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ENGINEERING AND ECONOMIC CONSIDERATIONS IN FORMULATING NONSTRUCTURAL PLANS

Michael W. Burnham, ASCE Member[1]

ABSTRACT

Acceptance and implementation of a broad classification of flood loss reduction actions, termed "nonstructural", have produced a set of measures which vary significantly with respect to physical attributes and performance. The measures may be implemented on a site-specific or broad-scaled basis, be permanent or temporary in nature, and reduce existing or future flood losses. The analyst's understanding of the engineering and economic attributes of the measures plays a major role in formulating viable alternatives in feasibility investigations. These alternatives should include integrated sets of structural and nonstructural measures.

KEY WORDS: Nonstructural measures, engineering and economic analyses, relocation, flood proofing, raising, regulations, flood warning-emergency preparedness plans, expected annual damage, plan formulation.

INTRODUCTION

Federal water resources investigations have placed greater emphasis on formulating nonstructural flood loss reduction measures during the past decade. However, broad-scaled implementation of these measures has not been found economically justified. This result has produced criticism that nonstructural measures have not been given proper attention in the evaluation process. The investigative findings and counter-beliefs by nonstructural measure proponents indicate a continuing misunderstanding of the functions and role of nonstructural measures in reaching the common goal - to reduce the flood losses of the nation.

This paper assists water resources professionals in understanding nonstructural alternatives by describing the measures in a classification framework that clarifies their attributes and performance characteristics. Emphasis is placed on engineering and economic study requirements and performance of the measures. Measure formulation guidelines are included to assist analysts in formulating nonstructural measures and comprehensive plans of structural and nonstructural measures.

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ANALYSIS OVERVIEW AND MEASURE CLASSIFICATION

Analytical Concepts

The Water Resources Council's Principles and Guidelines of 1983 (Water Resources Council 1983) define the primary goal of implementing flood loss reduction actions as enhancement of the National Economic Development (NED) account. An NED plan is determined from the final array of alternatives in the formulation process as the plan that maximizes the system net benefits (damage reduced minus cost). Computation procedures required to evaluate flood inundation benefits (damage reduced) involve the calculation of expected annual damage for with and without project conditions. The procedure for determining expected annual damage is shown in Figure 1. The process involves the integration of hydrologic (discharge-frequency), hydraulic (elevation-discharge), and flood damage (elevation-damage) relationships. Future changes in the watershed or floodplain may also change the relationships over the life of the project.

Equivalent annual damage calculations are required to account for changes over time. These calculations are performed by determining with and without expected annual damage values (Figure 1) for existing and future time periods (accounting for the change conditions). The results are discounted to the present and amortized over life of the project to obtain the equivalent annual values (U.S. Army Corps of Engineers 1977, Water Resources Council 1983). The concept of equivalent values is important in understanding the significance of future conditions in the evaluation process. However, for clarity, future discussions will center about the expected annual damage portion of the flood damage analysis process.

Cost analyses include interest on and amortization of the initial investment (sum of all first costs and interest during the construction period), plus operation and maintenance costs. Costs for replacements necessary to maintain conditions as constructed throughout the project life are also included (Water Resources Council 1983).

The economic evaluation process includes the basic engineering and flood damage study requirements for formulating nonstructural plans. The level of detail of the analysis involving hydrologic, hydraulic, cost estimates, and flood damage assessments should be consistent with respect to each discipline. Evaluations are required for with and without project conditions for existing and future conditions based on projected changes in the watershed and floodplain.

The process also forms the foundation for better understanding the role and performance of specific nonstructural measures. It should be evident that measures implemented for only existing structures may lose performance value if future conditions are altered. The converse is true for alternatives that only regulate future development. Formulated plans should therefore include sets of individual and combination of measures that perform for both existing and future conditions.

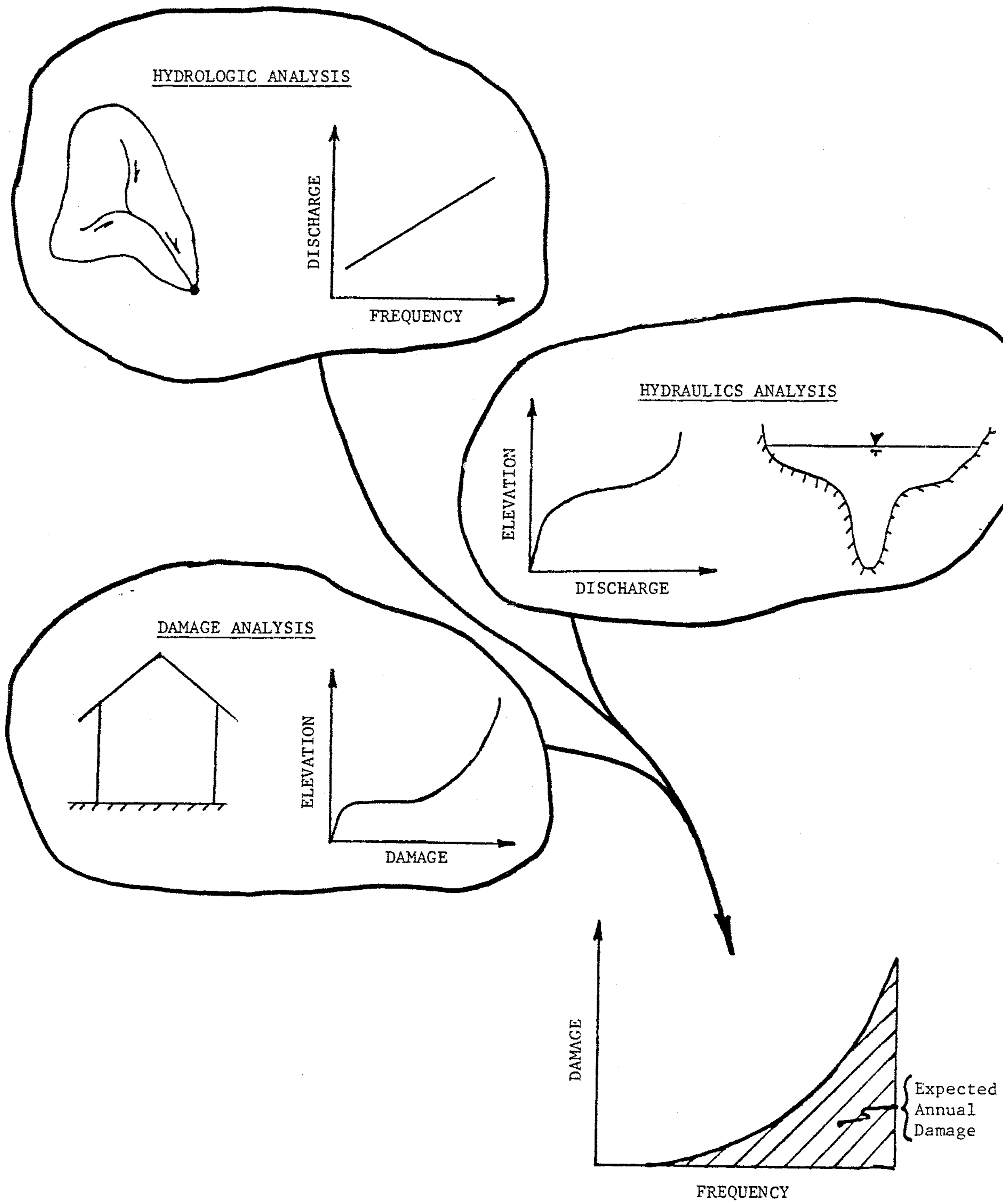

FIGURE 1 FLOOD DAMAGE ANALYSIS PROCESS

Classification of Nonstructural Measures

The research work of (U.S. Army Corps of Engineers, 1978) on the physical and economic feasibility of nonstructural measures evaluated a comprehensive list of individual measures that included:

- Temporary and permanent closures for existing structure
- Raising existing structures
- Small walls around new or existing structures
- Rearranging or protecting damageable property at existing structures
- Removal of existing structures and/or contents from flood hazard areas
- Flood forecast, warning, and evacuation
- Construction materials and practices for new or existing structures
- Zoning ordinances, regulations and building codes
- Public land acquisition
- Flood insurance

The list, essentially complete, demonstrates broad variation in the complexities and performance of the respective measures. It is this variation which makes formulation of individual measures and their interaction (combination of measures) difficult to both conceptualize and perform.

James in 1973, and Davis is 1976, present a classification of nonstructural measures which simplifies the conceptual aspects of the performance of the measures and provides a framework for plan formulation commensurate with the economic evaluation concepts. Their classification scheme placed nonstructural measures into three general categories: (a) permanent modification of the damage susceptibility to existing structures (flood proofing, raising, relocation); (b) management of future development and floodplain actions (regulatory policies, acquisition, taxes, etc.); and (c) temporary event responses associated with flood warning-preparedness planning. It is within this framework that the following discussion of the engineering and economic characteristics of nonstructural measures is presented.

PERMANENT MEASURES FOR EXISTING STRUCTURES

Description of Measures

Nonstructural measures that permanently modify the damage susceptibility of existing structures include: (a) relocation of people and/or people and structures from flood hazard areas; (b) flood proofing (installation of perimeter barriers, i.e., seals, earthen dikes, and walls); and (c) raising structures and contents. The measures normally are designed to protect individual or small groups of structures and, therefore, do not reduce damage to the infrastructure (bridges, streets and utilities) of the community, or to potential future development.

Relocation Alternatives. Relocation is generally considered the most attractive of the nonstructural measures in this classification since inhabitants and their structures and contents are removed from the flood hazard area. The alternative also enables compatible future use of the floodplain area. Utilities, streets and roads, bridges and other infrastructure aspects of the area involved in relocation are typically removed or modified to reduce future damage.

Permanent Flood Proofing. Permanent flood proofing of existing structures involves the placement of protective materials on the structure, or implementation of perimeter walls or dikes around the structure. Flood proofing by use of seals may include closures of openings or placement of sealant materials on the structure. The placement of perimeter walls and earthen dikes around a structure or small group of structures provides protection to the structure and surrounding landscape and utilities. The measures may be implemented for residential, commercial, and industrial structures, where sufficient right-of-way permits.

Permanent Raising of Structures and/or Contents. Permanent raising of existing structures is performed by placing the structure on a new foundation or piers. The measure provides protection to the structure but not to out-structures, utility lines, or surrounding landscape.

Implementation of actions to permanently raise structure contents are applicable for residential, commercial, and industrial structures. The measures reduce flood damage to selected contents that can be permanently raised, normally to a higher floor. Water heaters, furnaces, air conditioners, washers and dryers, and other equipment may be raised from basements or first floors to a higher floor or elevation in residential, commercial, and industrial structures. Machinery and inventories may be raised in commercial and industrial structures. Operations of commercial and industrial businesses may be maintained or downtime due to flood events significantly reduced by these actions.

Engineering Analyses

Hydrologic and Hydraulic Studies. Hydrologic and hydraulic studies involving relocation, flood proofing, and raising of structures, generally consist of without conditions assessments for existing and future conditions since these measures do not typically alter the hydrologic or hydraulic flow regime. An exception is alterations in conveyance (elevation-discharge relationships), such as, from changes in land use resulting in extensive relocation or demolition of structures in a damage reach.

Design and Cost Studies. Design analyses are required in planning studies of raising, flood proofing and relocation of structures to estimate the practicality of implementing these measures. These studies consider the physical attributes of the existing structures and construction requirements and materials necessary to perform desired actions. The results are used to develop generalized and detailed cost estimates for implementing the measures. The primary design consideration for implementing the measures is economics. The diversity of the structures and construction techniques nationally makes generalization of the feasibility of the measures difficult. However, basic design factors can be identified and hopefully detailed site specific designed estimates limited to situations where implementation is practical.

Flood proofing design studies of placing sealant materials and closures of openings require investigation of the capability of the structure to substain velocity, hydrostatic, and bouyancy forces during flood events. Because of their structure integrity, commercial and industrial structures are normally more likely candidates for flood proofing than residential structures. Most residential structures can withstand no more than about two feet of head differential between the interior and exterior before damage occurs to the walls, or the structure floats off the foundation.

Perimeter earthen dikes and walls offer flexibility with both site and use. Design factors include analysis of topography, flood velocities, hydrostatic pressure, and seepage. Perimeter dikes and walls around residential structures are typically limited to less than three feet for safety considerations. Higher barriers may be constructed around commercial and industrial structures, however, these measures fall under the freeboard and other design requirements associated with flood walls and levees.

Design costs involved with raising existing structures limit the alternative to single family residential and small commercial structures. The most practical application is for wood frame structures (including brick veneer and stucco) without basements. Design analyses must consider upgrading the structure foundation or piers, and utilities to meet present building codes. Since the incremental costs associated with structural design and other aspects are relatively small compared to the initial set-up, structures may be raised several feet to meet desired protection levels.

The economics of removing existing structures, and therefore inhabitants and contents from the flood hazard area, generally limit the alternative to one- or two-story residential or light commercial structures. Structural weights and access to the first floor joists make the measures most practical for wood frame structures on raised foundations or basements. Structures of brick, masonry, or slab-on-grade are less feasible due to special precautions required in transferring the structure (U.S. Army Corps of Engineers, 1978).

Demolition in place is applicable for a broader range of structures since many types of structures cannot be economically relocated. Both removal and demolition alternatives must consider relocation assistance costs specified in Public Law 91-646, "Uniform Relocation Assistance and Land Acquisition Policies Act of 1970".

An example of basic 1980 costs associated with removal and demolition options for single family residential structures in the metropolitan Phoenix area is provided in Table 1. The estimates show the annual cost of removing the structure and contents to be about $5400, and for acquisition and demolition to be $6700. The cost items listed are applicable for other locations throughout the nation.

Flood Damage Evaluations

Flood damage analyses determine flood inundation reduction benefits associated with implementing permanent relocation, flood proofing, and raising of structures alternatives. Expected annual damage calculations are performed for with and without conditions. The assessments evaluate the effects of the measures' modification to the elevation-damage relationship shown in Figure 1.

Damage assessments are typically performed for individual or small groups of structures of similar characteristics. The location of the structure in the floodplain significantly affects the expected annual damage of the structure. Research by U.S. Army Corps of Engineers (1978), and Johnson and Davis (1984), has shown that expected annual damage decreases rapidly (exponentially) as structures are located at higher elevations farther out in the floodplain.

TABLE 1

RELOCATION COST ESTIMATES
(U.S. Army Corps of Engineers 1980)

1. Remove Structure and Contents to Flood Free Site:
(1,600 square feet residential structure, block construction, slab-on-grade)

a.	Purchase land in flood hazard site	$ 5,000
b.	Purchase land in flood free site	10,000
c.	Prepare new site (grade, foundation, utilities, etc.)	15,000
d.	Move structure to new site (maximum of 15 miles)	11,000
e.	Conversion of vacated land to new use	4,400
f.	Moving and related expenses	800
g.	Conversion of vacated land to Government	500
	Subtotal	46,700
	Contingencies 25%	11,675
	Supervision and Administration 25%	11,675
	Total	$70,050

say $70,050 per structure

Annual cost @ 7-3/8%, 50-year life $ 5,400

2. Remove Contents and Demolish Existing Structure
(1,600 square feet residential structure, block construction, slab-on-grade)

a.	Acquisition of existing structure and site	$50,000
b.	Demolition of existing structure	2,700
c.	Moving and related expenses	800
d.	Conversion of title to Government	500
e.	Conversion of vacated land	4,400
	Subtotal	$58,400
	Contingencies 25%	14,600
	Supervision and Administration 25%	14,600
	Total	$87,600

Annual cost @ 7-3/8%, 50-year life $ 6,700

Investigative Considerations and Summary

Analysts have emphasized relocation, raising, and flood proofing of structures in formulating nonstructural alternatives. Often comparison of these measures with structural alternatives are made at the same protection levels, the .01 exceedance (100-year) frequency or greater. However, research by Johnson, (1978) and the experience of the Hydrologic Engineering Center indicate it is unlikely that relocation, raising, and flood proofing residential structures are feasible above a .04 exceedance (25-year) event. This is largely due to expected annual damage values decreasing exponentially as structures are located at higher elevations (U.S. Army Corps of Engineers, 1978, Johnson and Davis 1984), high residual damage associated with flood proofing and raising, and the relatively high costs of relocation alternatives.

The above finding is significant in formulating and implementing nonstructural measures that permanently modify the damage susceptibility to existing residential structures. Analysts must evaluate these measures at lower protection levels to find feasible implementation options. Implications are that feasible plans are likely to be found, but only for a relatively small group of structures located in the floodplain. Residual damage is also likely to be significant, perhaps 90 percent or more of the without condition expected annual damage of the reach. An issue becomes, is it appropriate to implement an alternative that reduces the hazard to a small portion of the floodplain structures in which the impact of the plan is likely to be unnoticed by the public and others?

Flood proofing analysis of multifamily residential, commercial, and industrial structures is normally performed on an individual structural basis. The feasibility of implementing flood proofing measures is highly dependent on the structural integrity, damage potential, and associated flood characteristics of the structure. This makes uniform protection of such structures in a reach unlikely.

A potential role of nonstructural measures in this classification, that has not been appropriately addressed by analysts, is that of incremental justification in conjunction with implementation of structural alternatives. For example, is it more feasible to provide a specific protection level by implementing solely a structural alternative, or by combination of a structureal alternative and relocation, flood proofing, or raising alternatives? For small numbers of structures involving implementation of nonstructural measures, the latter alternative clearly warrants careful investigation.

MANAGEMENT OF FUTURE DEVELOPMENT

Description of Measures

Managing future development and floodplain activities are applicable to new construction (on or off the floodplain), sanitary land fills, and other floodplain activities, such as gravel mining operations. The regulatory measures control land use through zoning ordinances, building codes and restrictions, or purchase of land or easement rights. Other measures are taxation, which makes floodplain locations more expensive, and flood hazard information systems. Structures and activities not precluded from floodplain locations are required to be maintained and operated to recognize the flood hazard and to not induce damage to existing structures and other infrastructure features.

Regulatory policies are compatible with other flood control measures by limiting encroachment inside the design limits of the project. Local sponsors are often required to sign regulatory agreements as part of the project to assure the design operation is maintained in the future.

The flood insurance program (National Flood Insurance Act 1968) requires participating communities to manage future development as part of the program. The economic feasibility or enhancements of the regulatory requirements may be performed as part of the plan formulation process.

Engineering Analyses

Hydrology/Hydraulic Studies. Hydrologic investigations of future land use conditions require analysis of changes in runoff due to urbanization and other effects. These include impacts of changes in volume (impervious areas) and timing (storm sewers, changes in upstream conveyance systems) on the runoff hydrographs. Analysis of the effects of regulatory compensatory storage systems located off the floodplain and extensive floodplain land fills which alter the storage may also be required.

Hydraulic water surface profiles evaluations of projected future conditions are required to evaluate the effects of changes in conveyance caused by development land fills or piers, sanitary land fills, stream crossings, and other floodplain activities. The evaluations may be used to assist in the type of development and encroachment limitations permitted as part of a floodplain regulatory policy.

Design and Cost Studies

Design studies for implementing floodplain regulatory actions primarily involve structural requirements associated with elevating future development on fill, foundations, or piers above the regulatory elevation. The analyses should consider the structural integrity associated with settlement, scour, erosion of fill, and flood velocity and debris impact forces. Design studies of flood proofing actions of future commercial and industrial structures to the policy elevations are similar to those described for existing structures. Cost items for elevating future structures are primarily for fill, piers, and foundations, access ramps, stairways, and utilities (Flood Insurance Administration).

Flood Damage Evaluations

Flood damage evaluations of alternatives designed to manage future development is important to the implementation of acceptable regulatory actions by community officials and public. The determination of the economic benefits associated with alternative plans provide decision makers with needed information on the value of respective alternatives.

An example of flood damage evaluations performed for alternative floodplain regulatory policies for the Salt River in the metropolitan Phoenix area is shown in Table 2. Plan 1 represents existing expected annual damage to buildings along the Salt River floodplain. Plan 2 represents the damage for the most probable future condition in absence of floodplain regulations. The evaluations indicate an estimated 68 percent increase in future damage without regulatory actions. Plans 3, 4, and 5 represent alternative regulatory policies that meet the requirements of the Federal Flood Insurance program. The analysis indicates that future damage will continue to increase if projected development occurs, even with the implementation of floodplain regulations. The increase, however, is significantly less than without such policies. The increase in future expected annual damage is due to events that can occur above the assumed 100-year regulation of future development.

TABLE 2

FLOOD DAMAGE ANALYSIS OF MANAGEMENT
OF FUTURE DEVELOPMENT ALTERNATIVES[1]
(U.S. ARMY CORPS OF ENGINEERS 1982)

	EXPECTED ANNUAL DAMAGE ($1000)				
LOCATION	PLAN 1	PLAN 2	PLAN 3	PLAN 4	PLAN 5
MESA	113.9	849.0	178.9	144.9	315.4
TEMPE	687.5	1392.2	1101.1	1057.9	1145.4
PHOENIX	1218.5	1285.4	1279.2	1287.6	1279.9
PHOENIX-BUCKEYE	254.8	304.4	302.8	324.1	302.8
TOTALS	2274.7	3830.8	2882.0	2816.5	3043.5
% CHANGE EAD	-	+68	+27	+24	+34

DESCRIPTION OF PLANS

Plan 1 - Exiting w/o Conditions
Plan 2 - Future Conditions w/o Regulatory Policies
Plan 3 - All Future Development on Fill to 100-Year Flood Level
Plan 4 - No Future Development in 100-Year Floodplain
Plan 5 - Future Residential Development on 100-Year Fill;
Future Commercial and Industrial Structures
Flood-Proofed to 100-Year Flood Level

(1) Values Do Not Reflect: Hydrologic/Hydraulic Effects from Reduction in Natural Storage or Channel Conveyance

Investigation Considerations and Summary

Regulatory floodplain management policies have been implemented throughout the United States, primarily as part of the Federal Flood Insurance Program. However, evaluation of alternative policies largely have been ignored in flood loss reduction investigations. More emphasis in analysis of regulatory measures is necessary to assist decision makers in adopting viable floodplain policies that reduce future flood losses.

Analytical investigations should include assessments of the impacts of various regulatory policies both on and off the floodplain. The assessments should be comprehensive to include impacts of projected future development, sanitary land fills, and other floodplain activities. The consequences of the absence of future regulations, even with an existing flood insurance program, should be clearly defined.

Analysts and decision makers should be aware that future flood damage is likely to increase, even with implementation of regulatory actions. This is due to the probability of events occurring above the regulatory policy level. An exception may be if the policies prohibit reconstruction of old or damaged structures within the regulatory boundaries.

Regulatory measures of future development and floodplain activities are compatible with other structural and nonstructural measures. They should be integral to plans involving reservoirs, channels, levees, detention storage basins, relocation, raising, and flood proofing measures.

FLOOD WARNING-EMERGENCY PREPAREDNESS

Description of Measure

A flood warning-emergency preparedness plan is a complex group of related temporary actions designed to mitigate flood losses. Plans consist of predetermined functional arrangements and emergency actions implemented on a response basis during flood events. Flood warning-emergency preparedness plan components include: flood threat recognition; warning dissemination; emergency response actions; post-flood recovery/reoccupation; and continuous plan management. Two distinct situations exist: flash flood conditions with short warning times, where loss of life is the primary concern; and conditions where sufficient warning exists so that the threat to life is less significant, and temporary flood loss reduction actions are implemented.

Flood Threat Recognition. Recognition of a flood threat requires means for predicting an impending flood, including a network of observers, weather and streamflow monitoring, transmission of data, and evaluation of a flood situation by forecasts.

Flood Warning Dissemination. Dissemination of a flood warning to floodplain occupants provides the link between recognition of a flood threat and desired emergency response actions.

Emergency Response Action. Emergency response actions include plans for evacuation of threatened inhabitants, flood fighting, search and rescue, and management of vital services.

Post-Flood Recovery/Reoccupation. Post-flood recovery/reoccupation component of a preparedness plan consists of steps and resources necessary to return the community to normal status as rapidly as possible after a flood episode.

Continuous Plan Management. The continuous plan management component provides for the necessary actions, on a periodic basis, to maintain the viability of the plan between flood events.

Plan Development

The development of a successful flood warning-emergency preparedness plan for a community requires a high degree of communication, cooperation, and coordination between a broad range of public and private organizations and the general public. Decisions as to the type and scale of emergency actions are based on numerous considerations associated with specific events and the impacted community.

The initial phase of the preparedness plan development is to determine existing arrangements for performing the various components of the plan. This is primarily accomplished through interviews of participating officials. Enhancement evaluations of existing arrangements are subsequently developed. These evaluations may include with and without conditions flood scenarios and hydrologic and hydraulic studies, and benefit and cost analyses of implementing temporary flood loss reduction actions.

Engineering Analyses

Hydrologic and Hydraulics Studies. Hydrologic investigations of enhancements to existing flood forecasting procedures may involve location of precipitation and stream flow gages, definition of data transmission procedures, development of runoff forecast models, and revisions to existing project operation procedures. For studies involving enhancements to existing flood forecasting and operations of physical works projects, such as gated reservoirs, with and without conditions discharge-frequency relationships are required to determine the economic feasibility of the enhancements.

In areas where enhanced operations of physical works projects are not applicable, the feasibility of forecasting equipment and procedures are determined by enhanced flood loss reduction actions resulting from increased flood warning times. Exceptions are flash flood conditions where installation of forecasting and alert procedures may reduce the potential for loss of life.

Hydrology and hydraulic data required to formulate the emergency response component of preparedness plans include estimations of warning times and flood inundation boundary maps for various levels of flooding. These data, along with estimates of flow velocities, and depths of flooding, are used to establish evacuation procedures, and temporary flood loss reduction actions.

Cost Studies. The cost of development and implementation of flood warning-emergency preparedness plans include: first costs associated with plan development; periodic costs of the plan maintenance; and costs associated with implementing the plan during flood events. First costs include: development of the formal plans; equipping administrative facilities; purchase of forecasting and other hardware; and stockpiling of equipment and materials. Periodic annual costs include those associated with updating formal plans and arrangements, operation drills, replacement of stockpiled materials, and updates to hydrologic, hydraulic, and damage potential data. Event costs include emergency staffing and overtime, equipment purchase and rental, transportation and storage of personal property, and operations of mass care units.

An example cost estimate for a flood warning-emergency preparedness planning study of the metropolitan Phoenix area is provided in Table 3. A range of estimted costs were used due to the variability and uncertainty associated with developing, maintaining and implementing the preparedness actions. (U.S. Army Corps of Engineers 1982)

TABLE 3

PREPAREDNESS PLAN COST SUMMARY
(U.S. ARMY CORPS OF ENGINEERS 1982)

First Cost

Item	Cost Range ($1,000)		
Formal Plan	$ 75	-	$100
Office/Administrative Outfitting	0	-	0
Equipment/Hardware (Stream Gage)	60	-	80
Information/Brochures	75	-	125
Equipment/Materials (Agency Use)	75	-	100
Equipment/Materials (Temporary Flood Mitigation)	75	-	75
Totals	$360	-	$480
Amortized (50 Yr. @ 7-3/4%)	28	-	38

Annual Cost

Item	Cost Range ($1,000)		
Equipment/Hardware (Stream Gage)	$ 10	-	$ 20
Storage/Rent	5	-	10
Public Information/Brochures, Drills	15	-	25
Flood Mitigation Materials	20	-	20
Totals	$ 50	-	$ 75
Total Annual Cost Range	$ 78	-	$113

Flood Damage Evaluation

Flood damage evaluations of with and without conditions are performed to determine inundation reduction benefits derived from implementing flood warning-emergency response actions. Except for conditions threatening loss of life, benefits must offset the cost of implementing the plan, including flood forecasting actions and associated hardware.

Flood damage reduction actions associated with emergency response actions include temporary measures of: raising or removal of contents; flood proofing (dikes, polyetheylene, etc.); and flood fighting measures (large scale implementation of flashboard, small dikes, sandbags, pumps, etc.). The percentage of structures and reaches that these measures are implemented is highly variable. The effectiveness of such actions is also variable.

An example of a flood damage reduction evaluation for emergency response actions is shown in Table 4. The estimate is for the metropolitan Phoenix area. Damage reductions were assumed for placement of temporary one-foot high perimeter barrier (30% attempted, 50% effective), contents removal (40% removed half of their contents), and raising contents (85% contents raised 3 feet). The assessments and percentages were performed for residential, commercial, and industrial structures (U.S. Army Corps of Engineers 1982).

TABLE 4

DAMAGE REDUCTION ESTIMATE
(U.S. ARMY CORPS OF ENGINEERS 1982)

	Annual Damage ($1,000)	Annual Damage Reduced ($1,000)	Adjusted* Reduction ($1,000)
Existing	$2,454	$ 0	$ 0
1 Foot Barrier	2,142	312	47
40% Content Removal	1,676	778	156
85% Content Raise	2,071	383	184
		Totals	$387

Investigative Considerations and Summary

The feasiblity analysis of implementing flood warning-emergency preparedness actions is difficult because of the unique features associated with specific flood events and the unknown reliability of implementing various actions. Emphasis has been placed on the implementation of enhanced forecasting procedures. More emphasis is needed in evaluating the payoff of enhanced warning time and accuracy of predictions - the emergency response actions. Evaluation techniques include extensive interviews to establish existing arrangements and emergency operations, and analytical assessments to determine the value of enhanced forecasting and response actions. With and without conditions flood scanarios may also assist in formulating plan enhancements.

Flood warning-emergency preparedness plans have a major role in managing catastrophic losses and social disruption associated with large flood events. Analytical considerations in formulating and evaluating flood warning-emergency preparedness actions should be given to implementing the measures on an interim basis, until other flood loss mitigation actions are implemented. Flood warning-emergency preparedness plans, however, should not be considered in lieu of other feasible flood loss reduction measures, due to their temporary nature and uncertain reliability during flood episodes.

Flood warning-emergency preparedness plans should be an integral part of any flood loss reduction plan. The measures enhance operations and reliability of other structural and nonstructural measures, and provide planned response actions when design limits of these measures are exceeded.

CONCLUSIONS

Water resources planning professionals have the responsibility of formulating viable nonstructural alternatives in flood loss reduction investigations. The formulation process involving these measures is complex and requires an understanding of the characteristics and performance of the measures. It also requires an understanding of the engineering and economic study requirements associated with evaluation of the individual measures.

The emphasis of nonstructural analysis to date has been placed on evaluating measures that permanently modify the damage susceptibility of existing structures - relocation, flood proofing, and raising of structures. Unfortunately, most evaluations have been performed at comparable levels-of-protection with structural measures, .01 exceedance probability (100-year) or greater protection levels. The implementation feasibility of these measures is more likely to fall within protection levels less than the .04 exceedance probability (25-year).

More emphasis is required in formulating nonstructural measures that manage future development and flood warning-emergency preparedness actions. Flood plain regulations, which manage future development are vital to reducing the impact of the nation's future flood losses. Preparedness plans can assist in managing losses and social disruptions of catastrophic events where other permanent measures have not been implemented. Both regulatory policies and flood warning-emergency preparedness actions are compatible with other structural and nonstructural alternatives. In fact, they are requisites for having viable flood loss plans for reducing future development.

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