance rates where they provide protection against 100-year or larger floods and where they meet specified structural design criteria including freeboard. All levees on which construction begins after a date to be determined by FEMA should be considered new levees.

With respect to structural safety, the same criteria shall be used for both existing and proposed levees in determining eligibility for recognition by the NFIP. Therefore:

- All levees (existing and new) to be given credit for reducing flood risk in the NFIP must meet standard minimum engineering

criteria with respect to geometric parameters, freeboard, soils and foundations, interior drainage, closure devices, and rights of way.

Flood stages that change over time due to any of a variety of factors (e.g., increased urbanization, removal of natural valley storage, construction of reservoirs in upper reaches of large river systems) influence the hydrologic risk at a specific site. Therefore:

- FEMA should monitor watershed and channel changes where hydrologic risk is increasing and respond to significant changes with restudies and subsequent map and rate revisions.

## Levee Inspection and Evaluation

Each levee must be individually evaluated, hydrologically and structurally, before acceptance into the NFIP. There is ample engineering expertise in federal and state water resources agencies and in engineering firms in the private sector to conduct design evaluations and construction conformance inspections. Since many urban levees exist or would be built along waterways where the federal government already has major levee responsibilities, it would appear prudent that:

- In its administration of design evaluations and construction conformance inspections, FEMA should first pursue the possibility of using the services of federal and state agencies having water resources experience. Where federal participation can not be arranged, FEMA must use state and private sector capabilities.

In order to reduce the workload for levee inspection:

- Where responsible federal or state agencies have had continuous maintenance responsibilities on levees they designed and constructed, and will attest to their adequacy under FEMA standards, independent evaluations should not usually be required. Evaluations should be required, however, on levees that were designed and constructed by federal agencies but are currently being operated and maintained by others.

In some cases, neither a federal nor a state agency will be willing to undertake levee evaluation:

- Where a federal or state agency does not evaluate a levee, levee evaluations should be done by "levee evaluation contractors" (LECs), private consulting firms designated by FEMA.

Since it will be to an applicant's financial benefit to have an existing levee at or exceeding the 25-year level (plus freeboard) recognized by FEMA for the purpose of reducing insurance rates it follows that:

- While FEMA should designate qualified private consulting firms to be LECs, the firms should work under contract to an applicant interested in having a levee evaluated for recognition by FEMA. All costs of the LECs' work should be borne by the applicant.

Further:

- Since recognition of 25-year levees for the purpose of reducing insurance rates would represent an important change in federal policy, FEMA should publicize the benefits, costs, and procedural details for levee recognition.

Communities may have had levees already credited with removing property from the 100-year floodplain even though those levees do not meet sound structural or maintenance standards or may no longer protect against the 100-year flood. It is, therefore, concluded that:

- FEMA should inventory all levees previously credited as providing protection from the 100-year flood, set priorities, and schedule communities for restudy to reevaluate the levees.

Since most previously credited levees are expected to prove adequate and since restudy funds should not be expended needlessly:

- FEMA should develop a short and simple checklist that can be used to make a quick assessment of whether a levee meets recommended criteria.

## Requirements of Levee Owners

Human operated closures such as street gates are legitimate parts of planned levee systems, but general human intervention (sand bagging, emergency earth fill, etc.) for the purpose of increasing a

levee's design level of protection during an imminent flood situation does not provide reliable protection. Consequently:

- FEMA should confirm its interim policy that does not recognize sand bags on top of levees and other types of human intervention, except for structural closures which are legitimate parts of planned levee systems, as augmenting a levee system's design level of protection.

The Corps of Engineers has a good record on levee operation and maintenance following procedures contained in Federal Code 208.10, Title 33. FEMA can use this code as a basis for developing its procedures:

- Federal Code 208.10, Title 33, "Local flood protection works; maintenance and operation of facilities," should be modified where not well suited, supplemented for interior drainage, and adopted by FEMA as a guideline for operation and maintenance of levee systems.

While this code can provide general guidelines, each local situation is different. Consequently:

- A specific operation and maintenance plan, tailored to the local needs, must be formally adopted by the levee owner for a levee to be credited and continue to be credited in the NFIP.

Only regular maintenance programs are effective. Consequently:

- The operation and maintenance plan must provide for periodic inspections. The plan should be completed within a designated time period, meet the requirements of, and be acceptable to FEMA. Each inspection must be by a professional engineer retained by the levee owner and registered in the state in which the levee is located. A written report to the levee owner should be promptly prepared and certified by the professional engineer making the inspection. The report must specifically describe items found deficient and emerging potential future problem areas. Copies of the certified report should be sent by the certifying professional engineer to the regional FEMA office. Also, a copy should be provided the local political entities which have responsibilities to FEMA for the levee-protected area. FEMA should follow up to assure corrections

are made within a reasonable length of time. In instances where corrections are not made to critical deficiencies, FEMA should withdraw recognition.

### Requirements of Local Communities

Levee recognition has many dimensions, each with its own requirements of local communities. For consistency with the policy of not permitting construction of unprotected new structures in the 100-year floodplain:

- FEMA should require the elevation of new residential structures and the flood-proofing of other new buildings in all areas protected by levees unable to contain the 100-year flood.

In recognition of the degree of residual risk behind levees providing less than 500-year flood protection:

- FEMA should require purchase of flood insurance in all areas where the ground is lower than the unconfined 100-year flood level except where protected by a levee built to contain the 500-year flood.

Critical facilities, such as hospitals and natural gas terminals, whose flooding or discontinuity of service would create untoward hardship or damage for the community as a whole should not be permitted in the floodplain where alternative sites are available nearby. Consequently:

- Communities should regulate the placement of critical facilities (not regulated by some higher level of government) in all leveed areas in accordance with the procedures of Executive Order 11988.

To minimize floodplain development by individuals unaware of the hazard:

- Owners, tenants, and lenders occupying areas designated as protected by levees should be notified periodically by responsible local officials that their land in the levee-protected area is still subject to flooding in the event of levee failure.

The damages, should levee failure occur, can be considerably reduced by warning people behind levees, identifying evacuation routes

and police procedures for expediting evacuation, advising of appropriate temporary shelter and food for evacuees, and assuring that law and order are maintained in the flooded area. Therefore:

- Local officials of any NFIP participating community protected by a levee, regardless of its size and reliability, should prepare and promulgate an action plan for warning and evacuation in the event of levee failure.

### Liability of Local Governments and Levee Districts Concerning Levee Maintenance and Floodplain Management

Since courts do not hold the federal government liable for levee failures but are displaying greater sympathy for the plight of land owners subjected to increased flooding due to municipal negligence, it is necessary that:

- FEMA should help make local governments and special districts aware of the possibility of liability for actions or nonactions that aggravate flood hazards.
- FEMA should, in appropriate cases, seek to recoup federal flood-related costs (including flood insurance payments, disaster assistance, etc.) from levee owners/operators when such costs arise from improper operation and maintenance of levee and associated interior drainage facilities.

### Treatment of Levees in the Insurance Aspects of the NFIP

Policyholders for property behind levees should pay premiums determined by reasonable estimates of the residual flood damages. Therefore:

- Regardless of the level of protection provided, the levee-protected area should be disaggregated into flood risk zones and an actuarial rate be established for each zone that reflects the degree of protection actually provided by the levees.

Insurance rate structures should encourage damage mitigating measures by recognizing well-engineered and maintained levees. Conversely, rate increases should follow levee owner failure to fulfill obligations. Therefore:

- Consistent with the design levels of protection recommended in Chapter 3, NFIP policyholders in areas behind existing levees that offer more than 25-year protection or new levees affording 100-year protection or greater should pay lower rates that reflect the reduced risk of property damage.

The adjustment procedure needs to be kept reasonably simple within the limits set by past practice. Specifically:

- The levee flood risk zones should match the existing flood risk zones established for the regular Flood Insurance Programs.

As part of a long-run goal of promoting program equity:

- FEMA should continue its efforts to establish an actuarial rate basis for the Flood Insurance Program and, as far as practical, convert its present rate schedule to actuarial rates. The actuarial rates, as is done by the private insurance industry, would be updated annually to reflect experience, claims paid, and the cost of doing business.

In order to facilitate levee rating according to physical condition:

- FEMA should contract for the development of a list of key categories concerning the physical condition of a levee that would be used to evaluate the levee's ability to function effectively and concerning use of those factors to estimate geotechnical risk. An unsatisfactory rating would result in increased flood insurance premiums.

### Floodplain Mapping Approaches in Levee-Protected Areas

A Flood Hazard Boundary Map (FHBM) is prepared by FEMA for community use on an interim basis until better mapping is developed. While revisions to the emergency program and published FHBMs are not desirable:

- All levees, dikes, or floodwalls should be labeled as such on any <u>new</u> or <u>revised</u> FHBM. Also, the areas protected by levees providing 100-year or greater protection should be delineated on the new or revised FHBMs as Zone LP. Areas protected by levees not meeting

this standard would continue to be mapped as Zone A.

The situation is different for the Flood Insurance Rate Maps (FIRMs) used by communities in the regular program:

- The location of all levees, dikes, or floodwalls credited as providing 100-year protection or more should be clearly denoted on all future FIRMs.

Implementing insurance purchase requirements in levee protected areas, the levee-protected areas must be so designated on the FIRM and the information necessary to determine insurance rates must be provided. Therefore:

- Areas behind recognized 100-year levees that would be flooded (assuming no levee) by a 100-year flood should be designated as Zone ALP. Areas between the 100-year flood boundary and 500-year flood boundary should be designated as Zone BLP.

To facilitate floodplain management activities:

- The locations of all credited levees, dikes, and floodwalls should be clearly denoted on all Floodway Maps.
- Areas behind credited levees providing 100-year protection that would be flooded during a 500-year flood should be shown on Floodway Maps.

If a levee with a level of protection of less than 100 years is to be recognized for flood insurance purposes, the FIRM must carry a designation that will allow appropriate rates to be determined for protected properties. On FIRMs:

- FEMA should create an AL(No.) Zone that would designate an area protected by a levee with a frequency of protection defined by the (No.). For example, if the levee had an elevation equal to the 40-year flood (plus required freeboard), then the Zone would be AL(40).

Since several FEMA maps may be required to show a complete evacuation route and the showing of route portions is not particularly helpful:

- FEMA should not make it a mandatory requirement to include evacuation routes on

maps. If the information is available when the maps are being prepared and if it makes sense from a community-to-community mapping standpoint, then the evacuation routes could be included on the maps. In other cases, it may be expeditious for communities to develop their own special evacuation route maps.

Greater attention should be placed on linking levee operation and interior drainage problems. Therefore:

- Interior drainage situations in areas on the landside of levees should be analyzed in conjunction with the riverine flood analysis, and the areas flooded by interior drainage should be shown on FEMA maps in accordance with current practice. Appropriate consideration should be given to correlation of the event on the river and the event causing the interior drainage problem.

## APPENDIX A:

## GLOSSARY

This appendix defines many terms used in the text of this report. The definitions are generally simplified and applicability may be limited to understanding of usage in the context of this report.

ACTUARIAL INSURANCE RATES--insurance rates that fulfill the financial need in risk transfer, are responsive to competitive market conditions, improve the availability and reliability of insurance, and result in insurance premium charges that are not excessive, inadequate, unfairly discriminatory, or otherwise unreasonable.

AVERAGE ANNUAL FLOOD DAMAGE--the average flood damage one could expect over a period of many years should neither flood hazard nor floodplain occupancy change nor inflation occur.

BERM--a horizontal strip or shelf of material built contiguous to the base of either side of a levee embankment for the purposes of providing protection against underseepage, erosion, increasing stability of the embankment, or reducing seepage. Can be located on either side of a levee, depending upon the berm's purpose.

CLOSURE DEVICE--any movable and essentially watertight barrier, used in flood periods to close an opening in a levee, securing but not increasing the levee's design level of protection.

COMMUNITY--any state or area or political subdivision thereof, or any Indian tribe or authorized tribal organization, or Alaska native village or authorized native organization that has authority to adopt and enforce floodplain management regulations for the areas within its jurisdictions.

COMPACTION--the placement in layers and densifying of fill materials in an earthen levee or dam structure, ordinarily by rolling or vibration.

CRITICAL FACILITY--a structure housing a community service of such a nature that the loss associated with discontinuity of service from even extremely remote (less than 0.2 percent chance per year)

incidences is not ordinarily acceptable. Examples of such facilities are electrical substations, natural gas terminals, and hospitals and schools where evacuations and other proper safeguards might not be able to be taken.

DISCHARGE--a rate of water volume flowing at a particular location in a given period of time, normally expressed in cubic feet per second.

EXECUTIVE ORDER 11988--a presidentially established policy (May 24, 1977) directed to all federal executive agencies discouraging actions that would do any thing to increase flood losses in the 1 percent chance (annual) or 100-year floodplains.

FEMA--Federal Emergency Management Agency, an agency of the federal government, established by Reorganization Plan No. 3 of 1978, to create a central point of management for emergency planning and response activities of the federal government.

FIA--"Federal Insurance Administration," a unit within the Federal Emergency Management Agency responsible for the administration of the insurance operations aspects of the National Flood Insurance Program as defined under the National Flood Insurance Act of 1968.

FLOOD--an overflow from a normal water course onto adjacent land not normally covered by water or a hydrologic event contained within levees but having discharges or stages higher than normally occur.

FLOOD, BASE--in the NFIP, the flood having a 1 percent chance of being equalled or exceeded in any given year.

FLOOD, DESIGN--the flood magnitude adopted to determine the dimensions of a hydraulic structure, normally expressed in terms of stage, frequency, discharge, or as a generic standard.

FLOOD FREQUENCY--based on statistical analyses; in terms of probability, the percent chance of an event being equalled or exceeded per year; the reciprocal of recurrence interval that is the average interval of time in years between floods equal to or greater than a specified discharge or stage.

FLOOD FRINGE--all that land lying within the 100-year floodplain that is not within the floodway.

FLOOD HAZARD DESIGNATION--NFIP classifications delineating flood zones encompassing defined ranges of annual probability of flooding. The classifications relevant to riverine levees are:

Zone A--areas subject to flooding by 100-year or smaller events.
Zone B--primarily, areas subject to flooding by events rarer than the 100-year and up to 500-year events.

Zone C--areas not subject to flooding by 500-year or smaller floods.

FLOODPLAIN--an area, adjoining a body of water, that has been or may be covered by floodwater.

FLOODPLAIN MANAGEMENT--nonstructural measures employed to reduce the exposure of people and property to floods, e.g., land-use planning, warning schemes, insurance, flood-proofing, evacuation, relocation.

FLOOD PROFILE--a graph showing the relationship of a flood water surface elevation to location, the latter generally expressed as lineal distance along a stream.

FLOODWALL--a concrete wall constructed adjacent to a stream for the purpose of preventing flooding of property on the landside of the wall; normally constructed in lieu of or to supplement a levee where the land required for levee construction is more expensive or not available.

FLOODWAY--the regular channel of a river or stream plus any adjacent floodplain areas that must be kept free of encroachment in order that the 100-year flood can be carried without substantial increase in height or the introduction of hazardous velocities. The basic NFIP standard for allowable increase in height is 1 foot, but some states are more stringent.

FREEBOARD--the vertical distance between a design flood elevation and the top of a hydraulic structure. In the context of this report, a levee or floodwall. Freeboard is provided to assure passage of the design flood without overtopping and is necessary to account for hydrologic and hydraulic uncertainties.

HUMAN INTERVENTION--engagement by people in defensive activity immediately prior to or during a flood period, e.g., installation of stop-logs, sand bags, operation of pumps, streetgates, etc.

HYDROGRAPH--a graphical representation of discharge, stage, or other hydraulic property with respect to time for a particular point on a stream.

INTERIOR DRAINAGE--the runoff or ponding of water, either overland, or channelized, or pooled, that originates from the landward side of a levee and drains to the levee-protected area. Seepage must also be considered in interior drainage planning.

LEVEE--an earthen embankment generally built parallel to a shoreline to prevent flooding of the landside of the embankment and engineered to accepted standards.

LEVEED AREA, LEVEE-PROTECTED AREA--the landside area and properties protected from inundation by the presence of a levee (or floodwall).

LEVEE, COASTAL--an earthen embankment or seawall, constructed adjacent to the sea or an estuary for the purpose of preventing flooding on its landside.

LEVEE FAILURE--any structural insufficiency, overtopping, or inability to close openings that results in flooding of a levee-protected area.

LEVEE PENETRATION--any placement of a pipe, utility conduit, or other facility through a levee embankment perpendicular or skewed to the direction of flow.

LEVEE, RIVERINE--an earthen embankment, constructed adjacent to a river or other watercourse, for the purpose of preventing flooding of the landside of the embankment. Levees may also be used to tie embankments paralleling a river to high ground to reduce inundated area during levee failure.

MAP, FLOOD HAZARD BOUNDARY (FHBM)--a community map of a preliminary nature, prepared by FEMA, and identifying, by approximate methods, areas of special flood, mudslide, or related erosion hazard.

MAP, FLOOD INSURANCE RATE (FIRM)--an official community map, prepared by FEMA and showing risk zones and base flood elevations within special hazard areas.

MAP, FLOOD BOUNDARY AND FLOODWAY--a map prepared for the purpose of floodplain management showing flood and floodway boundaries curvilinearly.

NATIONAL FLOOD INSURANCE PROGRAM--The program, created by the National Flood Insurance Act of 1968 as amended, and further defined by the Flood Disaster Protection Act of 1973, as amended, under which communities may be eligible for federally subsidized flood insurance on the condition that the communities enact satisfactory floodplain management regulations. The program is administered by the Federal Emergency Management Agency.

100-YEAR FLOOD--a flood estimated to be equalled or exceeded on an average of once in 100 years (1 percent chance of exceedance in any given year).

PONDING AREA--a relatively low, designated space within a levee-protected area where water is temporarily stored during floods and then drained by gravity or pumping, depending on the relative elevation to adjacent receiving waters.

RIVER STAGE--the height of water surface of a stream above some discretionary datum.

RISK--the probability or chance of loss or damage occurring.

RISK PREMIUM ZONE--a zone delineated on a Flood Insurance Rate Map, which identifies the Risk Premium Rate structure applicable to that area.

RISK PREMIUM RATE (see Actuarial Insurance Rates)--those rates established by the Federal Insurance Administrator pursuant to individual community flood risk studies undertaken to provide flood insurance in accordance with Section 1307 of the National Flood Insurance Act of 1968 and accepted actuarial principles. Risk Premium Rates include provisions for operating costs and allowances.

SEEPAGE--the movement of water through or under the materials of a levee earth embankment.

SIDE SLOPES--the inclined side faces of a levee, numerically expressed as a ratio of horizontal to vertical dimensions.

STABILITY ANALYSIS--a series of engineering calculations to determine the ability of an earthen structure, e.g., levee, to resist movement when loads are applied to it.

STANDARD PROJECT FLOOD (SPF)--a flood that might be expected to result from the most severe combination of meteorological and hydrological conditions considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. The SPF is often used as a Corps of Engineers' design goal for hydraulic structures in urban areas.

STOP LOG--a log, plank, cut timber, steel, or concrete beam fitting into end guides between walls or piers to close an opening in a levee, floodwall, dam or other hydraulic structure; the logs usually being handled or placed one at a time.

STREET GATE--a closure gate used during flood periods to close a roadway opening through a levee or floodwall.

WATERSHED--the area contributing runoff to river flow at a particular location; also river basin, catchment.

## APPENDIX B:

## FEMA INTERIM LEVEE POLICY

### I. POLICY (ISSUED FEBRUARY 10, 1981)

#### Ownership

FIA will not consider privately owned, operated, or maintained levee systems unless local ordinance or state statute mandates operation and maintenance. Levees for which the community, state, or federal government has responsibility for operation and maintenance will be considered by FIA provided that the criteria discussed below are met.

#### Design Requirements

The Federal Insurance Administration has the responsibility under Public Law 90-448 to identify the special flood hazard areas of the United States. A special flood hazard area has been defined as that area subject to a 1 percent or greater annual chance of flooding. In order for FIA to remove the special flood hazard designation from an area "protected" by levees, we must be assured that the area involved does not fall within this definition.

The degree of protection afforded by a levee system is uncertain because of both the uncertainty involved in establishing the 1 percent chance flood elevations and the uncertainty involved in the structural stability of the levee itself. Common engineering practice in the construction of flood protection works, such as dams and levees, is the inclusion of a freeboard allowance above the computed water surface levels, to allow for all of the uncertainties in analysis, design, and construction that cannot be fully or readily considered in an analytical fashion. In the case of the National Flood Insurance Program, freeboard allowances must be a major factor in establishing a levee's probability of providing protection against the true 1 percent annual chance flood. FIA must be reasonably certain of this level of protection before the floodplain management, insurance purchase, and lender notification requirements under the Program can be removed from the leveed area.

FIA will require a minimum levee freeboard of 3 feet, with an additional foot within 100 feet either side of structures within the levee or where ever the flow is constricted, such as at bridges. An additional half-foot above this minimum is also required at the upstream end, tapering to the minimum at the downstream end of the levee. This standard has been generally utilized by the Corps for levees protecting populated areas and is based on long-term experience with the success and failure of levee systems.

The above criteria will be utilized to evaluate levee systems in all ongoing and future analyses of flood hazards conducted by FIA. This includes initial identifications, studies, restudies, map revisions, LOMAs, etc. At the present time, no effort should be undertaken to revise maps for the sole purpose of implementing this policy. However, this policy shall be applied for all maps issued by FIA from the date of this memo and for which the 6-month compliance period has not yet started. Where this freeboard criteria has not been met, the onus for demonstrating that protection from the 1 percent chance flood does exist, with a lesser freeboard, will be on the levee owner. As discussed above, this will be a difficult analytical task that must address all the uncertainties involved in establishing flood discharges and the structural stability of the levee system itself. A report documenting such analyses must be submitted to, and approved by, FIA before such a levee will be credited.

Inspection and Evaluation

Prior to any levee system receiving credit on any future map issued by FIA, the contractor responsible for the production or revision of that map will be required to determine that the minimum design requirements itemized above have been met. In addition, a field inspection or suitable alternative, will be required to verify that the levee appears structurally sound and adequately maintained. A certification from a federal or state agency, or a registered professional engineer, that the levee meets the minimum design criteria above and that it appears, upon visual inspection, to be structurally sound and adequately maintained may be utilized in lieu of a site specific inspection by the contractor. Levees with obvious structural defects or obvious lack of maintenance will not be credited by FIA.

Human Intervention and Operation of Closures

In general, FIA will not recognize human intervention (e.g., capping of levees by sand bagging, earth fill, flashboards, etc.) for the purpose of increasing a levee's design level of protection during an imminent flood situation. The levee must be designed and maintained to provide adequate 100-year protection without human supplementation. Human intervention will only be accepted for the

operation of closure structures (e.g., gates, stop logs, etc.) in a levee system designed to provide at least 100-year flood protection, including adequate freeboard as described above. FIA will recognize levees with closures only under the following conditions:

1. The levee system was designed with the closure to be an integral part of the system during operation. Sand bagging of openings would not be sufficient.
2. The levee system was designed to require human operation of closures or human backup is provided for automatic systems.
3. Sufficient flood warning time exists for the operation of all closure structures, including necessary sealing, before flood waters reach the base of the closure.
4. Operation and maintenance of closure structures are responsibilities mandated by local ordinance.
5. A formal operation plan addressing closure operation and including specific assignments of responsibility is available and capable of being implemented.
6. Periodic operation of the closure structure (at least once annually) is performed for testing and training purposes.
7. Sufficient documentation, indicating that each of the above requirements has been met, has been provided to, and accepted by, FIA.

Mapping of Leveed Areas

Levees meeting the design, closure, and inspection requirements listed above will be credited with providing protection from the 1 percent chance flood on FHBMs and FIRMs. However, the protected area will be identified with a note on the maps stating

> This area protected from the 100-year flood by levee, dike or other structure subject to failure or overtopping during larger floods.

All such areas will be shown as Zone B on the FIRM and as areas subject to the 500-year flood on the FBFM, to highlight the residual risk of flooding. Floodways will be delineated at the inside toe of mainline and tributary levees that are credited on a map. This will assure that no development will occur on the outside of the levee, which may jeopardize the levee's integrity, or effectiveness.

As part of all future study, restudy or map revision effort, where credit will be given to levees providing 100-year protection, the adequacy of interior drainage systems will be evaluated. Areas subject to flooding from inadequate interior drainage behind levees will be mapped using standard procedures. Often, shallow flooding zones, or even numbered A Zones, may be applicable in these instances.

For the area contained within a levee (i.e., the protected area) providing less than 100-year protection, the base flood elevation to be shown is that computed as if the levee did not exist. For the area outside of such a levee, the elevations to be shown are those obtained

from the profile that would exist at the time levee overtopping begins, or from the profile computed as if the levee did not exist, whichever is higher.

This procedure recognizes the increase in flood elevation in the unprotected area, which is caused by the levee itself. This procedure may result in flood elevations being shown as several feet higher on one side of the levee than the other. Both profiles should be shown in the study report and labeled as "before levee overtopping" and "after levee overtopping," respectively. Separate Floodway Data Tables should be prepared for each side of the levee and adequately labeled. The Flood Insurance Rate Map should show a gutter line, running along the levee centerline, separating the areas of different base flood elevations and zones. Flood Hazard Factors and Zones should be computed independently for each area using the standard procedure.

### Proposed and New Levees

Requests to FIA for guidance on levee construction should be addressed by referencing the minimum requirements discussed above and the Corps of Engineers' manual, "Design and Construction of Levees" (EM 1110-2-1913), for basic principles to be applied. FIA approval of design plans and as-built certifications will be handled on a case-by-case basis. All future requests for map revisions or letters of map amendment, on the basis of newly constructed levees, will require FIA's review of as-built specifications according to the minimum standards outlined above and the principles outlined in the Corps' manual. Levees proposed for construction in an identified floodway must also be approved through the exception process outlined in Part 60.6 of the Program regulations.

## II. EXCEPTIONS TO LEVEE FREEBOARD REQUIREMENTS (AUGUST 17, 1981)

### Background

The interim levee policy issued on February 10, 1981, provides for exceptions to the minimum freeboard standard provided that the levee owner can demonstrate, to FEMA's satisfaction, that adequate protection is provided against the 1 percent chance (100-year) flood. A report documenting an assessment of the uncertainties involved in establishing the 100-year flood profile, as well as the structural stability of the levee, was required in order for FEMA to make an adequate technical evaluation.

This provides further guidance on the nature of the required report and essential elements that must be addressed. It is not intended to set forth the specific criteria with which these elements will be evaluated. This evaluation must be made on a case-by-case basis after a thorough review of the exception request report by FEMA's engineering staff or consultants familiar with the design of levee

systems. The elements outlined below pertain to the evaluation of freeboard exception requests only; additional factors may require consideration in the comprehensive evaluation of other aspects of a levee system.

Elements Required

The purpose of a freeboard allowance is to provide for those factors that cannot be rationally accounted for in design flood profile computations. When exceptions to the freeboard standard are sought, the levee owner must demonstrate that those factors that have not been directly considered in the 100-year profile computations are of insignificant consequences and do not appreciably increase the probability that the levee will overtop or fail during the true 100-year event. The elements that must be addressed in an exception request are discussed below.

1. Uncertainty in the Design Flood Profiles

Ideally, a levee system that is credited with providing 100-year flood protection would have no chance of overtopping or failure during the true 100-year flood, or a smaller event. This can never be the case because of the uncertainties associated with estimating the 100-year flood and the uncertainties in the structural stability of the levee itself. The freeboard allowance is an important factor in increasing the probability that protection from the true 100-year flood does exist, as an earth levee built only to the estimated 100-year flood profile has less than a 50 percent chance of providing true 100-year flood protection.

a. Hydrologic uncertainty. An exception request from the standard freeboard requirement must evaluate the variance in the estimated 100-year discharge, which could result in an underestimation of the magnitude of the true 100-year flood. In general, ungaged streams, or streams with a short period of gage record, have flood estimates with greater variance. Thus, there is less certainty that the estimated 100-year discharge will fall within reasonable limits of the true value. The exception request should include a computation of the 100-year discharge with the expected probability adjustment. The approximate confidence limit at which levee overtopping begins should also be identified in the report. Where confidence limits or the expected probability adjustment cannot be computed directly from statistical analysis of gaged records, they should be estimated by some reasonable method that is documented in the report.

b. Hydraulic uncertainty. Uncertainty in flood discharges can be translated into corresponding uncertainty in flood profiles using

standard hydraulic techniques. Stream reaches with a high degree of hydraulic sensitivity (i.e., relatively great changes in stage result from a relatively small change in discharge) would have a greater tendency for levee overtopping than a less sensitive stream. The freeboard exception request should include a profile developed using the 100-year flood discharge with the expected probability adjustment. It should also include a profile run at the discharge where levee overtopping just begins and an assessment of the approximate confidence limit corresponding to that discharge. Where a high degree of uncertainty exists in the 100-year discharge and the stream reach is hydraulically sensitive to changes in discharge, reduction in the freeboard requirement would not be warranted.

Other factors that must be assessed in the evaluation of the hydraulic uncertainty are the potential and magnitude of debris or sediment accumulation or ice jamming during the 100-year discharge event. Sources of debris, sediment, and ice in upstream areas should be considered, as well as any historical evidence of ice or debris blockage or sediment deposition. The behavior of such materials within the leveed reach, and particularly at bends or constrictions, should be addressed. Where such problems are common, the expected level of flood protection from a levee system designed considering only free-flow events can be greatly reduced. A reduction in the standard freeboard requirement would not be warranted in this situation.

## 2. Uncertainty in Levee Structural Stability

a. Seepage Levees work primarily on the principle of providing a mass of material large enough to prevent shear failure by the hydrostatic and hydrodynamic forces acting on the levee embankment and foundation. Because of the construction costs involved, levees rarely contain the impervious cores or drainage layers common to earth dams. Since levee embankments are actually flooded for relatively short periods of time, such expenditures are usually not warranted. Thus, levee mass is substituted for other design features that would control seepage. This is necessary, because, once the levee embankment becomes completely saturated during a period of high water, seepage emerges on the landside slope and failure probability through loss of slope stability and internal erosion increases greatly.

For given levee top widths and side slopes, the mass of a levee section is determined by the levee height. Thus, the freeboard above the 100-year flood level is a good indication of the relative mass of the levee section and the length of the seepage path before saturation occurs. Whenever freeboard lower than the standard is being proposed, this usually implies a levee of lower mass. In this situation, other factors that influence the rate and degree of levee embankment and foundation saturation must be addressed.

The analyses supporting the request for exception from the standard freeboard requirement should demonstrate that saturation through the levee foundation and embankment will not occur during the 100-year

flood, or that the levee is designed for stability against loading conditions for case IV as defined in the Corps of Engineers manual, "Design and Construction of Levees" (EM 1110-2-1913, Chapter 6, Section II). The following factors should be addressed in these analyses:

1. Depth of flooding
2. Duration of flooding
3. Embankment geometry and length of seepage path at critical locations
4. Embankment and foundation materials
5. Embankment compaction
6. Other design factors affecting seepage (e.g. drainage layers)
7. Other design factors affecting embankment and foundation stability (e.g., berms)

Where seepage control is critical and stability problems are likely, an exception to the standard freeboard requirement would not be warranted.

b. Surface Erosion As with seepage control, most levees rely primarily on greater mass to compensate for loss of levee material through erosion caused by flow velocity and wave wash. Requests for exception from the standard freeboard requirements should demonstrate that no appreciable erosion of the levee embankment can be expected during the 100-year flood, as a result of either stream currents or waves, or that anticipated erosion would not result in failure of the levee embankment or foundation directly or indirectly through reduction of the seepage path and subsequent instability.

The following factors should be addressed in these analyses:

1. Expected flow velocities, especially in constricted areas
2. Expected wind and wave action
3. Slope protection techniques
4. Duration of flooding at various stages and velocities
5. Embankment and foundation material
6. Levee alignment, bends, and transitions
7. Levee side slopes

Where erosion potential is significant, an exception to the standard freeboard requirement will not be made.

c. Settlement Levees constructed with minimal or no compaction, or where embankment or foundation materials are undrained or composed of materials of high compressibility, will often experience a significant amount of postconstruction settlement. This settlement can result in losses of freeboard as large as 15 percent of the total levee height. An exception request from the standard freeboard requirement must

evaluate the potential and magnitude of future losses of freeboard as a result of levee settlement and assess the following factors:

1. Embankment loads
2. Compressibility of embankment soils
3. Compressibility of foundation soils
4. Age of levee system
5. Construction compaction methods

For new or recently enlarged levee systems where minimal or no compaction was utilized in construction or where foundation soils are undrained or of high compressibility, a detailed settlement analysis must be made using procedures such as those described in the Corps of Engineers manual, "Soil Mechanics Design--Settlement Analysis" (EM 1110-2-1904). For established levee systems (more than 10 years old), the exception request should address the above 5 factors, the amount of settlement that has occurred since construction, and the amount and rate of expected future settlement. Where additional loss of freeboard due to expected future settlement could contribute significantly to the probability of levee overtopping or structural failure during the 100-year flood, an exception to the standard freeboard requirement will not be granted.

Procedure

Upon a determination that a levee system does not meet the minimum freeboard requirements as established in the February 10, 1981, policy memo, the levee owner may appeal FEMA's determination to designate the leveed area as flood-prone. The sole basis for the appeal shall be the demonstration that adequate protection from the 100-year flood exists. This demonstration will be accomplished through a technical report submitted by the levee owner that addresses each of the above elements. The report must be certified by a registered professional engineer to be correct and accurate to the best of his or her knowledge. The same registered professional shall also certify that the levee system is adequately designed and maintained to protect against the 100-year flood.

Upon receipt of this report and certification, FEMA will review the report either in-house, through another federal agency, or through a consultant familiar with the design and construction of levee systems. During this review, the levee owner may be required to provide additional data and certifications necessary to complete the review.

Upon completion of the review, FEMA will revise the appropriate community map or inform the levee owner why the levee system was found to be deficient. Maps will not be revised while either the levee system or FEMA's review is incomplete. The exception request, technical backup report, and certifications will be retained by FEMA as documentation for the exception.

## III. LOCAL FLOOD-PROTECTION STRUCTURES NOT COVERED BY THE INTERIM LEVEE POLICY

The interim levee policy, issued on February 10, 1981, is applicable only to riverine levees constructed of earthen materials. It is not applicable to coastal flooding situations or to structures constructed partially or wholly of concrete, or similar impervious materials. This is because the interim levee policy incorporates certain assumptions regarding the nature of flooding and modes of failure of typical earthen riverine levees.

In the case of nonriverine flooding, or of other structures, such as concrete dikes, seawalls, or levees with steel or concrete sections, the following procedures are to be followed.

### Federal Structures

Flooding within the area protected by federally constructed structures shall be as established by the agency responsible for their design and construction, provided that the structure has been adequately maintained. Where 100-year flood analyses have not been made by the agency, the analysis procedures recommended by that agency shall be utilized by FEMA contractors conducting the evaluation.

### Nonfederal Structures

For nonfederal structures, the "burden of proof" will be on the owner to demonstrate the degree of flood protection afforded by the structure. A technical report providing such demonstration will be reviewed and approved by FEMA staff, FEMA contractors, or another federal agency.

## APPENDIX C:

## GUIDELINES FOR OPERATION AND MAINTENANCE OF LEVEE, FLOODWALL, AND INTERIOR DRAINAGE FACILITIES

(a) GENERAL

(1) The structures and facilities for local flood protection shall be continuously maintained in such a manner and operated at such times and for such periods as may be necessary to retain designed capabilities and fulfill NFIP objectives.

(2) The state, political subdivision thereof, or other responsible local agency, which furnished assurance that it will maintain and operate flood control works in accordance with these regulations, as required by law, shall appoint a permanent committee consisting of or headed by an official hereinafter called the "Superintendent," who shall be responsible for the development and maintenance of and directly in charge of an organization responsible for the efficient operation and maintenance of all of the structures and facilities during flood periods and for continuous inspection and maintenance of the project works during periods of low water.

(3) A reserve supply of materials needed during a flood emergency shall be available at all times in a condition acceptable for immediate use.

(4) No encroachment or trespass that will adversely affect the efficient operation or maintenance of the project works shall be permitted upon the rights-of-way for the protective facilities.

(5) No improvement shall be passed over, under, or through the walls, levees, improved channels, or floodways, nor shall any excavation or construction be permitted within the limits of the project right-of-way, nor shall any change be made in any feature of the works without prior certification by appropriate authorities, FEMA, or their authorized representative that such improvement, excavation, construction, or alteration will not adversely affect the functioning of the protective facilities. Permitted improvements or alterations shall be constructed in accordance with standard engineering practice.

(6) It shall be the duty of the Superintendent to report annually and following flood events to FEMA on inspection, maintenance, and operation of the protective works.

(7) The levee owner will furnish other local interests with an Operation and Maintenance Manual. This manual shall begin with an outline of design functions and objectives and describe principles for operation and maintenance to keep the system functional and efficient. The manual shall be reviewed by the Superintendent for appropriateness and understandability for each project under his jurisdiction or separate useful part thereof.

(b) LEVEES

(1) Maintenance. The Superintendent shall provide at all times such maintenance as may be required to ensure serviceability of the structures in time of flood. Measures shall be taken to promote the growth of sod, to exterminate burrowing animals, and to provide for routine mowing of the grass and weeds, removal of wild growth and drift deposits, and repair of damage caused by erosion or other forces. Where practicable, measures shall be taken to retard bank erosion. Periodic (at least annual) inspections shall be made by the Superintendent to ensure that the following maintenance measures are being effectively carried out and further to be certain that:

a. No unusual settlement, sloughing, or material loss of grade or levee cross-section has taken place. Observation of continuity of grade of top of levee on periodic inspections is extremely important and must be supplemented by ground surveys of crest elevations at intervals no greater thann 100 feet or other acceptable modern methods.
b. No caving has occurred on either the land side or the river side of the levee that might affect the stability of the levee section.
c. No extraordinary seepage, saturated areas, or sand boils are occurring.
d. Toe drainage systems and pressure relief wells are in good working condition and that such facilities are not becoming clogged.
e. No revetment work or riprap has been displaced, washed out, or removed so as to expose the underlying embankment.
f. No action is being taken such as burning grass and weeds during inappropriate seasons, which will retard or destroy the growth of sod.
g. Access roads to and on the levee are being properly maintained.
h. Cattle guards and gates are in good condition.
i. Crown of levee is shaped so as to drain readily and any roadway thereon is well shaped and maintained.
j. There is no unauthorized grazing or vehicular traffic on the levees. Particularly, recreation vehicles should be kept off the faces of levee embankments.
k. Encroachments are not being made on the levee right-of-way that might endanger the structure or hinder its proper and efficient functioning during times of emergency.

Such inspections shall be made immediately prior to the beginning of the flood season, immediately following each major high-water period, and at such intermediate

times as may be necessary to ensure adequate care of the levee. Immediate steps will be taken to correct dangerous conditions disclosed by such inspections. Regular maintenance repair measures shall be accomplished during the appropriate season as scheduled by the Superintendent.

(2) Operation. During prolonged periods of high water the levee shall be patrolled continuously to locate possible sand boils or unusual wetness of the landward slope and to be certain that:

a. There are no indications of slides or sloughs developing.
b. Wave wash or scouring action is not occurring.
c. No settlement or deterioration has occurred to cause reaches of levee to be lower than the levee as a whole.
d. No other conditions exist that might endanger the structure.

Appropriate advance measures will be taken to ensure the availability of adequate labor and materials to meet all contingencies. Immediate steps will be taken to control any condition that endangers the levee and to repair the damaged section.

(c) FLOOD WALLS

(1) Maintenance. The Superintendent shall be responsible for periodic inspections to be certain that:

a. No seepage, saturated areas, or sand boils are occurring.
b. No undue settlement has occurred that affects the stability of the wall or its water tightness.
c. No trees exist, the roots of which might extend under the wall and accelerate seepage.
d. The concrete has not undergone cracking, chipping, or breaking to an extent that might affect the stability of the wall or its water tightness.
e. There are no encroachments upon the right-of-way that might endanger the structure or hinder its functioning in time of flood.
f. Care is being exercised to prevent accumulation of trash and debris adjacent to walls and to ensure that no fires are being built near them.
g. No bank caving conditions exist riverward of the wall that might endanger its stability.

h. Toe drainage systems and pressure relief wells are in good working condition and are not becoming clogged.

Such inspections shall be made immediately prior to the beginning of the flood season, immediately following each major high-water period, and otherwise at intervals not exceeding 90 days. Measures to eliminate encroachments and effect repairs found necessary by such inspections shall be undertaken immediately. All repairs shall be accomplished by methods acceptable in standard engineering practice.

(2) Operation. Continuous patrol of the wall shall be maintained during flood periods to locate possible leakage at monolith joints or seepage underneath the wall. Floating plant (e.g., barges, dredges) or boats will not be allowed to lie against or tie up to the wall. Should it become necessary during a flood emergency to pass anchor cables over the wall, adequate measures shall be taken to protect the concrete and construction joints. Immediate steps shall be taken to correct any condition that endangers the stability of the wall.

(d) DRAINAGE STRUCTURES, INTERIOR DRAINAGE, AND FLOODWAYS

(1) Maintenance. Adequate measures shall be taken to ensure that inlet and outlet channels and all interior drainages are kept open and that trash, drift, or debris is not allowed to accumulate near drainage structures. Flap gates and manually operated gates and valves on drainage structures shall be examined, oiled, and trial operated at least once every 6 months. Where drainage structures are provided with stop-log or other emergency closures, the condition of the equipment and its housing shall be inspected regularly, and a trial installation of the emergency closure shall be made at least once each year. Periodic inspections shall be made by the Superintendent to be certain that:

a. Pipes, gates, operating mechanism, riprap, and headwalls are in good condition.
b. Inlet and outlet channels are open.
c. Care is being exercised to prevent accumulation of trash and debris near structures and that no fires are being built near bituminous coated pipes.
d. Erosion is not occurring adjacent to a structure that might endanger its water tightness or stability.

e. The capacity of the channel or floodway is not being reduced by the formation of shoals.
f. Banks are not being damaged by rain or wave wash and no sloughing of banks has occurred.
g. Riprap sections and deflection dikes and walls are in good condition.
h. Approach and egress channels adjacent to the improved channel or floodway are sufficiently clear of obstructions and debris to permit proper functioning of the project works.

Immediate steps will be taken to repair damage, replace missing or broken parts, or remedy adverse conditions disclosed by such inspections.

(2) Operation. Wherever gates are permitted and high water conditions impend, the gates will be inspected a short time before water reaches the invert of the pipe and any object that might prevent closure of the gate shall be removed. Manually operated gates shall be closed to prevent inflow of flood water. All drainage structures in levees shall be inspected frequently during floods to ascertain whether seepage is taking place along the lines of their contact with the embankment. Immediate steps shall be taken to correct any adverse condition.

(e) CLOSURE STRUCTURES

(1) Maintenance. Closure structures for traffic openings shall be inspected by the superintendent every 90 days to be certain that:

a. No parts are missing.
b. Metal parts are adequately covered with paint.
c. All movable parts are in satisfactory working order.
d. Proper closure can be made promptly when necessary.
e. Sufficient materials are on hand for erection of closures and the location of such materials will be readily accessible in times of emergency.

Tools and parts shall not be removed for other use. Trial operations of one or more closure structures shall be made once each year, alternating the structures chosen so that each gate will be erected at least once in each 3-year period. Trial operation of all closure structures shall be made whenever a change is made in key operating personnel. Where road or railroad operation makes trial operation of a closure structure infeasible, rigorous inspection and drill of operating personnel may be submitted therefor. Trial

operation of sand bag closures is not required. Closure materials will be carefully checked prior to and following flood periods and damaged or missing parts shall be repaired or replaced immediately.

(2) Operation. Erection of each movable closure shall be started in sufficient time to permit completion before flood waters reach the top of the structure sill. Information regarding the proper method of erecting each individual closure structure, together with an estimate of the time required by an experienced crew to complete its erection, will be covered in the Operation and Maintenance Manual. Closure structures will be inspected frequently during flood periods to ascertain that no undue leakage is occurring and that drains provided to care for ordinary leakage are functioning properly. Boats or floating plant shall not be allowed to tie up to closure structures or to discharge passengers or cargo over them.

(f) PUMPING PLANTS

(1) Maintenance. Pumping plants shall be inspected by the Superintendent at invervals not to exceed 30 days during flood seasons and 90 days during off-flood seasons to ensure that all equipment is in order for instant use. At regular intervals, proper measures shall be taken to provide for cleaning plant, buildings, and equipment, repainting as necessary, and lubricating all machinery. Adequate supplies of lubricants for all types of machines, fuel for gasoline or diesel powered equipment, and flash lights or lanterns for emergency lighting shall be kept on hand at all times. Telephone service shall be maintained at pumping plants. All equipment, including switch gear, transformers, motors, pumps, valves, and gates shall be trial operated and checked at least once every 90 days. Tests of all insulation shall be made whenever wiring has been subjected to undue dampness and otherwise at intervals not to exceed 1 year. A record shall be kept showing the results of such tests. Wiring disclosed to be in an unsatisfactory condition by such tests shall be brought to a satisfactory condition or shall be promptly replaced. Diesel and gasoline engines shall be started at such intervals and allowed to run for such length of time as may be necessary to ensure their serviceability in times of emergency. Only skilled electricians and mechanics shall be employed on tests and repairs. Operating personnel for the plant shall be present during tests. Any equipment removed from the station for repair or replacement shall be returned or replaced as soon as practicable and shall be trial operated after reinstallation. Repairs requiring

removal of equipment from the plant shall be made during off-flood seasons insofar as practicable.

(2) Operation. Competent operators shall be on duty at pumping plants whenever it appears that necessity for pump operation is imminent. The operator shall thoroughly inspect, trial operate, and place in readiness all plant equipment. The operator shall be familiar with the equipment manufacturers' instructions and drawings and with the "Operating Instructions" for each station. The equipment shall be operated in accordance with the above-mentioned "Operating Instructions" and care shall be exercised that proper lubrication is being supplied all equipment, and that no overheating, undue vibration, or noise is occurring. Immediately upon final recession of flood waters, the pumping station shall be thoroughly cleaned, pump house sumps flushed, and equipment thoroughly inspected, oiled, and greased. A record or log of pumping plant operation shall be kept for each station.

(g) MISCELLANEOUS FACILITIES

(1) Maintenance. Miscellaneous structures and facilities constructed as a part of the protective works and other structures and facilities that function as a part of or affect the efficient functioning of the protective works shall be periodically inspected by the Superintendent and appropriate maintenance measures taken. Damaged or unserviceable parts shall be repaired or replaced without delay. Areas used for ponding in connection with pumping plants or for temporary storage of interior runoff during flood periods shall not be allowed to become filled with silt, debris, or dumped material. The Superintendent shall take proper steps to prevent restriction of bridge openings and, where practicable, shall provide for temporary raising during floods of bridges that restrict channel capacities during high flows.

(2) Operation. Miscellaneous facilities shall be operated to prevent or reduce flooding during periods of high water. Those facilities constructed as a part of the protective works shall not be used for purposes other than flood protection unless designed therefor.

(Paraphrased from Title 33, USCE)

## APPENDIX D:

## MINORITY OPINIONS

### (1) Counter Argument Favoring Recognition of New Levees Built to 25-Year Flood Level

by F. Webster, F. Wetmore, R. Platt, and P. Swift

This minority opinion favors recognition for the purpose of reducing insurance premiums of new levees that provide protection at the 25-year or greater level. It is the opinion of this minority that (1) to exclude this group of levees from the NFIP while recognizing existing levees in this same category is inconsistent, and (2) the purpose of the NFIP being to mitigate flood hazard for existing structures wherever possible, is best furthered by not discouraging the construction of engineered levees to provide whatever level of protection is economically justified. This opinion is based on the assumption that new buildings behind such levees would, as practiced and recommended by this committee, be required to meet the 100 year base elevation requirement.

Other expressed reasons for adopting this position include the fact that additional land must be used to construct larger levees; the visual impact of a larger levee may be objectionable; and a mixture of structural and nonstructural measures should be encouraged, rather than simply relying on structural solutions.

### (2) Counter Argument to Requiring Flood Insurance Purchase Behind Levees With a Level of Protection Between the 100- and 500-Year Floods and for Properties Below the 100-Year Flood Elevation

by L. Eisel, D. James, S. Tucker, and F. Wetmore

This is an issue in which there is no absolute right or absolute wrong, but the balance of evidence seems to be on the side of not requiring insurance to be purchased. The minority makes the following counter arguments:

1. The cost of insurance to the property owner is unknown. If the rates are high it could be an onerous burden. The property owner should have the opportunity to decide whether or not he wishes to buy insurance.
2. Occupants in levee protected areas according to committee recommendations would be advised periodically that their properties

are so situated. They can then be also advised that insurance is available and how it can be purchased. The property owner can then make an informed decision on whether or not to buy.

3. The standard of the NFIP is the 100-year flood, which has over time become an acceptable standard. Larger floods can and do occur, but the cutoff has to be reasonable; the test of experience has proven the 100-year flood an acceptable standard. This committee recommendation will create the only situation in the FIA program in which insurance is required for areas that are outside the 100-year floodplain. This is inconsistent with the rest of the program and represents a quantum policy leap for FEMA.

4. The committee is recommending standard criteria for levee acceptance and retention as recognized by NFIP. Enforced compliance with these standards will make levees more dependable on the average than in the past. Until recently FEMA has accepted levees that are at an elevation equal to the 100-year water surface elevation (without freeboard) as providing sufficient protection to obviate the mandatory insurance purchase requirement. The interim levee policy (Appendix B) and the standards recommended by this committee add 3 feet of freeboard plus geotechnical considerations plus operation and maintenance requirements that will tend to upgrade the level of protection of "100-year levees." It is unreasonable to require communities to adopt higher levee standards and then add insurance requirements to the burden.

5. During flooding events, considerable effort is typically developed to fight the flood. Sand bags are added to levees, sand boil problems are fought, pumps are activated, etc. In the recent Fort Wayne, Indiana, flood it was reported that 25,000 people participated in the flood fight. While this considerable effort did not prevent the flood, it certainly served to reduce damages. Such intense flood fighting efforts tend to counterbalance some of the other deteriorating effects that can reduce the effectiveness of a levee.

6. An argument used to support mandatory insurance is that "Congress will bail out the unfortunates when the disaster occurs." Mandatory insurance makes this unnecessary. This has happened, but it is not right. If it is not right, the situation should be addressed directly and not solved by requiring everyone to buy flood insurance even though they are already paying for flood protection from a 100-year levee of acceptable standards. The floodplain occupant should have a choice in this situation. Also, most federal aid available is in the form of Small Business Administration 8 percent loans (or as much as 15 percent loans, depending upon the financial standing of the applicant)--not exactly "bailouts."

(3) Counter Argument for Requiring Mandatory Insurance Purchase for Land Levels Less Than the National 100-Year Flood, Protected by Levees Greater Than Either the SPF or 500-Year Level

by F. Webster

It is my opinion that insurance purchase should be based on the expected consequences of flooding rather than just the probability of flooding. Although the chance of flooding a protected area under these circumstances may be less than that for 100-year protection by a factor of 5 to 10, the resulting damage during an overtopping or breach event can be catastrophic and result in larger expected damages than for a similar event in a normal B or C Zone. There is a difference between water lapping at your door step and water lapping at the eaves of your roof during a 500-year event.

(4) Counter Argument to Requiring Elevating New Buildings Behind Areas Protected by Less Than 100-Year Flood Levees (AL Zones)

by F. Wetmore

Consider the following points:

1. In some areas the elevation requirement will be the equivalent of prohibiting all new building construction.

There are many areas protected by substantial but less than 100-year levees where 100-year flood levels will require elevation of new buildings 10 to 18 feet above the ground. Small lots in existing built-up communities prohibit building or fill at this elevation. While it is technically possible to build buildings this high, it is economically infeasible for new houses to be so elevated.

2. Large areas will be affected by this construction prohibition.

On the Mississippi River and lower Illinois River in Illinois, the Illinois Department of Transportation (IDOT) has identified over 900 square miles of areas protected by substantial levees that will not be rated as 100-year levees according to the new criteria. In these areas, the IDOT has identified nine small cities and villages, some of them located as much as 4 miles from the nearest high ground. These incorporated areas have an estimated total population of 3,600 people. We have not attempted to estimate the population in the remaining unincorporated areas, although they include numerous small unincorporated communities.

3. Where there are substantial levees, the proposed standard will have to be defended against the following common sense arguments:

- Some of the levees that will not qualify as 100-year levees were not overtopped and did not fail during the 1973 flood. This flood has been rated by the Corps as being at least a 100-year flood upstream of St. Louis.
- To those who are protected to the 80- or 90-year flood, the 100-year standard and its additional prohibitory requirements will be declared arbitrary.
- If the committee recommends that existing buildings can have flood insurance rates that reflect the actuarial risks adjusted for the protection provided by the levee, why cannot new buildings be given that opportunity?
- The tough standard makes more sense when property owners have alternate construction sites outside of the floodplain. Communities that are located up to 4 miles from high ground do not have any alternate construction sites.
- The elevation requirement will make very little sense to those who are told to elevate a building even though the flood protection elevation is not as high as the tops of their levees.

Conclusion: It should be evident that requiring new buildings to be elevated above the 100-year flood level in areas protected by levees that have successfully withstood 100-year floods will result in serious political repercussions. The rule will seem grossly unfair to those who own property, whose taxes are paying to operate and maintain the levees, and who want to see their community continue to exist. This committee must recognize that implementation of the proposed rule is equivalent to telling a community that the government has decided that it should not have a future in spite of its investment in flood protection.

Alternative proposal: The proposed rule makes sense in theory but cannot be defended where there are substantial levees protecting entire communities. This alternative proposal is an attempt to modify the extreme effects of the proposed rule in the areas which will be hardest hit. It is based on the following conditions:

1. Since these areas will be rated as A Zones, there will still be an insurance purchase requirement.
2. This alternative is only proposed for areas protected by levees that are operated and maintained by a government agency.
3. This alternative could be limited to those areas where flood depths are at least, say 4 feet (i.e., those areas hardest hit by the elevation requirement).
4. A local ordinance should require mandatory notification of and purchase of flood insurance by all buyers (not just those who have to get mortgages from banks).
5. This proposal assumes that flood insurance rates will be actuarial.

Proposal: Builders of new construction should be allowed to make their own cost benefit calculations and decide whether it is cheaper to elevate the

building or pay the true actuarial insurance rates. In areas where there are substantial levees providing protection from all but the 100-year flood level, the actuarial rate may be low enough to permit construction of the building at grade.

Example of a cost-benefit analysis:

1. Annual costs to elevate on stilts in an AL Zone:

For a builder of a $50,000 house, the cost of the same house built on open pilings (the cheapest method) 15 feet above the ground (so the first floor is at the 100-year flood elevation) is $55,000-$60,000.

At 13 percent interest adding $5,000 to a 30-year mortgage means $664 in additional annual mortgage payments. Adding $10,000 to the 30-year mortgage increases the mortgage payments by $1,327 per year.

Flood insurance for structural coverage on that house in Zones A8-A14 (the zones for the Mississippi River at Quincy and the lower Illinois River) costs $0.16 per $100 for the first $35,000 coverage and $0.05 per $100 for the rest. The cost for a 3-year policy (again the cheapest method) $0.16 x 350 + $0.05 x 150 = $63.50 x 3 = $190.50 + $20 expense constant = $210.5 or $71 per year.

Annual costs = ($664 to $1327) + $71 = $735 to $1398.

2. Annual costs on a building that is not elevated:

Flood insurance for structural coverage on a $50,000 house not elevated but in an AL Zone protected by a substantial levee is unknown.

Assume that the building is rated as if it were flood-proofed (there are a lot of similarities between a flood-proofed building and one protected by a levee). The rating would then be the same as for a building elevated to less than a 100-year flood level in the A8-A14 Zones. For a building elevated to 2 feet below the 100-year flood level, the rate is $0.55 per $100 coverage. For a 3-year policy the annual payment would be $282.

Assume an arbitrarily chosen but high rate of $1.00 per $100 coverage. For a three year policy the annual payment would be $506.

Annual costs = $282 to $506.

It can be seen that in areas where buildings have to be elevated very high, but, where the levees provide a lot of protection, it will be much cheaper for the buildings to build at grade and pay the extra insurance premiums than to pay the lower insurance and additional mortgage costs. However, in areas with insubstantial levees, the levees will not provide much assistance in actuarial rating. Therefore, it will be cheaper for the builders to elevate.

This committee wanted to avoid the all or nothing requirements of the Flood Insurance Program for insurance rating purposes. This proposal follows that direction by providing an alternative to the all or nothing, elevate/do not elevate, requirement.

## (5) Counter Argument for Requiring Floodplain Management Restrictions Within the "Natural" 100-Year Floodplain Behind Sub-SPF Levees

by R. Platt and E. Wood

This minority opinion addresses the need for floodplain management measures in areas within the "natural" 100-year floodplain and protected by a levee of less than the "Standard Project Flood" design.

The reasons for this position are:

1. Estimation of levels of protection is an inexact science. A levee considered to provide protection against a 100-year flood may in fact fall short of this goal due to miscalculation of the 100-year flood discharge or stage.

2. Levels of protection are diminished by increases in the frequency of flooding of a given magnitude due to land use changes (e.g., increased urban runoff, storm sewer discharge) in the watershed upstream.

3. Design levels of protection of a levee on one side of stream may be diminished by activities across the stream (e.g., filling, channel alteration, or construction of a levee). Frequently, floodplains on opposite sides of streams are in different political jurisdictions, they have little or no control over each other's actions, but both influence flood heights in leveed reaches.

4. Even recently built and well-designed levees are subject to (a) overtopping due to floods of greater than design magnitude and (b) failure due to unforeseen deficiencies in design, maintenance, or operation. The new Corps levee system on the Pearl River at Jackson, Mississippi, for instance, failed to completely withstand a discharge of less than its design magnitude due to design defects (unplugged sewer pipe extending under levee from river side to "protected area" and low point where levee met interstate highway embankment).

5. Urban levee systems often involve levee segments of varying age, quality, design level of protection, and general reliability. Fort Wayne, Indiana, for instance, has a levee system constructed between 1913 and 1980. Newer portions are designed to withstand a 100-year flood; older portions are not. The public, however, may not realize that the entire levee system is of uneven reliability and will not know which areas require special precautions. The majority opinion would apparently require floodplain management behind sub-100-year levees but not behind greater-than-100-year levees. This creates a confusing and inequitable situation. Problems of mapping the area protected by each segment of the levee system are obvious. The minority believes that floodplain management should apply to the entire natural 100-year floodplain behind the levee.

6. Floodplain management under the NFIP operates prospectively and selectively. In the flood fringe, residential dwellings must be elevated to the "base flood" (100-year) elevation while commercial facilities may be elevated or flood-proofed to that level. The minority believes these constraints are reasonable for new construction. Public investment in a levee is largely to protect existing development and should not be permitted to encourage new construction in the natural floodplain. Elimination of all restrictions on private land use behind a less-than-SPF levee would induce new construction in areas subject to catastrophic flooding, without appropriate design safeguards.

## APPENDIX E:

## BIOGRAPHICAL SKETCHES OF LEVEE COMMITTEE MEMBERS

L. Douglas James is professor of civil and environmental engineering at Utah State University, director of the Utah Water Research Laboratory, and a member of the NRC Water Technologies Board. He received his Ph.D. in civil engineering from Stanford University. Dr. James has been in his current position at Utah State since 1976. His previous teaching and research experience has been with the Environmental Resources Center, Georgia Institute of Technology, and the University of Kentucky. Dr. James has been a major contributor to reports and studies concerning flood control structures such as "Federal Guidelines for Dam Safety," December 1978; "Federal Dam Safety: Report to OSTP Independent Review Panel," December 1978; "Flood Damage Mitigation in Utah," Utah Water Research Laboratory Report 1980; and many other text books and journal articles.

Leo M. Eisel received a B.S. in forestry from Colorado State University, an MS in hydrology from University of Canterbury, New Zealand, and a Ph.D. in engineering from Harvard. Dr. Eisel is presently with Wright Water Engineering firm in Denver. He has been the director of the Water Resources Council in Washington and director of the Illinois Division of Water Resources in previous years. Dr. Eisel is also a member of another NRC committee reviewing the U.S. Army Corps of Engineers' planning study of the metropolitan Washington, D.C., area water supply.

Gerald E. Galloway, Jr. is a colonel in the U.S. Army and is presently professor and deputy head of the Department of Geography and Computer Science at the U.S. Military Academy at West Point, New York. He received his M.S. in civil engineering from Princeton, an M.P.A. from Pennsylvania State (Capital Campus), and a Ph.D. in geography from the University of North Carolina. He is a registered professional engineer with over 20 years of service in the Army Corps of Engineers. His last assignment was District Engineer for the Vicksburg Engineer District of the Corps of Engineers. At West Point he teaches courses in water resources management and land use planning.

Carl W. Kreitzberg is currently professor of physics and atmospheric sciences at Drexel University. He holds a Ph.D. in meteorology from the University of Washington. His professional experience has been as research

physicist, Meteorology Lab, Air Force Cambridge Research Laboratories, and assistant professor in meteorology at Penn State University.

Rutherford H. Platt is associate professor of geography and planning law at the University of Massachusetts at Amherst. He received his Ph.D. in geography from the University of Chicago and also holds a J.D. from the University of Chicago Law School. He served as assistant director and staff attorney for the Open Lands Project, Inc., Chicago, and is a member of the Illinois bar. He has served on two other NRC committees: the Committee on Flood Insurance Studies, 1979-1982, and the Committee on Water Resources Research Review in 1980. He has also served as a consultant on floodplain policy to various federal and private agencies.

Henry M. Reitz has been president of Reitz and Jens, Inc., consulting engineers since 1969. He received an M.S. from Harvard University. Mr. Reitz's experience includes consulting engagements in manufacturing, commercial housing and utility construction, resource development, and waste disposal for private interests and governmental units. He has a working knowledge of water, mechanics, and physiochemical properties of soils. He has consulted in development of limiting criteria for flood protection, storm drainage, and foundations. From 1970 to 1977 he was a consultant to St. Louis County, responsible for technical criteria for flood protection by levees and special geotechnical considerations. From 1955 to 1958 he was a professor and department head of civil engineering at Washington University in St. Louis, Missouri.

Robert L. Smith is the Deane Ackers Professor of Civil Engineering at the University of Kansas and a member of the NRC Water Technologies Board. He received an M.S. in hydraulics from the University of Iowa and is a member of the National Academy of Engineering. His nonacademic professional experience includes 12 years of work in state water resources planning, first as executive director of the Iowa Natural Resources Council and subsequently as executive director and chief engineer of the Kansas Water Resources Board; a tour as special assistant, Office of Science and Technology, Executive Office of the President, and chairman, Committee on Water Resources Research, Federal Council of Science and Technology; numerous advisory consulting assignments with state, federal, and foreign agencies; and for the past 14 years as a water resources consultant to Black & Veatch, Consulting Engineers, Kansas City, Missouri. Some selected prior professional service activities include chairman, Interstate Conference on Water Problems, 1961; member, U.S. National Committee for the International Hydrological Decade, 1968-71; chairman, ASCE Committee on Water Resources Planning, 1962, also in 1976; and chairman, Committee on Flood Insurance Research Studies, NRC, 1979-81.

Walter D. (Pete) Swift has recently retired from the American Insurance Association (AIA), an organization with whom he had been with since 1960. As assistant/deputy general adjuster he spent 6 months a year developing catatrophe response procedures to expedite the orderly, equitable settlement of insurance losses under stressful conditions. In 1971 he became vice president of the Claims Administration and Property Claims

Services, where he is responsible for planning, direction, control, and economic accomplishments of several programs covering the entire spectrum of property and casualty loss adjustments from catastrophe operations to claims research. He cooperated with the National Flood Insurance Association and the FIA in developing practices consistent with the best interests of the public and compatibility with private sector insurance procedures. He also established formal arrangements with the FEMA, to provide for adequate response to insurance inquiries in disaster relief centers. Mr. Swift holds a law degree from John Marshall Law School.

Scott L. Tucker is executive director of the Urban Drainage and Flood Control District in Denver, Colorado. He received an M.S. in civil engineering from the University of Arizona. Presently he is responsible for managing the activities of the Urban Drainage and Flood Control District, which encompasses 1,200 square miles consisting of 6 counties and 28 cities and towns. The District is involved in a full range of drainage and flood control activities, including drainage way master planning, floodplain management, and construction. Some of his professional consulting activities include: co-chairman of 1975 Engineering Foundation Conference on Floodplain Management; member, Water Quality Management Task Force, Denver Regional Water Quality Study (1976-78); chairman, Water Pollution Control Federal Committee on nonpoint sources of pollution (1978-81); chairman and secretary, ASCE, Urban Water Resources Council (1975-78).

Frederick A. Webster received his Ph.D. in civil engineering from Stanford University in 1972. He was an assistant professor of structural design at the University of Illinois from 1972 to 1975; from 1975 to 1979 he worked for Engineering Decision Analysis Co., Inc., where he was a project engineer responsible for both research and projects, including seismic criteria development, risk analysis, and fire safety system reliability. Presently, he is a project manager with Jack R. Benjamin Associates, Inc., on projects including multiple hazard assessment and mitigation decision analysis for an urban water supply system including levee hazard analysis.

French Wetmore received an M.P.A. from Syracuse University in 1972 and has been chief of Local Floodplain Programs, Division of Water Resources, Illinois Department of Transportation, since 1976. As head of the state's office he advises and assists cities and counties in the preparation of floodplain management programs. He is also the state coordinator for the NFIP. Along with his staff he advises and assists 700 local governments in the program and coordinates the activities of regional agencies and 20 state and federal agencies. He is currently chairman of the Floodplain Regulations Committee of the Association of State Flood Plain Managers.

Eric F. Wood received an Sc.D. in civil engineering from Massachusetts Institute of Technology in 1974. He is currently an Associate Professor of Civil Engineering and, since July 1980, has been director of the Water Resources Program at Princeton University. His expertise is in stochastic hydrology, hydrologic forecasting, and application of mathematical systems theories to river basin planning. Dr. Wood is the editor of a book published in 1980 by Pergamon Press titled Recent Developments in

Real-Time Forecasting/Control of Water Resources Systems and author of numerous papers on hydrologic models and systems analysis of water management. He serves on a number of professional committees and journal editorial boards.

Technical Consultant

George W. Brazier, Jr., is a consulting civil engineer in private practice. As the head of the Corps of Engineers' civil works construction and operations division in its Washington, D.C., headquarters he gained considerable experience applicable to the waterways of the United States. He holds a B.S. degree from the University of Kansas. Mr. Brazier has previously been involved in National Academy of Sciences deliberations concerning the use of double-hulled barges on inland waterways.

## APPENDIX F:

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