ESTIMATING COSTS AND BENEFITS FOR NONSTRUCTURAL FLOOD CONTROL MEASURES

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FOREWORD

In early 1975 a training document was prepared to illustrate the capability of computer program HEC-5C for analyzing combinations of structural and nonstructural flood control measures. It was recognized at that time that this analysis was dependent upon realistic estimates of aggregate costs and benefits applicable to each damage reach for various magnitudes of protection. This was especially true for nonstructural measures, and led to the awarding of a research contract to develop cost estimates for screening these measures and to further identify current procedures for estimating both costs and benefits.

This research note reports the findings of William D. Carson, Research Economist at the University of California, Davis, on procedures used for estimating costs and benefits of three nonstructural measures: flood proofing, evacuation/relocation, and land use regulation. Cost data from a number of Corps reports are summarized for flood proofing and evacuation. There is also a discussion on benefit evaluation for flood insurance. One objective throughout the investigation was answering the question, what constitutes an adequate analytic tool for screening nonstructural measures? Conclusions reached on this question are also presented.

The material contained herein is offered for information purposes only and should not be construed as Corps of Engineers policy or as being recommended guidance for field offices of the Corps of Engineers. The study was supported by Contract No. DACW05-75-C-0009 from the Hydrologic Engineering Center to the University of California, Davis. Funds were provided by the Institute for Water Resources, Corps of Engineers, Washington D. C. through Intra-Army order No. IWR 74-26.

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INTRODUCTION

Statement of the Problem

Flood losses have continued to increase in spite of huge federal outlays for flood control facilities. This apparent paradox is partly explained by the emphasis which has been placed on the control of flood waters to reduce losses. Structural flood control facilities have often encouraged unwise flood plain development which leads to greater potential losses. Realization of this problem has led to increased interest in measures which are "nonstructural" in the sense that they attempt to control exposure to flooding rather than control the flood itself. Measures such as floodproofing, evacuation - relocation, land use regulation and flood insurance have become important in flood control planning. The need for a methodology to evaluate them has become acute. The explicit need is for a tool which can assess the efficiency of nonstructural measures in a way comparable to the evaluation of structural measures.

Flood control measures are evaluated using cost-benefit analysis.[1] The analysis ranks different flood control measures on the basis of their relative net benefits. Net benefits are determined in two steps. First, gross benefits are calculated as the expected annual damage reduction[2] when comparing the conditions with and without the proposed measure. Second, the annual costs of the measure are subtracted from the gross benefits to arrive at net benefits. Benefits and costs are both annualized using an "appropriate" discount rate and economic life of the project or measure. All of this is well known and is frequently applied by the Corps of Engineers in decisions concerning flood control measures.[3] What has not been adequately addressed is the evaluation of nonstructural measures. The two main shortcomings of present methodology include: 1) estimates of costs and benefits sometimes are made perfunctorily because

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[1]Cost - benefit analysis is not at issue here and so will only be very briefly discussed. Excellent treatments of the topic can be found in: Eckstein, 1958; Mishan, 1968; Misgrave, 1969; and, Prest and Turvey, 1965.

[2]Two other categories of benefits have been identified, these are: intensification and location benefits. No adequate measures of these categories have been developed.

[3]Obviously other factors are considered in decisions regarding flood control. The most prominent considerations are currently the environmental and social effects of the measures.

adequate care is not taken to define the measure in its spatial dimension (see Appendix); and, 2) some estimates are made in detail while other nonstructural measures are written off as unfeasible without apparent economic analysis.

Floodproofing

Floodproofing is an adjustment to a structure or its contents, or both, such that either water is kept from the structure or, the damaging effects of water entry are eliminated or reduced. [U.S. Department of the Army, Flood Proofing Regulations] Measures can be classified as permanent, contingent or emergency. Permanent floodproofing measures do not depend on judgement, flood forecast or warning to put the protection into effect. Contingent, or partial, measures are not effective unless, upon receipt of warning, some minimal action is taken to make them operational. Emergency, or temporary, measures are, upon receipt of warning, either improvised just prior to or during an actual flood or carried out according to an established plan of action. [Flood Proofing Regulations]

Some examples of permanent measures are: 1) site elevation using fill or stilts (raising structures in place); 2) site protection using dikes or flood walls; and, 3) structure protection using anchorage to resist buoyancy, sump pumps, sealing of floors or basement, and increasing the structural strength of buildings to withstand hydrostatic pressure. Examples of contingent measures would include: 1) structure protection through provision of closures for openings below the design flood elevation, protective coverings for appliances, etc.; 2) utility backup protection using valves; and, 3) intentional flooding with clean or flood water to equalize hydrostatic pressures. Emergency measures would include: 1) site and structure protection using sandbags and, 2) contents protection by means of temporary removal to higher elevations (e.g., upper floors). In some cases, short warning times preclude use of all but permanent measures. In this study we limit the empirical discussion to raising in place (raising) and sealing (floodproofing) but the methodology would be appropriate for the other kinds of measures as well.

Evacuation - Relocation

This measure involves the physical and permanent evacuation of activities and people from the floodplain to relocation sites where the flood hazard is lower. Structures are purchased and destroyed, or moved from a specified area of the floodplain (e.g., the floodway). Contents and owners are relocated on sites less floodprone but with equivalent public services. The evacuated area is restored by filling basements, removing debris, reseeding, and etc. The Uniform Relocation and Assistance Act defines the amounts that must be paid for moving expenses and losses as a result of moving and relocation assistance. The implications of this law are important in evaluating the evacuation - relocation measure. Relocation programs are, and probably will continue to be, more difficult to implement than other nonstructural or structural measures because of the social and economic disruption which they entail.

Land Use Regulation

While floodproofing allows present land uses to continue by reducing their susceptibility to damage of structures and relocation alters present land use to make total damages from floods less, regulation attempts to direct future land use in such a way that it is consistent with the flood hazard. Regulations preclude the use of the floodplain for high hazard uses, such as residential, and instead encourage the use of the floodplain for open space, agriculture or other activities not highly susceptible to flood damage. Regulation can take many forms, including; zoning, building codes, subdivision regulation, encroachment lines, public purchase of open space properties [James and Lee] and purchasing the right to develop property. All of these measures have one objective in common - the prevention of future development on the floodplain which is incommensurate with the flood risk. Regulations often take the form of excluding urban development from some areas of the floodplain (the floodway), allowing only agricultural or open space uses there and regulating urban development in other areas of the floodplain (the fringe) such that the structures will be compatible with the flood risk there. For example, building codes might require floodproofing of structures in the fringe to the 100-year probability flood level.

Evaluation of regulation is different than evaluation of floodproofing or relocation because of the requirements of the Flood Disaster Act. This act is interpreted by the Corps of Engineers (EC 1105-2-12) to mean that the with and without conditions are both characterized by the existence of floodplain regulations to the limit of the 100-year flood. This implies that costs and benefits of regulation must only be measured in the case where the Corps recommends regulations beyond the limits of the 100-year floodplain.

Plan of Presentation

The objective of this report is to describe appropriate ways to evaluate costs and benefits associated with nonstructural measures. Relevant professional literature is reviewed to provide a basis for empirical studies. A number of Corps of Engineer studies and planning reports are reviewed and data on costs of nonstructural measures are summarized. Even in reviewing a large number of these reports, including many of those which consider nonstructural measures, only a small amount of usable data are found to be available. These data are presented in Appendix A and in tables in the text. Some synthesis of the data are made where it appears that such a synthesis would be useful to planners of flood control projects. Finally, the need for cost and benefit data are evaluated in the context of macro and micro tools for evaluating flood control systems and local floodplains.

Chapter II

COSTS OF NONSTRUCTURAL MEASURES

Floodproofing

The best estimate of the cost of floodproofing in a floodplain would be made by examining different designs for each structure and choosing the least expensive to add into the total cost estimate. In planning and evaluating future projects, however, a more general process is desirable so that the least efficient alternatives can be eliminated. With a limited budget, this allows for more thorough consideration of the more efficient alternatives. In this section we examine different approaches used to estimate floodproofing cost. We could categorize the approaches into those that employ an estimating equation and those that employ a table of average costs. The equations are found in the professional literature and the tables are sometimes found in reports written by practitioners of flood control planning.

Equations

James and Lee suggested a linear formula for floodproofing costs,

$$C_p = C_d C_2 (CRF_p + M_p) M_s hA \qquad \text{(II.1)}$$

where the symbols are defined as follows: C_p is the average annual cost of floodproofing; C_d is a factor to account for contingencies, design and administration (they suggest 1.30); C_2 is the initial cost of floodproofing per foot of flood depth per dollar of market value of the structure (they suggest 0.035 from Bristol study); CRF_p is a capital recovery factor; M_p is the annual maintenance cost of the floodproofing measures expressed as a fraction of total installation cost; M_s is the market values of all structures to be floodproofed, in dollars per acre (estimated from assessment records); h is the average depth of flooding in feet; and, A is the area flooded in acres. [James and Lee]. This formula assumes that costs increase linearly with depth of flooding and market value of structures in the floodplain. It also assumes that "development is scattered over the floodplain in a reasonably uniform pattern." Statistical tests of this type of equation would be necessary to determine whether it would be appropriate for a particular floodplain. Only very limited data is available on floodproofing costs since interest in this measure is only recent and little implementation has been carried out.

James [1965] also uses a floodproofing cost function based on Sheaffer's work at Bristol.[1960]. Sheaffer calculated that "the average cost of floodproofing 21 types of establishments in Bristol was computed to be $920 per foot of depth of flood water. Based on an average market value per structure of $25,000, the cost of floodproofing is about

$$C_{fp} = 0.035 M_s h \qquad \text{(II.2)}$$

M_s is the market value of structures and h is the design flood depth. In this study James also suggests a more complicated formulation to express the annual cost of floodproofing to protect against a given flow in excess of existing channel capacity (Q_x) as

$$C_p = \tfrac{1}{2} C_d V_f C_2 (CRF_{fp} + M_{fp}) MUK_2 K_1{}^2 Q_x{}^{0.75} \qquad \text{(II.3)}$$

C_p, C_d, C_2, CRF_{fp}, and M_{fp} are all as defined in (II.1); V_f is the proportion of the design flood area which requires floodproofing; $\frac{1}{2}$ is ratio of the average to the maximum depth of flooding; M is market value of structures per urban acre; U is proportion of the floodplain devoted to urban uses; and, K_1 and K_2 are constants determined from the characteristics of the floodplain.

Day and Weisz [IWR 74-P2, p. 945] use a floodproofing cost function based on Sheaffer [1960] of the following form:

$$CP_p = D \cdot SF \cdot p \qquad \text{(II.4)}$$

where: p is the level of floodproofing in feet above the level of dirt fill; CP_p is the cost of floodproofing to level p; D is the cost per square foot of floor space per foot level of floodproofing; and, SF is the square feet of floor area which they predict with market value equations. D is initially set to $.68/SF/p. They comment:

> The general relationship appears to be a reasonable one; all other things being equal, floodproofing cost will increase with increasing size of building structure and with increasing level . . . [but] . . . it would be naive to believe that the cost of floodproofing equation accurately reflects the costs of a wide array of floodproofing alternatives.

These costs occur at site development time and are stated in terms of present value.

All of these formulations posit a fairly simple linear relationship between floodproofing costs, market value of structures and depth of flooding. In fact, the cost functions have a striking resemblance to James' [1965, p. 12] depth-damage relationship

$$\$_u = C_1 M_s d \qquad \text{(II.5)}$$

where $\$_u$ is urban damages, C_1 is a coefficient (presumably empirically determined), M_s is market value of urban structures flooded (only ground floor market value in multistory structures) and d is depth of flooding (less than or equal to five feet). The general thrust of these formulations seems reasonable, i.e. floodproofing costs increase with increasing market value of structure and increasing depth of flooding.

Restating the equation used by James as:

$$C_p = K_p \text{ UMhA} \qquad \text{(II.6)}$$

where,

- C_p = initial cost of floodproofing in a floodplain;
- K_p = average initial cost of floodproofing structures per foot depth per dollar of market value of structures;
- M = market value of structures in the floodplain/acre;
- h = average design flood depth in feet;
- U = fraction of floodplain in urban development; and
- A = floodplain area in acres

we can compare the results of his investigations with the estimates used in Corps of Engineer reports. (See Appendix A and the next section of this chapter.)[1]

The factor K_p is the important parameter in this equation because it represents the average costs of floodproofing the various structures. James [1972, p.984] determined K_p

> by designing floodproofing for a group of representative structures and plotting cost per dollar of structure market value versus design flood depth. Term K_p is the slope of the best fit line through the origin.

He found K_p to be equal to \$0.04 per foot. Some tentative calculations of K_p were made from data gathered in this study. The results varied widely from about .05 to .28. Again the samples were small and only residential structures were included in the calculations. These reasons may indicate that the result-

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[1]The capital recovery factor has been removed here to make the estimates initial rather than annual costs.

ing values of K_p are somewhat high. However, the Telegraph Canyon Creek study (in process in the Los Angeles district) calculated K_p as follows:

Height	K_p
2'	.052
3'	.046
4'	.043
5'	.040

My calculations also showed some variation with height of floodproofing.

At a preliminary stage in the planning process equations such as (II.1)-(II.6) may provide useful estimates of the costs of floodproofing. It seems, however, that the cost relationships will be neither linear nor solely functions of market value and height of floodproofing as more detail becomes available. From the tentative calculations reported here it may be concluded that James' value of K_p may be low -- no definitive statement can be made without more data and a more thorough statistical study.

Corps Reports

Several floodplains have been studied for possible floodproofing by the Corps of Engineers. The methodology of these various reports is given in detail in Appendix A, but here an example will suffice.

The Tug Fork study is probably the most thorough of all the Corps' attempts to cost floodproofing. Because of the large number of structures and floodproofing alternatives in the Tug Fork basin, the applicability of these measures was examined by a thorough study of one principal community and the results were extrapolated to other areas of the valley. Structures were categorized and classified by determining the "correlations between floodproofing costs and such variables as structural value, type of structure, type of construction material, condition, floor area, perimeter length, type of foundation and access." [Tug Fork, p. 50]. Fifteen residences in Matewan were chosen to represent the range of values, construction type and condition of houses in the valley. It was found that for commercial structures there was very unreliable correlation between costs and structural value. Therefore, the commercial structures chosen for analysis were chosen to represent a typical mix of commercial structures representing the four basic types of structures.

Residences in Matewan were found to be of construction type and material such that raising in-place would be the only practical means of floodproofing.

The upper limit of raising in-place was set at 6 feet because raising higher would require expensive structural changes and would result in "an ungainly appearance not easily remedied by landscaping and architectural treatment." Costs were developed for raising houses 2, 4 and 6 feet and houses were classified into three groups: sound, deteriorating and dilapidated. An example is shown as Figure II-1. The ratios of floodproofing costs to the value of the structure for each condition were determined and the average ratios are shown in Table II-1.

Using these ratios, average annual costs of floodproofing were related to the value of structures for each height of floodproofing (see Figure II-2).

Table II-1: Ratio of Floodproofing Costs to Value of Structure

	Floodproofing Height		
Condition	2 feet	4 feet	6 feet
Sound	0.17	0.23	0.31
Deteriorating	0.65	0.75	0.90
Dilapidated	4.50	4.90	5.30

[Source: Tug Fork]

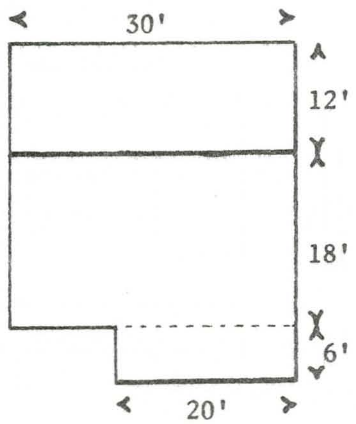
Commercial structures were considered individually and the costs to protect to 3 feet above the finished first floor were estimated. For example, the R.W. Buskirk Building, a two story brick building with a basement, would require the "package" of floodproofing measures shown in Table II-2.

Table II-2: Commercial Floodproofing Package

Adjustment	Estimated Cost
1. Gate value on 8" sewer line	$ 300
2. Sump pumps & drains	800
3. Rework walls	700
4. Waterproof coating for walls	400
5. Bulkheads	7,600
Total	$9,800

[Source: Tug Fork]

Figure II-1: An Example of Floodproofing Costs for a Residential Structure



TWO STORY BRICK WITH BASEMENT

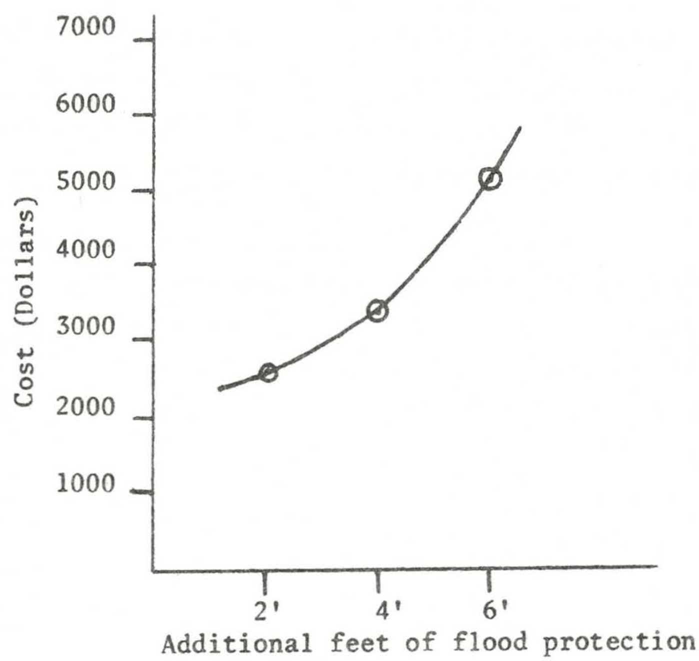
CONDITION OF HOUSE - SOUND

VALUE OF HOUSE - $17,000

SQ. FT. OF HOUSE WITH BASEMENT = 900 SF

SQ. FT. OF HOUSE INC'L PORCH WITHOUT BASEMENT = 120 SF

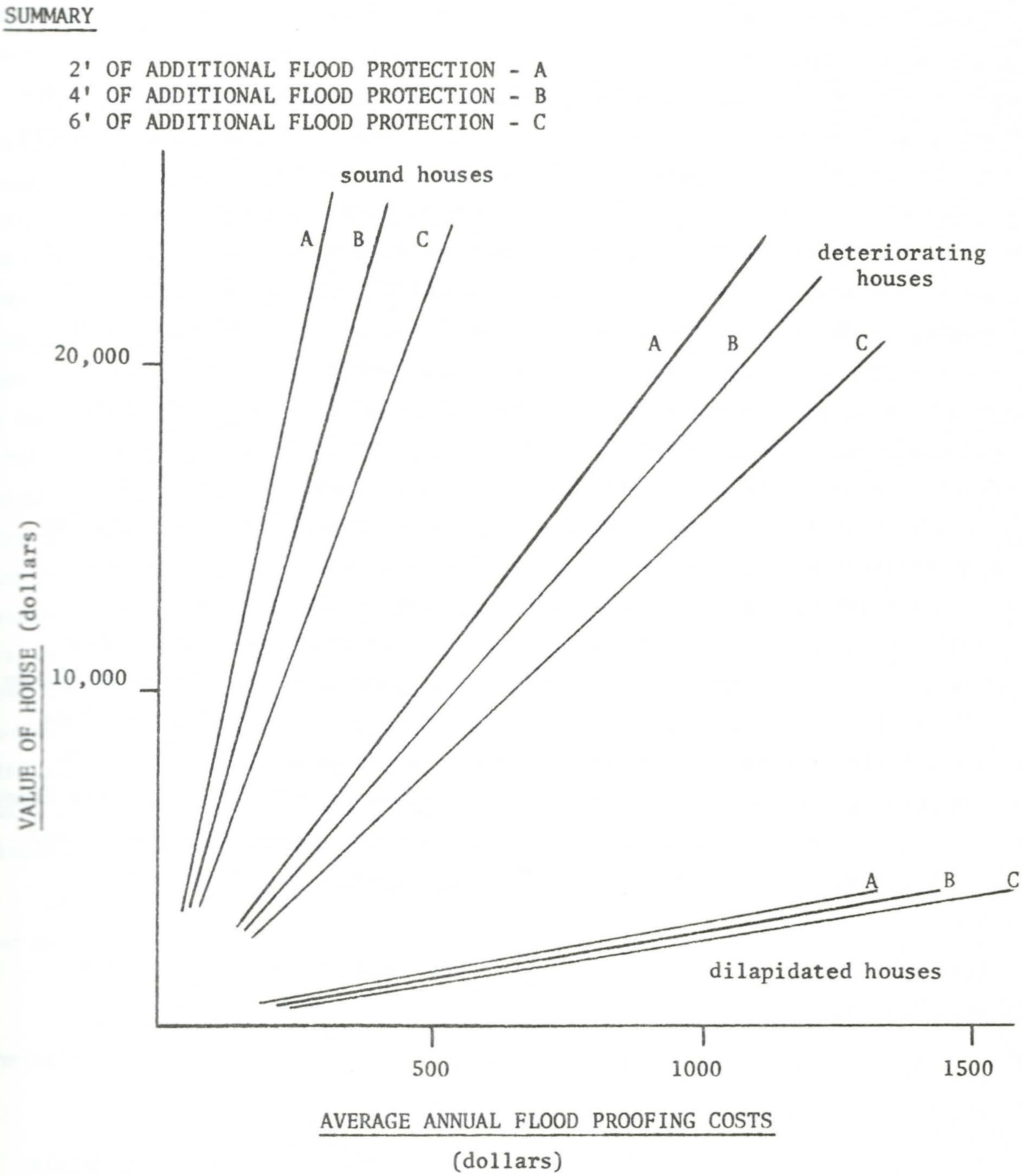
PERIMETER OF FDN WALL = 185 FT.



NOTE: All dimensions are estimated.

[Source: Tug Fork]

Figure II-2: Annual Cost of Floodproofing and Value of House



[Source: Tug Fork]

Tables

Structures in the floodplain could be classified in many ways. Probably the simplest would be to divide structures into the categories of residential, commercial, industrial and public. Each of these structural categories will require a different floodproofing program and there will be considerable variation even within categories (more on this below). Several variables, however, can be identified which are important in determining costs in all categories. First, the unit costs of the materials used to floodproof the structure must be determined. These materials include fill and stilts for raising in place, sealing paints, waterproof adhesives, protective coverings, anchors, etc. These could be determined at local hardware stores, contractors or other suppliers. Second, unit labor costs would need to be determined. Local contractors would be the best source of this information. Third, physical characteristics of the structure would be important in determining the type of floodproofing to be undertaken and its ultimate total cost. Important characteristics include: whether or not there is a basement, the size of the structure (i.e. perimeter, number of stories), first floor elevation and type of construction material. Sources of information would be developers for proposed sites, the local assessor's office for existing sites or, a survey. Fourth, to determine total floodproofing costs certain characteristics of the floodplain need to be determined. The density of development and number of structures in each category at each potential flood depth would help determine total floodproofing costs by category of structure. The potential depth, flow velocity and speed of rise of floods would help determine what type of floodproofing measures would be used. Finally, the extent of efforts to make the floodproofing measures aesthetically pleasing will determine alternative designs and costs. The sources of information in this case are the contractors and owners of the structures.

Total floodplain floodproofing initial costs could be estimated by the following formula:

$$C_{FP} = C_R + C_I + C_C + C_P \tag{II-7}$$

where,

C_{FP} = total initial cost of floodproofing for a particular floodplain area;

C_R = initial cost of floodproofing residential structures;

C_I = " " " " industrial " ;

C_C = " " " " commercial " ;

C_P = " " " " public " .

Each of the quantities on the right hand side of equation II.7 would be determined separately. It should be recognized that floodproofing will seldom be a complete alternative to other measures. It is more likely that floodproofing will be a part of a floodplain management scheme. With this in mind, the methodology suggested for planning purposes should be able to handle selective as well as general floodproofing.

Because of the variations among floodplains it is best to tailor the cost estimates to the floodplain and structures studied. This can be done by taking a sample from each of the different types of structures which inhabit the floodplain. Commercial, industrial and public structures will usually need to be evaluated individually because of their uniqueness. This is feasible because they are often few in number compared to residential structures. Second, select a sample of typical structures of each type and design a floodproofing plan for them. Determine what the cost of the floodproofing plan is for each structure in the sample. Ideally, the sample of structures would be large enough so that a relationship between height of floodproofing, market value (or size) and costs could be determined. Better estimates of total costs should come as the sample size becomes larger. Finally, total costs are determined by multiplying the number of structures of each type to be raised a certain height by the costs determined from the samples and summing. This procedure will give fairly consistent estimates of costs because it is based on the actual costs in that area for floodproofing and because of the statistical properties of sampling. However, the accuracy of the estimate will depend on a variety of factors, including: the sophistication and size of the sample, the homogeneity of structures classified within a type, and the degree to which the design of sample floodproofing plans include all of the costs that will occur.

Each of the categories in (II.7) could be divided into subcategories and costs determined as, for example:

$$C_R = N_i C_i + N_2 C_2 + \ldots + N_n C_n \qquad \text{(II.8)}$$

where,

N_i = number of residential structures of type 1;
C_i = average cost to floodproof structures of type 1;
n = number of types of structures.

The individual C_i's would be determined from the sampling process suggested above. The value of n will depend on the type of structures, for instance, a large number of residential structures might be covered with a few types, while n for commercial and industrial structures might be equal to the number of that type structure in the floodplain.

Appendix A contains information on a number of studies of floodproofing. The data from these studies is summarized in Table II-3 for floodproofing by raising and in Table II-4 for floodproofing by sealing or otherwise altering the structure without changing its elevation. Notice that not all of the studies which consider floodproofing include the same components in the cost estimation. Tables II-5 and II-6 provide a synthesis of the various studies in the form of lists of variables which should be evaluated in a floodproofing cost study. That is, these are the costs to be included when estimating the cost of a particular design for a typical structure. Local labor and materials costs will have a strong influence on the estimate because of the characteristics of the floodproofing alternative.

At an even earlier stage of the planning process it may not be practical to go through the process suggested above. For example, a preliminary planning question might legitimately be "which of the several nonstructural alternatives should be examined more closely and which are clearly not feasible." Even a rough estimate of benefits and costs would be useful for screening out the worst alternatives. For this purpose estimates with relatively large errors would be acceptable. If a given alternative has a B/C ratio of 0.1 then a doubling or halving of costs would not change its status for screening purposes. The expenditure of very few resources for further evaluation of that alternative would be justified. In the case of an alternative which exhibited a preliminary B/C ratio of 0.5 we would need to make a decision whether or not to study it further. If we halved costs the ratio would be 1.0 so the alternative should remain for further analysis. Hopefully, cost estimates would not be off by more than one hundred per cent.

For the screening process, estimates like those shown in the Tables II-7 and II-8 can be used. The ranges of floodproofing costs shown in these tables were developed from the data in Tables II-3 and II-4 and by combining data from different studies to make complete estimates. Little data is available on the actual costs of floodproofing different types of structures. The data used in this study are estimates of costs and not actual costs. For this reason the ranges presented in the tables can be considered only preliminary and rough. Barring a major data collection effort, the sampling process described above and supplemented with information on value and size of structure could be very

Table II-3: Summary of Project Information for Floodproofing by Raising in Place and on Fill

Information (Costs are stated in March 1975 dollars) \ Project	Raising Residential Structures in Place: Tug Fork Sound Structures					Tug Fork Deteriorating Structures					Tug Fork Averages			Cameron Run	East Lake
Structural data:															
Type of construction - material	brick	frame	brick & stone	frame	frame	frame	frame	frame	perma-stone	brick	sound	deteriorating	dilapidated	masonry	
Type of construction - design	2 story	2 story	1 story	1 story	1 story	1 story	2 story	2 story	1 story	1 story				1 & 2 story duplex	
Foundation material		brick	masonry	masonry	masonry	masonry	masonry	masonry	masonry						
Size of structure (ft^2)	900	760	1120	975	930	500	500	1340	1490	2075					
Size of structure - perimeter(ft)	185	135	190	155	170	190	150	225	280	265					
Basement?	yes	no	no	no	no	yes	yes	yes	no	yes				yes	
Value	27200[1]	19200	11200	27200	11200	14400	16000	14400	9600	27200					
Date of study	5/70	5/70	5/70	5/70	5/70	5/70	5/70	5/70	5/70	5/70				6/69	12/73
Cost components:															
Cost of fill ($\$/yd^3$)															
Cost of fill/structure															
Plumbing, heating, lighting, and insulation															
Raising structure by jacking															
Temporary housing storage															
Revetment of fill slopes															3850
New foundation															
Building blocks															
Concrete: steps, landing, etc.															1650
Floor installation															
Landscaping															
Elevated site ($\$/ft^2$)															
Reinforced concrete tilt-up construction - ($\$/ft^2$)															
Total costs for floodproofing by raising:															
one foot															
two feet	4160	2720	4000	2720	2720	5600	5100	11520	12800	17900	3200[2] (.17)	10560 (.65)	14240 (4.50)	4250[3]	
three feet														5950	5500
four feet	5440	3840	5440	3680	3680	6880	6080	12960	14720	20160	4480 (.23)	12160 (.75)	14720 (4.90)		
five feet															
six feet	8160	4960	6880	4800	4640	8800	7680	16160	16640	24480	5920 (.31)	14720 (.90)	15840 (5.30)		

[1]These are estimates of value converted to March 1975 prices. To be confident of these they should be confirmed with local data.

[2]The number in parentheses is the cost of floodproofing in proportion to the value of the house.

[3]Raising structures two-three feet for additional protection over that given by sealing.

[4]Updated Tug Fork estimates -- with apparently some changes.

[5]Includes pressurizing water and sewer systems and revetment.

[6]Sewer valves.

[7]Incremental cost estimate for floodproofed construction.

Table II-3: Summary of Project Information for Floodproofing by Raising in Place and on Fill (continued)

Information (Costs are stated in March 1975 dollars) \ Project	Raising Residential Structures in Place								Raising on Fill						
	Blue Waters Ditch			Buena Vista[4]	AIA Elevated Residential Structures Study				Cucamonga Creek			Telegraph Canyon Creek			
Structural data:															
Type of construction - material	frame			frame					single	tract	new construction	frame			
Type of construction - design	1 story with attached garage														
Foundation material	concrete slab				wood pole	wood pile	concrete pier	slab plus fill				slab			
Size of structure (ft^2)	Approximately 1000														
Size of structure - perimeter(ft)												200			
Basement?												no			
Value												22,000[1]			
Date of study	1/74			9/71	1/74	1/74	1/74	1/74	2/72						
Cost components:															
Cost of fill ($/yd^3$)									1.90	1.90	4.45	5-6	5-6	5-6	5-6
Cost of fill/structure									950	2325	6350[5]	3250	4885	6510	8130
Plumbing, heating, lighting, and insulation	1375	1375	1357								1.60[6]				
Raising structure by jacking	2200	2200	2200									2750	2750	2750	2750
Temporary housing or storage															
Revetment of fill slopes									1300	2310					
New foundation									2030	2030					
Building blocks	385	440	495						950	950	.95				
Concrete: steps, landing, etc.	1540	1650	1760												
Floor installation	3300	3300	3300												
Landscaping	550	550	550						200	200					
Elevated site ($/ft^2$)					3.70	3.35	3.95				1.90				
Reinforced concrete tilt-up construction ($/ft^2$)											10.00				
Slab & site fill															
Total costs for floodproofing by raising:															
one foot	9350			3575											
two feet		9515		4485								12330			
three feet			9680	5110			7700	4400	5430	7815	14.25[7]		14900		
four feet				5785			7920	5610						17480	
five feet				6500			8030	7150							19950
six feet				7345			8250	8800							

Table II-4: Summary of Project Information for Floodproofing
Using Methods Which Structurally Exclude Water

Information (Costs are stated in March 1975 dollars) \ Project	Lockhaven						Cattaraugus		Scajaquada		Cameron Run	Twin Valley Lake	Cucamonga	Telegraph Canyon
Structure data:														
Type of construction - material	frame	brick	frame	brick	brick	brick	perm. res.	cottage			1 or 2 story masonry		frame	frame
Type of construction - design											duplex			
Foundation material														
Size of structure (ft[2])	800	2500	1400	1000	700	600								200
Basement?	yes	yes	yes	yes	yes	yes	no	no			yes			no
Value														20,000[5]
Date of study	7/74						6/73	6/73	7/74	7/74	6/69	1/74	1/72	11/73
Floodproofing method	seal basement walls w/ gunite						seal-ing	sealing	blocking windows, etc.	new walls, sidewalks, etc.	seepage control of closures	flood-proof	contiguous floodwalls	precast floodwalls
Cost of Components:														
Waterproofing measures														
Utility adjustment	340													
Sump pumps - drain tile														
Sewer valve											442			
Sealing	3320										1660[7]			
Closures	210										850			
Exterior adjustments														
landscaping sidewalk	500													
Structural changes	673													
Floodwalls														
Costs - $/lineal ft.														
Total costs for floodproofing														
one foot												4400[2]		
two feet	6550[1]	10,000	7700	7280	6030	4900						4950[3]		
three feet							6380	3585	625	6970	3570[6]	5500[4]	2280	3015
four feet														3750
five feet														4375
six feet														

[1]Includes contingencies, overhead and profit.

[2]To level of basement.

[3]Basement + two feet.

[4]Basement + more than two feet.

[5]In 11/73 prices.

[6]Includes contingencies.

[7]Includes sump pump and drains.

Table II-5

Important Variables -- Raising Costs

Existing Structures

Temporary housing costs of residents, plus storage if necessary

Unhooking utilities

Modifying and rehooking utilities

Raising structure -- jacking
Moving and return (for fill)

Utility backup prevention (i.e. sewer values)

Cost of fill and compacting (cost of fill plus haul cost)
or
Cost of poles, extended foundation or piers (labor and material)

Backfill, landscaping -- restoration of environment

Other pertinent information

- Value
- Size
- Type

Table II-6

Important Variables -- Floodproofing Costs

Existing Structures

Temporary housing costs of residents, plus storage of household goods if necessary

Unhooking utilities if necessary

Modifying and rehooking utilities if necessary

Sealing structure or providing floodwalls, gates, etc.

Utility backup prevention

Any structural costs to provide strength necessary to withstand hydrostatic forces of design flood

Restoration of landscaping if necessary

Other pertinent information

- Value
- Size
- Type

helpful in developing more thorough, representative and accurate cost range tables. The entries in Tables II-7 and II-8 were limited by the data available. For example, splitting the existing residential structures into sound and deteriorating was occasioned by the fact that one of the key studies presented the data in this way and there was a significant difference between the costs for these two conditions of houses. It is clear that because of the nature and tentativeness of the numbers in the table they should be used with caution and that adjustments should be made for local conditions where possible.

The tables can be used as follows: First, define the limits of the floodplain and determine the number of structures which will require floodproofing. Second, divide the structures into types either corresponding to those in Table II-7 or II-8 or into more detailed classification if more detailed tables become available. If even this amount of detail is unavailable the number of structures can be estimated by assuming some number of houses per acre and dividing these into predominant structural types by educated guess. In most cases the planning process should have progressed to a point where reasonable detail is possible. Third, specify the method of floodproofing to be used. The method chosen may differ from the least cost method for practical considerations. For example, the least cost alternative may be to enclose housing developments with floodwalls but the necessary contingent actions may make this measure impractical. The placing of gates and the responsibility for them may be particularly difficult due to short warning time or the characteristics of the population (mobility, age, etc.). In addition, the aesthetics of this measure may be unacceptable to local residents. In this example, it may be necessary to use the method of raising houses on fill even though it is considerably more expensive.

Using the results of steps two and three, and the tables, a cost range can be estimated for floodproofing residential structures in the floodplain if a height of floodproofing is specified. The cost ranges in the tables can be adjusted for differences in prices. This is easily handled using ENR construction cost indices. (ENR, 1st issue in March of each year.)

Determining the costs of floodproofing for commercial structures could be handled in much the same way as residential structures. Unfortunately, it is difficult to classify commercial structures because of the individual nature of their design. Unless these structures dominate the floodplain the extra effort required to evaluate each one may not be justified at this stage. One method which should give reasonable results would be to apply the procedure or estimates

Table II-7: Cost Ranges (March 1975 Prices) for Floodproofing by Elevating a Typical Residential Structure of About 1500 Square Feet.

EXISTING

Structural Type	Masonry w/ basement		Masonry w/o basement		Frame w/ basement		Frame - conventional found		Frame on slab	Frame on slab		Other
Cost of Raising in place:	sound	deteriorated	sound	deteriorated	sound	deteriorated	sound	deteriorated		single	tract	
one foot	4000-4250	10,000-12,000	4000-4250	10,000-12,000	2500-3000	7000-7500	2500-3000	6000-7000	8850[1]			
two feet	4230-4750	12,000-14,000	4250-4750	12,000-13,000	3000-3500	7500-8500	3000-3250	7000-8000	9000			
three feet	5000-5500	14,000-15,000	5000-5500	13,000-14,000	3500-4000	8500-9000	3500-4000	8000-8500	9150			4000[2] 7000
four feet	5750-6250	15,000-17,000	5750-6250	14,000-15,000	4000-4500	9000-9500	4000-4500	8500-9000				4300-7900
five feet	6500-7500	17,000-18,000	6250-6750	15,000-16,000	6000-7000	9500 10,000	4750-5250	9000-9500				4600-8000
six feet	8500-9000	18,000-20,000	7000-7500	16,000-17,000	7000-7500	10,000-12,000	5250-5750	10,000-11,000				5000-8250
Cost of Raising on fill:												
one foot												
two feet									12,000	3000-3300		
three feet									15,000	4000-4400	31.50	
four feet									17,500	5000-5600		
five feet									20,000	6500-7150		
six feet										8000-8800		
Cost of ($/$ft^2$)												
wood piles												
wood poles												3.35
concrete piers												3.95
slab on grade[3]												1.40
crawl space[3]												2.15
basement[3]												3.84

[1]Includes the cost of a new floor.

[2]These ranges are from the AIA Elevated Residential Structure report and represent the range between brick pier (cheapest) and concrete pier (most expensive) methods of construction.

[3]These are included for comparison purposes, i.e. only the added costs (above those of the most likely conventional foundation) are costs of floodproofing.

Table II-8: Cost Ranges for Floodproofing by Excluding Water from a Typical Residential Structure of about 1500 Square Feet (March 1975 Prices)

	Residential structures with basement					Residential structures--frame w/ slab foundation
Method	Using gunite	Seepage control & closures	Blocking window openings, check valves, vent outlets[3]	New walls, sidewalks, etc.		Contiguous walls
Cost of floodproofing:				permanent residences	cottages	
one foot		3500-4500[2]				
two feet	4900[1]-	4500-5500				1800-2300
three feet	10,000		625-700	6250-8000	3500-4500	2300-3000
four feet		5500-6500				3000-3800
five feet						3800-4400

[1]Roughly \$7-8 per SF for ≤1000SF, \$4-5 per SF for ≥1000SF — The limit of this protection is the height of the basement wall above grade.

[2]To first floor level -- floodproofing basement wall.

[3]This alternative requires construction which is already impervious to water.

Table II-9: Floodproofing Costs -- Commercial

(March 1975 Prices)

		Commercial Structures -- With Basement							Without Basement				
	(1) Cost per firm in a block of Townhouse Commercial	(2) Large Comm	(3) Church	(4) Hos-pital	(5) Furni-ture Store	(6) City Bldg	(7) Bank	(8) Post Office Bldg	(9) School	(10) Super-market	(11) Laun-dromat	(12) Lumber Supply	(13) Car Dealer
1 foot	3100												
2 feet	3200		5300	6900	9100	4700	3200			3500	2100	8500	4000
3 feet	3750	15,700						4500	7850				
4 feet													
5 feet													
6 feet	4150												
7 feet													
8 feet													
9 feet	4700												
10 feet													
11 feet	5000												
12 feet													
13 feet	5200												
Characteristics													
Construction material		brick	block	brick	block	block	brick	brick	block	block	block	block	block
Size (lineal ft)		600	212	338	280	330	256	222	686	330	192	488	370

(continued)

[1]Columns (2) - (13) show cost for maximum floodproofing height without extensive structural modifications.

Table II-9: Floodproofing Costs -- Commercial (continued)[3]

(March 1975 Prices)

	Commercial Structures - Lockhaven Report					Industrial Structures - Lockhaven Report		
	With Basement	Without Basement	With Basement	With Basement	With Basement	Airline Co	Aircraft Manufacturer	Paper Co
1 foot								
2 feet								
3 feet								
4 feet	8850		2100	4200	3450			
5 feet						17,250	130,000	146,000
6 feet		36,400						
7 feet								
8 feet								
9 feet								
10 feet								
11 feet								
12 feet								
13 feet								
Characteristics								
Construction material	brick & stone	brick & stone	brick & aluminum	brick & aluminum	Brick & aluminum			
Size (ft^2)	4700	20,000	10,000	15,000	12,000			

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[2]A 5' levee would cost $203,000. An 8' levee would cost $458,000.

[3]Other estimates are shown in Appendix A. These are not included here because the height of floodproofing was not specified.

Table II-10

ESTIMATING FORM
TO DETERMINE LOCAL COSTS

SLAB ON GRADE

Compute the following and enter:

_____________ Square Footage of Floor Area

_____________ Lineal Footage of Perimeter

_____________ Square Footage of Foundation Wall

Enter your costs (combine labor and material) and extend:

Layout house on lot	_____________	x	_______	=	$_____________
Trench for footing	_____________	x	_______LF	=	$_____________
Place footing	_____________	x	_______LF	=	$_____________
Lay-up or form & pour foundation wall	_____________	x	_______SF	=	$_____________
Fill & grade for slab	_____________	x	_______SF	=	$_____________
Place vapor barrier, wire mesh & insulation	_____________	x	_______SF	=	$_____________
Place & finish slab	_____________	x	_______SF	=	$_____________
	Grand Total				$_____________

[Source: Federal Insurance Administration, Elevated Residential Structures, p. 4-17]

Table II-11

ESTIMATING FORM
TO DETERMINE LOCAL COSTS

WOOD POST

Compute the following and enter:

______________ Square Footage of Floor Area
______________ Lineal Footage of Girders
______________ Number of Posts

Enter your costs (combine labor and material) and extend:

Layout house of lot	______________	x _____		= $______________
Auger or dig post holes and remove spoil	______________	x _____	Qty	= $______________
Place concrete punching pad	______________	x _____	Qty	= $______________
Place poles	______________	x _____	Qty	= $______________
Backfill poles and plumb	______________	x _____	Qty	= $______________
Set girder	______________	x _____	LF	= $______________
Frame floor	______________	x _____	SF	= $______________
Place insulation & sealer	______________	x _____	SF	= $______________
Place subfloor	______________	x _____	SF	= $______________
	Grand Total			$______________

[Source: Federal Insurance Administration, Elevated Residential Structures, p. 4-20] developed in the James River (Richmond) study. Assuming a proportional relationship between size and cost, an estimate was made for a small commercial establishment of 6250 square feet. Estimates for other size commercial structures are made by multiplying the cost for the small commercial by the ratio of the larger structure's size to 6250. The assumption of a proportional relationship between size and cost may not be precisely correct but the total can be very close because high and low errors balance out. The validity of such an assumption can only be tested using statistical methods requiring more data than is available. Other studies make estimates for different types of commercial structures and use these to determine total costs of commercial floodproofing in much the same way as we have done for residential structures. Some of these estimates are shown in Table II-9.

For new residential structures the Federal Insurance Administration's report entitled "Elevated Residential Structures" provides procedures and estimates for costing floodproofing by elevating the structure. This will probably be the most effective and efficient method of protecting new houses against the design flood. Included as Tables II-10 and II-11 are two estimating forms from the report. The first is for slab-on-grade conventional construction and the second is for wood post elevated construction. In determining the cost of floodproofing only the added costs of construction are included. For example, the difference between the cost of elevating on wood poles and the most likely conventional alternative, say slab-on-grade, will be the cost of floodproofing for the new structure.

Evacuation - Relocation

Measuring the costs of an evacuation-relocation program has apparently not been a topic of interest in the professional literature. However, it is fairly clear that there are two distinct cost categories that must be considered. The first category is the physical costs of carrying out the program and the second is the loss of income occasioned by the relocation of the activity away from the location chosen in the market.

An evacuation-relocation program has three physical components: 1) movement of existing structures and/or people from the design flood area to sites which are less flood prone; 2) providing alternative sites with equivalent public services; and, 3) restoration of the evacuated floodplain. In part, the cost of carrying out components 1) and 2) is determined by the provisions of the Uniform Relocation Assistance Act[2] (PL 91-646). This Act requires that persons

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[2] It should be noted that in strict economic terms, the costs of fulfilling the requirements of PL 91-646 are not legitimate costs of the flood damage reduction

(continued next page)

relocated by any federal program be assured a safe, sanitary and decent alternative to the residence, or structure, evacuated. In determining the annual costs of the relocation program any costs associated with maintaining the floodplain compatible with the hazard should also be included.

In addition, when people and businesses are relocated by administrative action rather than by response to market forces, a loss in economic advantage is expected to occur. The reasoning is as follows: If rationality is assumed then activities will only locate in the floodplain if it is profitable to do so. Rationality means that consumers maximize their satisfaction, and producers their profit, and that they make their decisions based on full information. The net income of the activity in the floodplain location after expected flood damages are accounted for must exceed that at the off floodplain location in order for the activity to locate on the floodplain. Relocation of these activities to off floodplain will therefore lower their net income and this loss in net income is a cost to the evacuation-relocation program. The same reasoning applies equally well if the activity considered is residential housing. People will only locate on the floodplain if the advantages, less expected flood damages, outweigh the advantages of other locations.

If the decisions which placed the present mix of activities on the floodplain were not made rationally then it is not clear that any loss in net income will occur due to relocation. Many factors can contribute to irrationality in location decisions. Probably the most important is the lack of information. This is particularly true for housing where mobility of population, high turnover and fraudulent real estate practices lead to many irrational location decisions. Herfindahl and Kneese [1974] question the assumption of rational decision making by residents of floodplains. They suggest two problems with this assumption.

> One is that for various reasons people may not find it reasonable to act on the basis of expected values of damage (for example, in decisions to occupy floodplain lands).

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program. The purpose of PL 91-646 as understood here is twofold. First, this Act guarantees that the federal government gives displaced persons a fair payment for their property in terms of local property values. But second, and more importantly, the relocation becomes an occasion to upgrade housing for lower income residents. Ideally, benefit-cost analysis would be applied to the Uniform Relocation Assistance Program to determine whether the program is effective in fulfilling its purposes. By default, many such programs are counted as costs of other programs which are not necessarily related. A sort of second best approach would be to count the benefits of the upgraded housing as part of the benefits of the flood damage reduction program.

A second is that even if people are willing to act on this basis, they almost never understand the concept or have the necessary information to do so.

In any event, the measurement of the economic loss is difficult in practice. It requires projection of alternative locations and income for the displaced activities and projections of income for the activities which replace those displaced from the floodplain. The new floodplain activities must be compatible with the flood risk, i.e. open space, golf courses, agriculture, or etc. In the case of open space the value in use is particularly difficult to measure.

If we assume that the economic losses are small in relation to the physical costs of relocating floodplain activities they can be safely ignored in a preliminary planning study. The more easily measured physical costs will be large and will be taken as the lower bound of costs of the program. It is doubtful that extra expenditure of resources, which would be necessary to measure the economic loss, would be justified early in the planning process. If the estimated benefits of relocation outweigh the physical costs then the effort necessary to measure economic losses would be appropriately undertaken.

Relocation in a Corps Report

One report carefully considers and recommends evacuation and relocation. At Prairie du Chien, Wisconsin, evacuation and relocation and floodplain regulation was the only plan where benefits exceed costs. In an attempt to make realistic cost estimates the following were considered basic [Prairie du Chien, p. 17-18]:

a. Average moving costs are developed from interviews with homeowners and residents who have moved their property from the floodplain recently. Consideration is given to whether the structure is with or without a basement.

b. Residential development is limited to the fringe (i.e. residential structures greater than 100 feet riverward of the design flood outline or subject to greater than 2 feet of flooding would be evacuated). Industrial and commercial establishments could remain if floodproofed.

c. Open space and historic uses could remain if floodproofed.

d. Residential properties bordering the fringe would not be evacuated if first-floor elevation could be raised to the design flood level economically and practically.

e. An additional payment of up to $5,000 toward the purchase of another house of suitable standard sales value for the area was included in the estimated cost for each house to be purchased.

f. Estimated moving and raising costs are compared with estimated purchase price to determine which alternative would be least costly as well as most practical.

The proposed plan of improvement includes evacuation, floodproofing, and flood-plain regulation. Evacuation includes the relocation of 157 buildings and the purchase of 48 buildings. Relocation costs are moving costs plus the cost of grading and landscaping of new building sites, construction of driveways and basements and hooking up all utilities. Costs of purchase are the purchase price plus the cost of demolishing the buildings, removing the debris and filling and grading the site. Seven existing business and industrial structures are to be floodproofed and thirty-three residences are to be raised. Flood plain regulation, the responsibility of local interests, is to prevent unwise development from reoccurring. In this regard, land for future expansion is not constrained since only about 30% of the developable flood free land of the city is developed [p. B-5].

The estimate of first costs of moving a house[3] are developed as in Table II-12.

Table II-12: Estimate of First Costs of Moving a House [Prairie du Chien, C-1]

Item	Estimated Cost
House moving	$2,200[1]
New basement	2,400
New foundation	900
Grading, topsoil, seeding	400
Utilities and services	
Streets	200
Curb and Gutter	100
Sewer and Water	700
Power and Telephone	300
Lands	300
Engineering and Contingencies	
With basement	1,300
Without basement	1,000
Total cost per house	
With basement	7,900
Without basement	6,100

[1]Includes cost for backfilling vacated basement.

The cost of raising houses was estimated to be $2,500 for a house with a basement and $2000 for a house without. The total cost of raising thirty-three structures and floodproofing seven business-industrial buildings was approximately $217,000 including utilities. Total costs were estimated by adding floodproofing and raising costs to total relocation costs which were developed by multiplying each cost in Table II-12 by the number of structures requiring that action.

[3]Presumably a typical, or average, house.

A Formula and Table Method for Measuring Costs

The cost of an evacuation-relocation program can be stated as a formula:

$$C_E = E_E + I - I_a - I_p \qquad \text{(II.9)}$$

where,

C_E = annual cost of evacuation and relocation;

E_E = the physical costs of administering and carrying through the program (changed to annual terms using an appropriate capital recovery factor);

I = discounted average annual income which could be earned at the floodplain site;

I_a = average annual agricultural income at the floodplain site;

I_p = value of open space or open land which is not reflected in the market.

Here we are ignoring I, I_a and I_p and concentrating on E_E. As in the case of floodproofing, the best way to determine total evacuation costs would be to survey the structures in the area proposed for evacuation, interview moving companies and demolition companies, determine relocation site costs for each move, and add the costs of conforming to PL 91-646. For preliminary planning a less thorough technique would be sufficient.

For this purpose E_E can be further defined[4] as :

$$E_E = CRF[A_mN_m + A_pN_p + A_dN_d + A_fN_f + A_rN_r + (A_iN_i - A_sN_s) + A_aN_a] + M \qquad \text{(II.10)}$$

where,

A_m = average moving costs per structure;

N_m = number of structures to be moved;

A_p = average cost of purchasing structures;

N_p = number of structures to be purchased;

A_d = average demoliton and removal costs per structure demolished;

N_d = number of structures to demolish;

A_f = average costs to fill basement;

N_f = number of affected structures with basement;

A_r = average cost to restore floodplain (seeding, grading, etc.);

N_r = number of acres in floodplain to be restored;

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[4]It may be necessary to divide development into types as for floodproofing. Each type would then have a different formula.

A_i = average market price of relocation sites and cost of improving these to make them equivalent to evacuated sites;

N_i = number of relocation sites required;

A_s = average salvage value per acre evacuated (i.e. for parks or agriculture);

N_s = acres evacuated;

CRF= capital recovery factor;

M = annual maintenance cost for preventing future development;

A_a = cost of relocation assistance;

N_a = number of structures receiving assistance.

The values of the variables could be determined locally from land use maps, assessor's records, interviews with moving companies and contractors, surveys of relocation sites and local interpretation of PL 91-646. If the floodplain is densely populated the costs of an evacuation-relocation program may not be adequately represented by a linear formula. The large mobilization of equipment and personnel necessary to undertake the program, especially if it is to be done within a short time period, implies that the costs will rise faster than the number of structures. This is a result of the fact that moving and demolition companies do not have the capacity to undertake such a program.

Dense development further compounds the difficulty of evaluation if it extends beyond the floodplain making the supply of alternative sites limited. The market prices of the existing alternative sites will be bid up by competition for relocation sites. This is particularly true if the evacuation program is short in duration and if the floodplain is within a dynamic, rapidly growing urban area. Predicting the market price of the sites, and therefore the relocation costs, is difficult under these conditions.

The values of the variables in (II.10) can be determined in the same way as suggested for floodproofing. Sampling can be used for the values of A and a preliminary survey for the values of N. Applying the part of the formula in brackets will give a good estimate of the first cost of a relocation program. If local estimates of the A's are not available the values presented in Table II-13 will give a rough idea of the costs of the program. Table II-13 is based on estimates of the various parameters made in different districts of the Corps of Engineers. Because PL 91-646 has changed during the period when the cost estimates are available these costs are not included in the table. A_a could be determined from local conditions based on Table II-15 which categorizes relocation benefits as of March 1975.

Table II-13: Residential Evacuation Costs from Corps Studies

Information (Costs are in March 1975 prices)	Prairie du Chien (typical house)	Scajaquada	East Lake (brick & frame)	Souris River[9]			Twin Valley Lake Ada	Buena Vista
Date of study	7/70	7/74	12/73	7/73			1/74	7/72
House moving	3,300[1]		8,250[2]		4,048[3]			
New basement	3,600							2,232
New foundation	1,350		1,430		3,080[5]			
Grading topsoil & seeding			660					
(new site)	600							
Utility changes	1,950		2,310		1,705[4]			
Lands	450							
Eng. & contingencies								
w/ basement	1,950							
w/o basement	1,500				440			
Moving mobile home	300		275					
Purchase costs				22,600[17]	550			
Demolition/house		1,670						
/cu yd		.16					22,000[10]	2,294[13]
Debris removal/house		340					33,000[11]	3,224-
/w/yard		3.00						3,720[14]
					90[18]		22,000[12]	4,340[15]
Basement fill/house		1,260						15,872[16]
/cu yard		5.40						
Seeding/acre		1,200						
Total per structure cost				16,060	17,050	19,470		
w/ basement	11,850							
w/o basement	9,150							
Replacing substandard								
houses (5-10,000)					5,687			
Improved lot cost total					1,606			
Street (residence)					1,433			
Land					836			
Water line					396			
Sanitary sewer					836			
Storm sewer					110			
Boulevard landscape					440			
Sidewalk					2,530			
Site work								
seeding/acre old								

[1] Includes cost of backfilling vacated basement.

[2] Brick & frame construction.

[3] Including disconnecting utilities, left, move (less than 5 miles over good road), set down and connect.

[4] Utilities within the basement including soil pipe, water pipe, hot water heater, electric and gas lines, furnace and duct work and chimney.

[5] Foundation including excavation and backfill, 12-inch block wall with waterproofing, 4-inch slap, footings, steel and windows.

[6] Including sanitary service, water supply, topsoil, sod, driveway and sidewalk (on lot).

[7] 40-60,000 31,000.

[8] 36 x 25 feet, 1 1/2 story home.

[9] The three columns represent house values of $10-15,000, $15-20,000 and $20-40,000, respectively.

[10] Farms.

[11] Buildings with farms.

[12] Other dwellings.

[13] Small bungalow.

[14] Medium frame.

[15] Brick or cinder block.

[16] Two-story building with new foundation.

[17] For substandard housing, worth less than $15,000.

[18] Foundation fill.

Table II-14: Commercial Evacuation Costs from Corps Studies

(March 1975 Prices)

James River Demolition Costs		Souris River Moving		Souris River Purchase	
Size (ft)	Cost				
50 x 25	$ 1,695	Office Building	$ 28,815	Business with Apartments	$ 46,330
75 x 100	6,780	Office Building	67,800	Apartment Building	90,400
125 x 125	11,300	Rest Home	28,250	Bar and Restaurants	51,428
125 x 150	13,960	Storage	31,075	Garage or Light Industry	64,410
150 x 150	16,950	Bars & Restaurants	18,645	Retail Store	144,640
150 x 200	24,860	Service Stations	22,600	Office Building	89,270
200 x 250	33,900	Apartment Bldgs	31,640	Storage	72,320
250 x 300	45,200	Retail Stores	25,990	Miscellaneous	159,330
300 x 300	56,500			Structure on RR Property	98,310
				Church	430,530
				College	1,176,330
				Nursing Home	3,436,330
				School	809,080

Table II-15: Relocation Benefits			
Category	Business	Owners	Renters
Reasonable moving expenses up to 59 miles	Actual cost	Actual cost	Actual cost
Losses as a result of moving	Actual cost	Actual cost	Actual cost
Search expenses	≤500	none	none
Optional fixed amount for moving		≤300	≤300
Dislocation allowance		200	200
Dislocation allowance for business = average net annual earnings	2500-10,000		
Supplemental housing payment			
1. Cost of safe, decent, sanitary housing less payment for present dwelling		≤15,000	
2. Increased interest cost			
3. Closing costs			
1. Four years of excess rent to secure a decent, safe and sanitary dwelling			≤4000
2. Supplement to apply to down payment and closing costs to purchase a safe, decent and sanitary dwelling			≤4000

Table II-13 does not present estimates based on categories or classifications of structure like those used in the floodproofing table because data on evacuation costs is very limited. As more data is collected by various Districts it could be usefully incorporated into the framework presented here. With only a small amount of extra effort information on the size, value and design of the typical structures could also be collected. Each floodplain management study should collect information on each of the A's in (II.10) and make it generally available to other Corps offices. Eventually this information would provide a better data base for making preliminary planning estimates of costs. Local information is necessary in all cases for estimating purchase costs, salvage values and relocation assistance.

Most commercial structures are not easily moved so to carry out a relocation program the structures are purchased. The cost of a purchase and demolition program will require knowledge of the replacement values of the various enterprises. PL 91-646 allows for an additional payment of up to $10,000 for business dislocation costs (see Table II-15). The maximum cost for a commercial establishment would then be the replacement cost plus $10,000 for dislocation benefits. Obviously, the discussion of rationality, irrationality and net income change holds here, too. If rationally located, net income at the floodplain site must be larger than at the off floodplain site by at least the amount of annual flood damages perceived by the owner. If irrationally located the sign of the difference in net income is not known, *a priori*. Again, it seems reasonable to ignore the differences in net income for preliminary planning purposes.[5] When a program of evacuation is undertaken many of the advantages of floodplain location are removed and therefore some of the difference in net income is removed also. For example, an evacuation program will usually include most segments of a given floodplain business community. If complementary businesses are moved and assuming comparable transportation links are assumed at the new location, much of the locational advantage of the floodplain is reduced. Rivers are no longer the sole providers of cheap transportation. However, if the evacuation is only a piecemeal program with only one, or a few, of several complementary businesses relocated, net income losses would be more substantial. Here the advantages of easily accessible supply, markets or complementary business enterprise are removed. This would cause a marked change in the net income of the moved enterprise and possibly some loss of income to those enterprises remaining. It is important that only losses which are not compensated elsewhere are counted. For example, one enterprise is relocated causing a loss of business to remaining enterprises but the relocated enterprise has increased net income due to increased patronage from a relocated freeway. If the increased income of the relocated enterprise outweighs the non-relocated enterprises' loss there is no net income loss to record.

Clearly, there may be a loss of advantage in relocating public buildings. For example, if a school must be relocated such that the students must travel further to get to class the added cost of time and travel should be counted as a cost of the program.

All of these costs of loss of advantage are specific to particular floodplains and can best be determined after careful analysis of which structures are to be moved, the interrelationship among structures and population, location of transportation facilities and other unique characteristics of a floodplain and surrounding area which will determine the loss in net income experienced by an industry or commercial enterprise. Again, due to the complexity of determination and the likelihood that the loss will be small in relation to the other costs of the evacuation program these costs will not be included here. Purchase costs are specific to sites and could not be presented in a report such as this.

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[5]Attempts have been made to measure this net income difference using differences in land values with little success. (c.f. Day and Weisz and discussion pages II-34-8.)

Land Use Regulation

Land use regulation is a flood damage reduction measure in the sense that it controls future development to prevent damages from occurring. Regulation has its greatest impact on floodplains not presently developed or only partly developed. Future damages can be reduced on developed floodplains by a combination of evacuation of high hazard areas and subsequent regulation of these areas to prevent redevelopment insuring that any open space remains open. The measurement of the costs of a regulation program requires projection of future development which will occur in the floodplain and determining what costs are incurred by excluding this projected development from the floodplain.

Identifying the Costs of Land Use Regulation[6]

The cost of land use regulation on the floodplain (hereafter simply called regulations) includes the cost of developing and enforcing the regulations and the net loss of economic advantage caused by forcing activities to locate at off-floodplain sites instead of on the floodplain. "The economic loss caused by an outside force (such as floodplain zoning) preventing the realization of the full potential income from the land would equal the difference between the potential and actual income." [James & Lee, p. 246]. The basic formula for determining the cost of land use regulation is then[7]:

$$C_{LR} = E_R + I - I_a - I_p \qquad \text{(II.11)}$$

where,

- C_{LR} = annual cost of land use regulations;
- E_R = annual enforcement cost of regulations;
- I = discounted average annual income which could potentially be earned at the floodplain site;
- I_a = average agricultural income at the floodplain site;
- I_p = any "net value nonowners realize from agricultural (or open space[8]) use over that realized from urban use, . . . I_p is difficult to evaluate but should increase with urbanization as vacant land becomes scarcer." [James and Lee]. The value which I_p takes is an indication of the value of open land which is not reflected in the market.

Enforcement costs for regulation, E_R, would be the administrative costs of developing, implementing and enforcing a comprehensive land use control package. These costs would also include whatever costs are incurred by landowners as a

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[7]This is the same formula used by James [1968] and essentially the same as that used by James and Lee [1971].

[8]added

[6]In discussing land use regulation the reference will often be made to zoning. However, broadly defined it would include all types of regulatory activity including purchase of floodplain lands and housing codes.

result of the regulations, i.e. if building codes required floodproofing in a part of the floodplain, then the costs of this floodproofing would be the cost of the regulations. A formula for E_R would be difficult to specify but these costs would be a function of present density of development, size of the area to be regulated and type of regulation program to be undertaken. The most accurate way to estimate these costs is by interviewing local officials, but if sufficient data were available on presently regulated floodplains these variables might be statistically related to regulation costs as

$$E_R = f(D, R, P) \qquad \text{(II.12)}$$

where

D = density of present, or future, development in number of units per acre;

R = size, in acres, of area to be regulated;

P = type and scope of regulatory program indicated by dollars per unit per year.

This relationship would be in annual terms and would increase with time and with increasing pressure of urban development--it may be linear but it is more likely that it will be an increasing function (i.e. exponential).

Identifying the economic loss induced by land use control is more difficult. James and Lee [1971, p.241] suggest that the "major economic cost is the advantage lost by those kept from locating in the floodplain." They also suggest that the potential income from the land be determined by using the market for land rather than the more difficult method of predicting land use patterns with and without the floodplain regulations. The market value of land is

$$M_o = \sum_{i=1}^{\infty} d_i I_i \qquad \text{(II.13)}$$

where

d_i = the present value factor which converts future monetary values to present monetary values--determined by the chosen rate of time preference;

I_i = monetary income in year i.

If M_t is the market value of land in period t[9], the series may be terminated and solved for I to yield

$$I = d_i(M_o - d_i M_t) \qquad \text{(II.14)}$$

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[9] Projected in some way. James and Lee [1971] suggest correlating land use and income with population and projecting land values using population projections and these correlations.

where I would be the discounted average annual income the owner could expect over the next t years.[10] The economic loss is then the difference between this potential income and the income that would be experienced under the land use regulations. I is determined using comparable flood free land, I_a is determined from farm income analysis to be the income expected from agricultural use of the floodplain, I_p is determined as the extra market value of open space and finally the cost of land use regulation is expressed as equation (II.11).

An alternative approach is to use a land use simulation model to determine the with and without regulation land uses and values. From these values, using equation (II.14), the potential income of regulated and unregulated use could be estimated.

Day and Weisz [IWR 74-P2] estimate the impact of floodplain regulations on the productivity of a single parcel of land using the following formula:

$$SR_{ijfpts} = LV_{ijt} - CF_{ijft} - CP_{ijpt} - SD_{ijfpts} - OD_{ijfpts} \qquad (II.15)$$

where

- i = index denoting a specific land use;
- j = index denoting a specific location;
- f = index denoting a specific level of fill;
- p = index denoting a specific level of floodproofing;
- t = index denoting a specific time period during which development for land use i may begin to occur at a site at location j;
- s = index denoting a specific development policy and/or engineering measures considered;

SR_{ijfpts} = site rent to ijfpt activity given public investment in s;

LV_{ijt} = "land value which would be expected in the absence of a flood hazard" to the ijt activity;

CF_{ijft} = cost of fill to the level f for the ijt activity;

CP_{ijpt} = cost of floodproofing to the level p for the ijt activity;

SD_{ijfpts} = residual site damages to the ijt activity after private investment in fill to level f and floodproofing to level p, and after public investment in s;

OD_{ijfpts} = residual off-site damages associated with the ijt activity after private investment in fill to level f and floodproofing to level p and after public investment in s.

Land price(LV) is predicted using a multiplicative regression model of the form

$$Y = B_0 X_1^{b_1} X_2^{b_2} \; . \; . \; . \; X_n^{b_n} E \qquad (II.16)$$

[10] A reasonable value of t is ten years [James and Lee, p.246.]

The intent of Day and Weisz is slightly different in that they are estimating the total benefits from flood control or floodplain management rather than the costs of floodplain regulations per se. Their approach may be useful, however, in estimating the economic loss associated with a particular set of floodplain regulations.

The costs of land use regulation are less physical and tangible than those of floodproofing or those of structural programs. However, these costs are quantifiable. The main difficulties lie in the projection of land values into the future, attributing changes in these values to a particular program or regulation, and in determining the cost of administering the regulations. A brief examination of Corps reports which consider regulatory programs will give some insight into how regulations are presently handled.

Land Use Regulation in Corps Reports

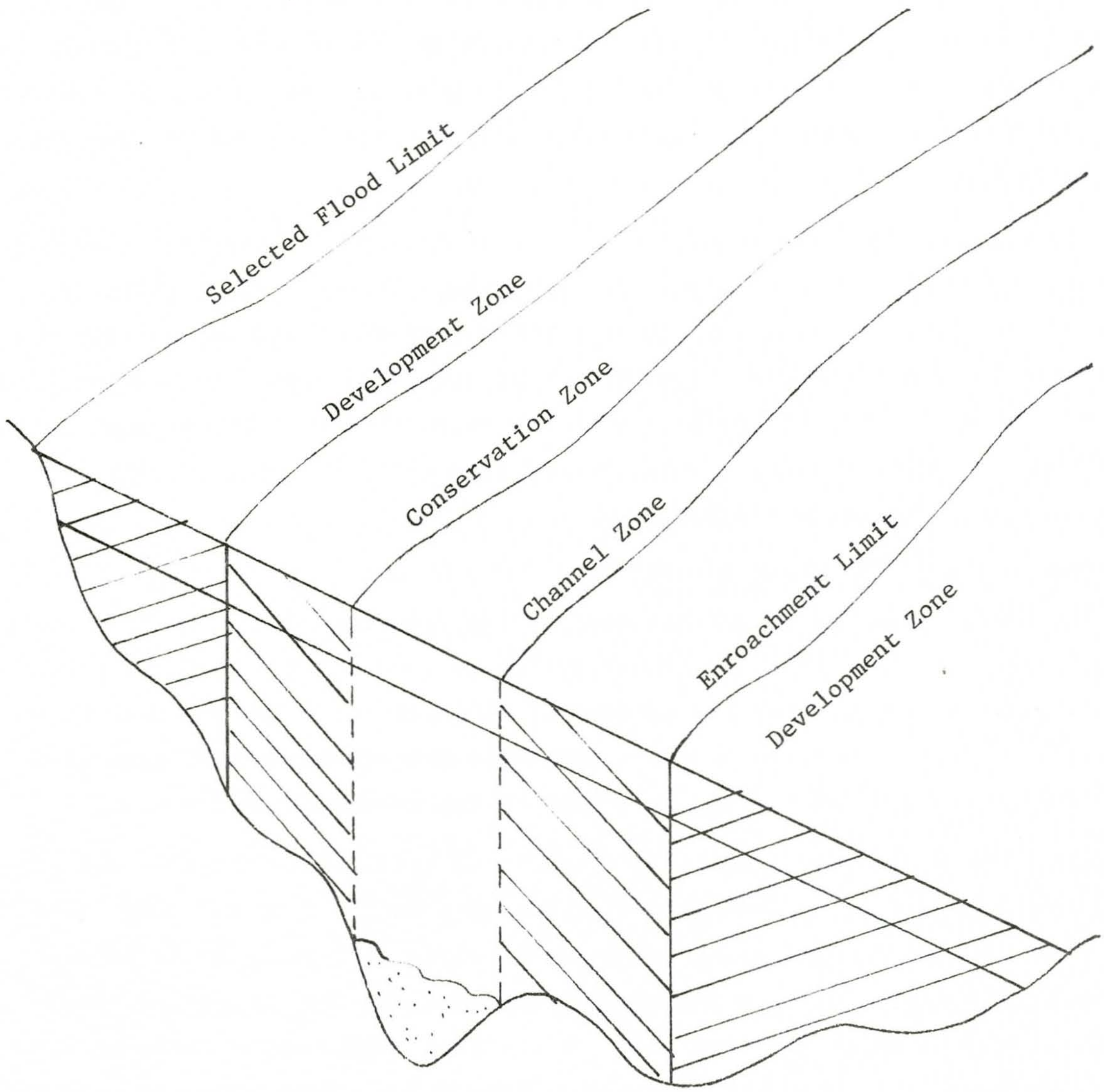
The Beals Creek Report defines part of its recommended plan as "the designation of a floodway in which no future construction or land filling would be permitted if such works would restrict the passage of floodwaters." The floodway is not to exceed 1000 feet in width and will look like the schematic in Figure II-3. No cost estimates are developed for this part of the recommended plan.

The Buena Vista report shows an estimate of total costs for the best non-structural plan which includes a combination of floodproofing and ring levees for industrial and commercial establishments, raising in place and relocation for residential structures, and floodplain regulations for the entire floodplain. Benefits exceeded costs for this plan but fourteen deficiencies were pointed out. A major deficiency is that the plan would leave six million dollars of damages from the reference flood. Other drawbacks include: some industries are left unprotected, other industries and the commercial district have less protection than the recommended structural plan; neither unifom nor maximum protection is provided; areas between buildings and property outside (i.e. automobiles) are still subject to inundation and damage; and, adoption of nonstructural measures could lead to the elimination of a structural program with greater protection for all and the possibility of developing existing floodprone land.

The Charles River report concludes that

> a combination of Federal and non-Federal actions to preserve the marshes, swamps, and wetlands in their present state as natural floodwater detention areas is needed to reduce growth in future flood losses and to safeguard natural open space. . . . Recommended is the Federal acquisition of lands or easements in 17 natural valley storage areas totaling 8,500 acres that are critical to the comprehensive flood reduction plan for the entire watershed.

Figure II-3 Floodplain Utilization



Conservation Zone (C)

Suggested Uses

- Farms, Truck, Gardens and Nurseries
- Livestock
- other Agriculture
- Non - obstructive structures
- Parking Lots
- Playgrounds and Parks
- Golf courses
- Open recreation
- Preserves and Reservations

Uses not Appropriate

- Land fills
- Obstructive structures
- Floatable storage
- Feeding or Disposal of Garbage, Rubbish, Trash or offal
- All uses precluded from the D Zone

Development Zone (D)

Suggested uses

- Uses permitted in C zone
- Residential, Commercial, industrial, public and other Development with floodwater entry points at or above design elevation for encroachment.

Uses not Appropriate

- Hospitals
- Boarding Schools
- Nursing Homes
- Sanitariums
- Detention Facilities
- Refuge Center
- Orphanages

[Source: Beals Creek]

At present, the upstream reaches of the Charles River are not developed and natural storage is available. Table II-16 shows the projected increase in expected damages as wetlands are lost.

Table II-16: Annual Flood Losses as a Function of Wetlands Loss

Condition	Annual Loss [in 1971 dollars]
Current - 1971	$158,000
With 10% loss of storage	229,000
With 20% loss of storage	414,000
With 30% loss of storage	641,000
With 40% loss of storage	957,000

[Source: Charles River, p. 32]

The report indicates that Federal acquisition is required because individual or local action is too piecemeal and cooperation is not very likely. The plan provides flood control for all events up to the standard project flood. The system of natural storage areas is considered as a unit with all wetlands purchased in fee or as a permanent easement. Much of the wetlands are protected and managed as wildlife refuges with only limited public access.

The costs of this regulatory program are shown in Table II-17. Real estate

Table II-17: Summary of First Costs and Annual Charges (1971 Price Level)

Plan First Cost	
Land Value*	$3,834,000
Severance Damages	952,000
Administrative Costs	723,600
Boundary Marking	287,200
	$5,796,800
Contingencies	1,203,200
Total Real Estate Cost	$7,000,000
Engineering and Design	340,000
Total Plan First Cost	$7,340,000
Annual Charges (100 year life)	
Interest (5 3/8% or 0.053750)	$ 395,000
Amortization (0.00028)	2,000
	$ 397,000
Operation and Maintenance	80,000
Annual Charges	$ 477,000

*Includes state-owned land but not land owned in perpetuity by the Massachusetts Audubon Society and the Trustees of Reservations.

[Source: Charles River]

acquisition costs are calculated on the following basis: land values are based on the comparable sales approach, i.e. the value of the property is set by finding the prices at which comparable property has sold recently. Land values are average unit values estimated through a gross appraisal. Severance damages to the part not taken which arises by reason of the taking, i.e. a more limited or difficult access or the loss of access. Administrative cost for acquisition averages approximately $1200 (this is Corps experience nationally [Charles River, H-22]) per tract including the costs of real estate mapping, appraising, negotiating closing and etc. The cost of boundary surveys and marking is estimated at $2,000 per mile.

Several other reports suggest regulations as a valuable and often necessary supplement to other structural and nonstructural programs. In general, however, floodplain regulations are found to be an insufficient flood control program when considered alone.[11] Little cost information has been gathered in these various studies. This is particularly true of the costs induced by loss of economic advantage.

Costs of Regulation and the Flood Insurance Act

Above we define the costs of regulating floodplain property to include an administrative and an economic loss component. It is clear that any such program will have costs but it can be argued that the legal requirements of the Flood Disaster Protection Act and the interpretation of this Act by the Corps of Engineers make efforts to measure the costs unnecessary.

The Federal Flood Insurance Program, with its related flood regulation requirements, should be evaluated on its own merits to decide whether it is economically justified and should be continued. This, however, is not the question at issue here. The question is how, or whether, the costs of regulations should be handled in Corps studies? The following language is found in "Evaluation of Economic Benefits for Flood Control and Related Water Resource Planning." [Circular 1105-2-12, Dept. of the Army].

> The adoption and enforcement of a land use regulation pursuant to the Flood Disaster Protection Act of 1973 (PL 93-234) will be assumed, both with and without a Corps plan. This is to insure that Corps evaluation procedures conform to Federal policy . . . Further structural, non-structural and mixed alternatives will be considered in Corps plan formulation. The with condition will assume a zoning ordinance compatible with the without condition ordinance in those cases where the 100 year flood is not contained by the Corps plan. Where the flood is contained, it may be assumed that no zoning ordinance is in effect." [EC 1105-2-12, p. A-10]

[11] They could be sufficient to protect future development of an undeveloped floodplain.

Since the regulation of the floodplain is assumed, no benefit can be claimed and no costs need be calculated. The Corps is apparently responsible for evaluation of a regulatory program only if it recommends more stringent regulations than those required by the Federal Insurance Administration.

Floodplain regulations are an exercise in police power meant to protect people from death and damage caused by floods. By excluding people and businesses from the floodplain, their health, safety and welfare are maintained. Implicit in this argument is the recognition that once a law such as the Flood Disaster Protection Act is passed regulation no longer requires evaluation. Also implicit is the assumption that such a program would not exist unless its benefits always outweigh its costs.

It could also be argued that the costs of regulation are so small that they can safely be ignored. The administrative component of the regulation costs are small because the activities making up the administration will likely be performed within existing units of government. Local zoning or planning commissions will add floodplain zoning and regulation to their agenda since the machinery for this activity exists and because the act implies that local units of government should assume responsibility for the zoning. Many organizations can add floodplain zoning without significantly expanding their staffs.[12] There is a tradeoff whenever new work is added but the incremental cost is small in comparison to the cost of any other flood control alternative. In order to effectively zone a floodplain, a thorough flood hazard study should be done. The Corps of Engineers is involved in mapping floodplains identified by the Flood Insurance Administration. The cost of such a study could easily be identified.

Where there are suitable alternative locations which provide comparable development sites within the local area the difference in net income off the floodplain and the net income less expected flood damages on the floodplain can be assumed small.[13] Historical changes in transportation patterns have lessened the advantage of river transport over land transport. Pollution control laws have also lowered the advantage of riverbank location for industry. Other floodplain locations gain their superiority from better terrain or proximity to businesses and markets which tend to locate near rivers. If the floodplain is presently undeveloped and suitable alternative sites are available the income difference is likely to be small. Two extreme examples where this argument would not hold are: 1) a floodplain girded by steep cliffs, the tops of which

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[12] This idea surfaced in conversations with members of several flood control districts.

[13] Presumably land value differences would also be small.

are undeveloped and not serviced by overland transportation; and 2) a floodplain on which exists integrated industrial and commercial development and markets. In these cases the loss would be larger to those activities rationally wishing to locate there.

The point we are attempting to make is not that floodplain regulations are always justified and can be ignored, but due to the relatively small costs and the interpretation of the Flood Disaster Protection Act it is felt that the question of evaluating regulations is best left for another research project. This future research project should attempt to put the Act, the regulations and their interrelationships into proper prospective and to address the question raised by the implied assumption that benefits always outweigh costs for floodplain regulations within the limits of the 100-year flood.

Chapter III

BENEFITS

This chapter examines the theory, policy and practice of estimating flood control benefits from nonstructural measures. Because the benefits are essentially the same as those from structural measures, the accepted procedures for damage and benefit estimation are briefly discussed. Reference is made to specific policies required by the Corps of Engineers and to the adjustments which must be made to apply the procedures to nonstructural measures.

Damage and Benefit Determination

Three categories of flood protection benefits have been identified. The first is the "inundation reduction benefit" [EC 1105-2-12] which is the reduction in expected damage, or the increase in net income to an activity[1] which uses the floodplain in the same way with or without a flood control project. The second is the "intensification benefit" [EC 1105-2-12] which is the increased net income to an activity, which changes its operation due to the increased flood protection, over the income of the activity in its previous mode of operation. The benefits are due to the intensification of the activity. The third is the "location benefit" which is

> the difference in net income to the new activity comparing the floodplain site which would be used without the plan less the difference in net income for the activity displaced by the new activity. [EC 1105-2-12.]

Inundation Reduction Benefits

Inundation reduction benefits are estimated as the reduction in damage to existing and future development which uses the floodplain the same with or without the flood protection project. The procedure for estimating these benefits begins by determining what the flood damages would be without the project. Damages include physical damages, business and financial losses and emergency costs. These are estimated for the present and for the future, discounted at an appropriate interest rate to make them comparable, and are correlated with flood stage to develop a stage-damage relationship. Stage-damage data are correlated with the hydrologic information in stage-discharge and discharge-frequency relationships to develop a damage-frequency function. This function relates expected damages to exceedance frequencies for flood events. The area under the damage-frequency

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[1] An activity is defined as any firm, household or public service entity. [EC 1105-2-12.]

curve is average annual flood damages. Benefits from flood protection, i.e. flood damage reduction, are the difference between average annual damages with and without the project. The benefits are produced by modifying one, or all, of the stage-damage, stage-discharge or discharge-frequency curves in beneficial ways. [Davis, "Flood Damage-Frequency Analysis.] Nonstructural measures shift the stage-damage function upward by either reducing the number of physical units exposed to flooding or by decreasing the damage susceptibility of units. James and Lee have investigated relationships between flood damages and other variables. They find that damages to yards, buildings and contents increase "approximately linearly with depth" [James and Lee, p.251] as

$$C_d = K_d M_s h \qquad \text{(III.1)}$$

where,

C_d = "direct flood damage in dollars";

M_s = "market value of inundated structures in dollars" (may be determined from assessment records);

h = depth of flooding in feet;

K_d = "a factor determined by analysis of the direct damage caused to like property by historical floods."

Values for K_d are scattered for buildings of any type but average about 0.044. [James and Lee, p.252.] For deeper flooding the damage function takes the form shown in Figure III-1. More realistically, damage and stage may be related using historical data in a graphical but not necessarily linear fashion.

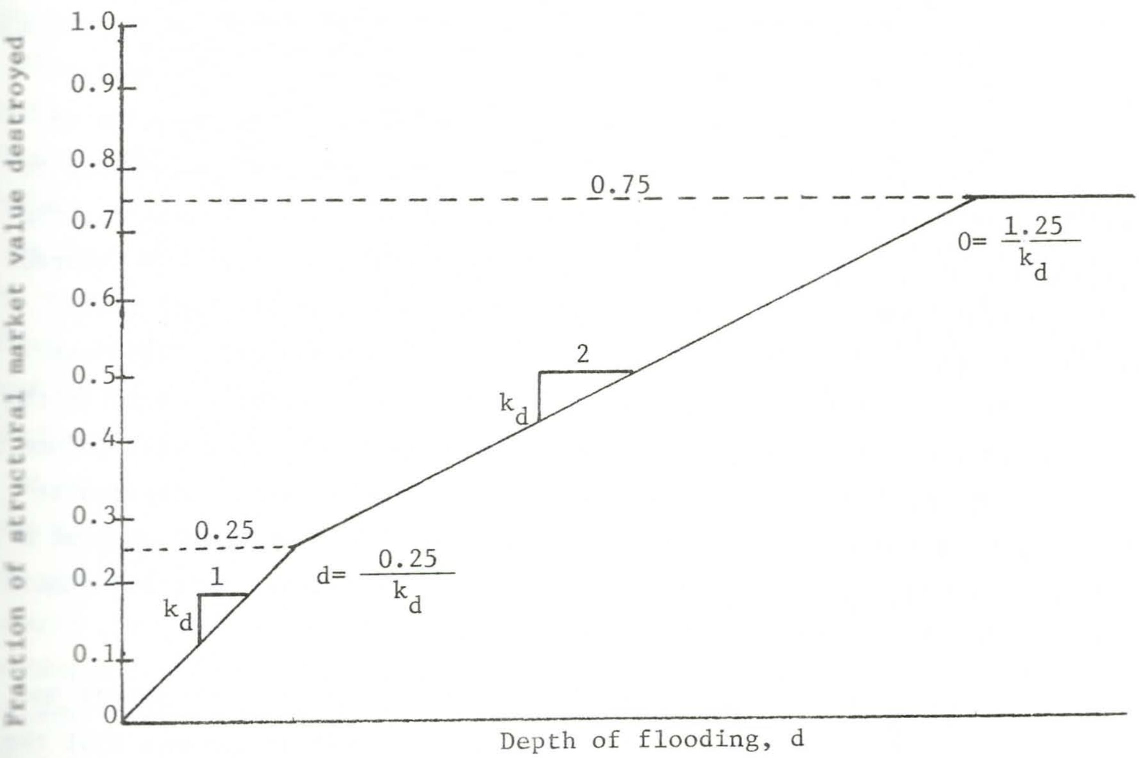
An alternative measure of the inundation reduction benefit of a flood control project is the difference in market value of land with and without the project. The change in market value should theoretically reflect the capitalized increase in net income associated with the project. "This proxy is not perfect [EM 1120-2-111], and in some instances, such as floodplain evacuation, is meaningless." [EC 1105-2-12, A-24.] Nevertheless, this measure is suggested as a check on the flood damage reduction calculation.

Intensification Benefit

The intensification benefit is due to intensified activity which is induced by the flood control program. Measuring benefits in this category is straightforward in the case of agriculture since standard procedures are available for measuring the net income difference with and without the project. [EC 1105-2-12, A-28,29.] Although more difficult to measure, the same benefit occurs in urban setting, i.e. where older homes are not renovated and vacant land is not utilized

Figure III-1

Linear Depth - Damage Curve



Source: Figure 10-5 Flood-damage-depth curve for urban property {James and Lee, p 253} because of the flood threat, removal of the threat leads to intensification.

Location Benefit

The location benefit is the net increase in value of new uses of the floodplain made possible by the increased flood protection. Location benefits may come from any plan which reduces potential flood losses.

> Location benefits are narrowly defined in this regulation. The benefit for producers is the difference in the net income accruing to users of land resources which would locate on the protected floodplain when compared to what these users would earn in the absence of a plan. For consumers, the benefit standard is defined as the difference between the cost of obtaining a site of equivalent value in an alternative manner and the cost of locating on the protected flood plain. [EC 1105-2-12, A-24.]

Three techniques are suggested for measuring these benefits. The first is to measure the net income increase to the new activity less the net income loss to the displaced activity. The second is to use "threshold levels." That is, the benefit is the flood damages reduced for those new activities which are induced into the floodplain because protection is provided above the threshold level. The threshold level is that level of protection where the user is indifferent between off floodplain and floodplain location. Any less protection implies the activity will be located off the floodplain and any more protection will induce the activity to locate on the floodplain. Finally, the benefit may be measured as the difference in the market value of land in the floodplain with and without a plan. These three methods are not equivalent so it is suggested that two should be used and their results and reliability compared.

Lind [1967] suggests that "all benefits will accrue to property owners and activities in the form of changes in rent and profits" if it is assumed that the land use changes which take place due to increased flood protection leave prices other than rents unchanged. The correct measure of location benefits is then the increased profits at the initial set of prices and rents. Demonstrating this result requires a general equilibrium model. The advantage of this measure is that only rents in the initial situation must be known--no projection of rents is required. The process does require assuming that floodplain occupants and potential occupants act rationally and this is an empirical question which is not yet answered. The expression for benefits which Lind derives is:

$$B = n[(S_f^x - P_f) - (S_u^x - P_u)] \qquad \text{(III.2)}$$

where,

B = benefits;

P_f = rental value, in initial equilibrium, of land subject to flooding (floodplain site);

P_u = rental value, in initial equilibrium, of land not subject to flooding (off floodplain site);

S_u^x = earnings of activity (net receipts exclusive of the cost of land) given a location outside the floodplain;

S_f^u = earnings of activity if located on the floodplain;

n = the number of activities.

Lind suggests equation (III.2) as the upper bound of benefits.

Benefits from Nonstructural Measures

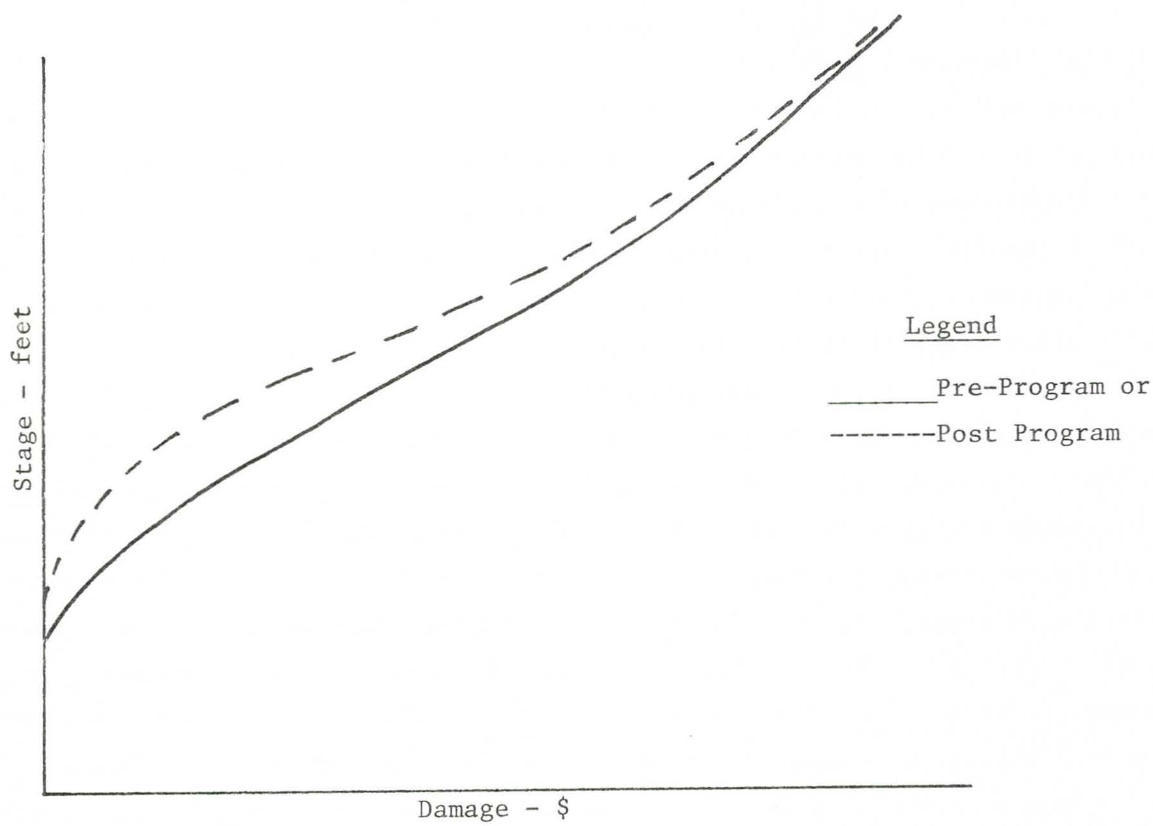
Inundation Reduction Benefits

Floodproofing, evacuation-relocation, and land use regulation create inundation reduction benefits by lowering the damage susceptibility of individual structures or of the aggregate of structures on the floodplain. In most instances these will not affect the hydrology or the frequency of the flood events. The hydrology will only be changed if the program is large enough to change the runoff characteristics or the storage capacity of the floodplain. This would be possible if the floodproofing program was an extensive one involving fill or if all the structures were removed from the flood plain in an evacuation program. In either case, the floodplain characteristics might change enough to change the hydrologic relationships. Here we assume that the hydrology remains the same before and after the nonstructural program but recommend this question for further research. Of the three interrelated curves--stage-damage, stage-discharge and discharge-frequency--only stage damage is usually affected. [Davis, 1974.] Figure III-2 illustrates the change in the stage-damage curve. Floodproofing reduces the damage susceptibility of structures and thereby shifts the stage-damage curve. To the extent that it is effective, floodproofing reduces structural damage to zero below the design level. Residual damages to grounds, outbuildings, roads and autos remain. Evacuation-relocation shifts the stage-damage curve by removing structures from the floodplain and replacing these with activities which are less damage-susceptible. Damages are reduced by the amount of damageable property removed from the floodplain. Floodplain regulation reduces future damages that would have occurred if the regulations had not been instituted by preventing flood-prone activities from locating in the path of floods.

Lind [1967] questions the capability of floodplain regulation (zoning) to produce benefits. His reasoning is: in order for zoning to reduce the expected flood damages it must affect the pattern of development in such a way that some activities which could have profitably located in the floodplain are excluded. Although the expected value of flood losses would be decreased

Figure III-2

Stage - Damage Curve



[Source - Davis, 1974, p. 14]

> by zoning, it would be at the cost of foregoing uses of the floodplain that are of greater value than the losses prevented. [Lind, 1967, p. 346.]

In order to come to this conclusion the assumption must be made that activities are operated to maximize profits (the expected value of the future stream of earnings) and that rationality is exhibited by the operators of the activity. With these assumptions the activity will locate in the floodplain only if the increase in the present value of expected profits, over those at the best alternative off-floodplain site, is greater than the present value of expected flood losses. Zoning would prevent flood losses at the expense of greater profits. Lind's result is dependent upon floodplain users having knowledge of the expected value of flood losses. In cases where the location decisions are made in ignorance of the flood threat flood zoning could produce benefits. Lind suggests that information and education are a good substitute for zoning in these cases.

Intensification Benefits

Intensification benefits occur when an activity is allowed, or induced, to intensify its operation as a result of a flood control program. Floodproofing could produce intensification benefits if an activity could expand with decreased threat of flood damage due to the floodproofing program. Evacuation-relocation and floodplain zoning could produce these benefits if the program allows for expansion of an activity in high demand.

> A floodplain management plan which embodies preservation or enhancement of open space, parks or historic sites may also result in large intensification benefits in urban settings where a high demand for such exists. [EC 1105-2-12.]

Of course, the benefits from uses such as these are difficult to measure and are sometimes considered intangible.

Location Benefits

Location benefits arise when an activity is induced to locate in the floodplain by added protection. Floodproofing is capable of producing location benefits. For example, a firm considering a floodplain location but rejecting it because of expected flood losses might be induced to locate there if a government-sponsored (or possibly financed) program of floodproofing became available. Neither evacuation-relocation nor floodplain regulations produce positive location benefits.

> The creation of land-enhancement[2] benefits is critically dependent on the reduction of the costs of flooding to firms and households that will occupy the floodplain; since zoning merely excludes the

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[2] Land enhancement here refers to location and intensification benefits.

activities that would incur these costs, it cannot produce benefits. [Lind, 1967, p. 350.]

Evacuation-relocation and floodplain regulations produce a loss of income to an activity when it is forced to locate at an inferior location off the floodplain. In Chapter II this is counted as a cost. It might better be listed as a negative benefit. Equivalent net benefits would result in either case.

The Flood Disaster Act

The Flood Disaster Protection Act of 1973 [PL 93-234] will have a definite effect on the calculation of flood control benefits. Under the provisions of EC 1105-2 12, land use regulations consistent with the Flood Disaster Protection Act are assumed adopted and enforced in both the with and without conditions. The zoning ordinance will be assumed in effect in the without condition and in the with condition unless the 100-year flood is contained. This implies that growth in the floodplain and the damage susceptibility of existing and future structures will be modified by the provisions of the zoning ordinance. In particular, the regulation will be assumed to include the following two crucial features:

> (1) no further development of the floodplain unless the first floor of the building is elevated to the 100-year level for residences on floodproofed to that level for non-residences; and (2) no occupancy of the floodway which when taken with other developments raises the height of the 100-year flood by greater than one foot anywhere in the floodplain. [EC 1105-2-12.]

This assumption limits future benefits claimed for damage reduction. In addition, the possibility for intensification and location is reduced because the objective of the Flood Disaster Protection Act is to control future development of the floodplain rather than foster it. The implications of this act for particular floodplains should be carefully considered in any proposed program for flood damage reduction.

A further question raised by the assumption that land use regulations are in effect is concerned with the extent to which floodplain management plans may claim benefits from nonstructural measures. Clearly, many of the nonstructural options are assumed already in effect due to the Flood Disaster Protection Act. Only those nonstructural measures which provide protection above that required by the act can be used to legitimately increase benefits.

Corps Reports

This section attempts to compare the methodology used by practitioners for estimating the benefits produced by nonstructural measures with that suggested by the regulation [EC 1105-2-12]. Several Corps of Engineers project reports are examined. Sometimes the discussion of the benefits from nonstructural measures is sketchy. This is especially true with respect to the methodology used. In some of these cases the methodology is implicitly identified as that used in the calculation of benefits for structural measures but in others no identification of methodology is possible. Neither intensification nor location benefits play an important role in any of these studies so, unless identified otherwise, the term benefits will refer to inundation reduction benefits.

Buena Vista

At Buena Vista the stage-damage relationship was developed using a different approach for each class of structure. For residences and commercial structures the first floor elevations were determined from field surveys. For residences, market value was determined from assessed valuation data furnished by city officials and then damages to each residence and its furnishings were determined from tables prepared for this purpose by the District office. Commercial establishments were classified as small, medium or large and damages were again determined from tables. Damages to public facilities were determined by interviewing public officials. Benefits for the proposed structural program were calculated as flood damages reduced. No land enhancement benefits[3] were included because there is no land within the project area that would be put to higher use with the improvement.

Benefit estimates are shown for each of the nonstructural measures considered but these are not detailed. It seems reasonable that the above methods are used for both structural and nonstructural alternatives as evidenced by the statement that "the development of costs and benefits follows standard Corps of Engineers practice." [Buena Vista, p. F-2.] No location or intensification benefits are included for the nonstructural measures.

Cameron Run

At Cameron Run, permanent evacuation and floodproofing were considered. Evacuation was rejected as a possible solution because the cost of land and improvements in the floodplain, and thus the cost of relocation, far exceeded the cost of structural protection. Benefits for evacuation were therefore not calculated.

[3]Land enhancement here seems to include both intensification and location benefits since their exclusion is justified by the statement that no land would be put to higher use with the improvement.

Floodproofing benefits were calculated for residential developments as follows: First, flood zones were developed on a frequency basis and the zone designation for each development was based on the zero damage elevation rather than first floor elevation. Second, an array of average annual damages was computed using the zero damage elevation for each class of development in the reach. Third, the first floor elevation was shifted up in increments of one-half foot and average annual damages were calculated at each elevation. These computations provided the annual damage array needed to evaluate the benefits from different degrees of floodproofing in various zones. Finally, the benefit computations were made using the stage frequency curve. Representative calculations are shown in the Cameron Run report Figure D-1. A "package" of floodproofing protection for a large commercial-industrial warehouse and benefits were calculated as damages reduced to the activities in this structure. Annual benefits were calculated using the characteristics of the building and the stage-frequency curve. No intensification or location benefits were included.

Charles River

The proposed plan at Charles River is the acquisition of 8,422 acres in 17 natural valley storage areas. These areas are a critical part of the comprehensive flood reduction plan for the entire floodplain. The methodology for the benefit calculation is based on hydrologic analysis to determine the effect of shrinking natural valley storage on flood flows. The pressure of development on the upstream reaches of the Charles River, if not controlled, would lead to a progressive loss of natural storage areas. The volume of floodwater expected was correlated with projected shrinkage of storage. Other hydrographs were developed assuming different degrees of upstream storage and comparable flood volumes but with higher peaks and shorter time periods. "The resulting stage vs. loss of wetland curves were the source of potential damage figures for increased flood heights." Benefits are calculated as the difference between annual losses under present conditions of land use and those which would occur under conditions of 30% loss of natural storage projected for 1990.

This approach appears to be slightly different than standard Corps procedure but the thrust is essentially the same. Damages are calculated without the plan--loss of 30% of natural storage--and compared with damages with the plan--preservation of present storage conditions. The requisite with and without conditions are present and are related with stage-damage-frequency curves.

No intensification or location benefits are calculated. An interesting question arises concerning negative location benefits. It appears that, in the Charles River study, no account was taken of negative impact of the regulations on the potential net income of prospective floodplain occupants. Some activities are prevented from locating in the natural storage areas which would have located there, in the absence of the plan. The curtailment or prevention of these activities implies the reduction of net income and increased project costs or decreased project benefits. Further investigation would be justified.

Prairie du Chien

Floodplain management plan benefits were calculated with the standard approach using historical information to develop the discharge-damage curve and the damage-frequency curve. The area under this curve (changed to an equivalent dollar value) is the average annual damage. Over time the damage potential will decrease due to the age of the existing structures, frequency of flooding and state law governing development of the floodplain. Based on decreasing damages the average annual damage figure was adjusted. Benefits were calculated for both the evacuation-relocation and floodproofing parts of the plan. Floodproofing was assumed to be 100% effective because it was primarily accomplished by raising in-place.

A case might be made for negative benefits from the evacuation-relocation part of the plan due to reduced net income when activities are forced to leave the location of their choice. However, in the case of Prairie du Chien, the activities evacuated and relocated may not be the highest and best uses of the floodplain. Some of the residences open space uses might be substituted. These may have more value than the deteriorating structures replaced. This question merits further investigation.

Tug Fork

At Tug Fork the proposed plan was primarily a program of floodproofing supplemented with floodplain regulations. The benefits from floodproofing residences at Matewan, chosen for intensive study and to represent other communities in the Tug Fork Basin, are the damages prevented, i.e. the difference in average annual damages that might be expected before and after raising. Using first floor elevations, types and values of structures, stage-frequency data and representative residential damage tables, it was possible to calculate average annual damages prevented by floodproofing for all residences in Matewan for various levels of protection up to a maximum of six feet.

For commercial structures, expected damages vary with the nature of activities conducted in the structure rather than market value. For this reason, the techniques used to determine damages prevented was to make a careful study of the results of floodproofing twelve commercial structures. The average of expected damage prevented by floodproofing these twelve structures was calculated to be ten percent of the average annual damage expected without the program. The assumption was made that the percentage of damages prevented by a given floodproofing scheme for a representative mix of commercial structures at Matewan would be applicable to a corresponding scheme of commercial floodproofing in other Tug Fork areas. [Tug Fork, p. 52]. This assumption was necessary to allow for extrapolation of the results to all of the Tug Fork basin. Protection can be provided up to six feet for residences and three feet for commercial establishments. No intensification or location benefits are calculated. The Tug Fork report is the most thorough and explicit treatment of the benefits from a nonstructural program encountered.

Developing a Procedure for Measuring Benefits

The general question of estimating benefits for nonstructural measures was addressed earlier. There the three types of benefits--inundation reduction, intensification and location--were discussed in the context of nonstructural measures. It was suggested that, at least conceptually, some nonstructural measures could produce benefits of all three types. We find however, that the measurement of intensification and location benefits is difficult in practice. This is particularly true when attempting to interpret the regulations pertaining to these types of benefits [EC 1102-2-12]. Because of the complexity of this issue and the remaining questions to be answered in the area of inundation reduction benefits, location and intensification benefits are left for future study.

Here we attempt to address the question: How should inundation reduction benefits for nonstructural measures be computed? Again the inquiry is limited to floodproofing and evacuation since the without condition assumes regulation of the 100-year floodplain. Regulation beyond the 100-year level would produce benefits (for the remainder of this section "benefits" implies "inundation reduction benefits") by reducing potential future damages to structures which would have located within the limits of the regulation but are precluded by the regulation. That is, the damages at the lower frequencies (higher stages) are reduced by just that amount of damages that would have occurred had the development been allowed.

Floodproofing affects the stage-damage relationship for a single structure by eliminating damages to the structure and its contents when the floodwaters are at or below the design level. This assumes that the floodproofing is 100% effective until it is overtopped. For floodproofing by raising this is likely to be true but for structural floodproofing there may be damages to the structure below the design level. For example, in the evaluation of floodproofing using gunite sealing in the Lockhaven report, some seepage or foundation wall failure might be expected. When constructing the stage-damage curve for the modified condition this possibility should be accounted for. Since we have little data on floodproofing programs and their effectiveness, the size of the correction for this potentiality is difficult to determine. Damages below the design level for this type of floodproofing will also occur when flooding is characterized by high velocity or debris laden flows.

Damages to property outside the structure are not changed unless the floodproofing program encompasses the entire property. Even if the entire lot or site is raised by filling, damages to utilities, streets and autos will remain. So to compute a modified stage-damage relationship for a floodproofing program[4] the curve is truncated at the design level, but not to zero since residual damages remain.

In an evacuation program[5] the source of the damages--floodplain occupants, their structures and related property--are removed from the floodplain. The damage will therefore be lowered at every stage since the damageable property has been removed. There will be residual damages to the extent that the activities, which replace those evacuated, are damaged by floods. Presumably, the replacing activities will have considerably less damage potential than the replaced activity. Figures III-3a and III-3b illustrate conceptually the changes which take place in the stage-damage relationship for floodproofing and evacuation respectively.

Clearly, this discussion is an oversimplification of the process by which a practitioner would arrive at an estimate of the benefits for a nonstructural program. Since we are interested in simulating the nonstructural alternative we take a slightly less detailed approach than that of the practitioner but more detailed than that of the simple description above.

In all of the earlier sections of this report each nonstructural measure is considered an entity in itself. A floodproofing program is implied to be floodproofing all the structures within a reach and an evacuation program is the removal

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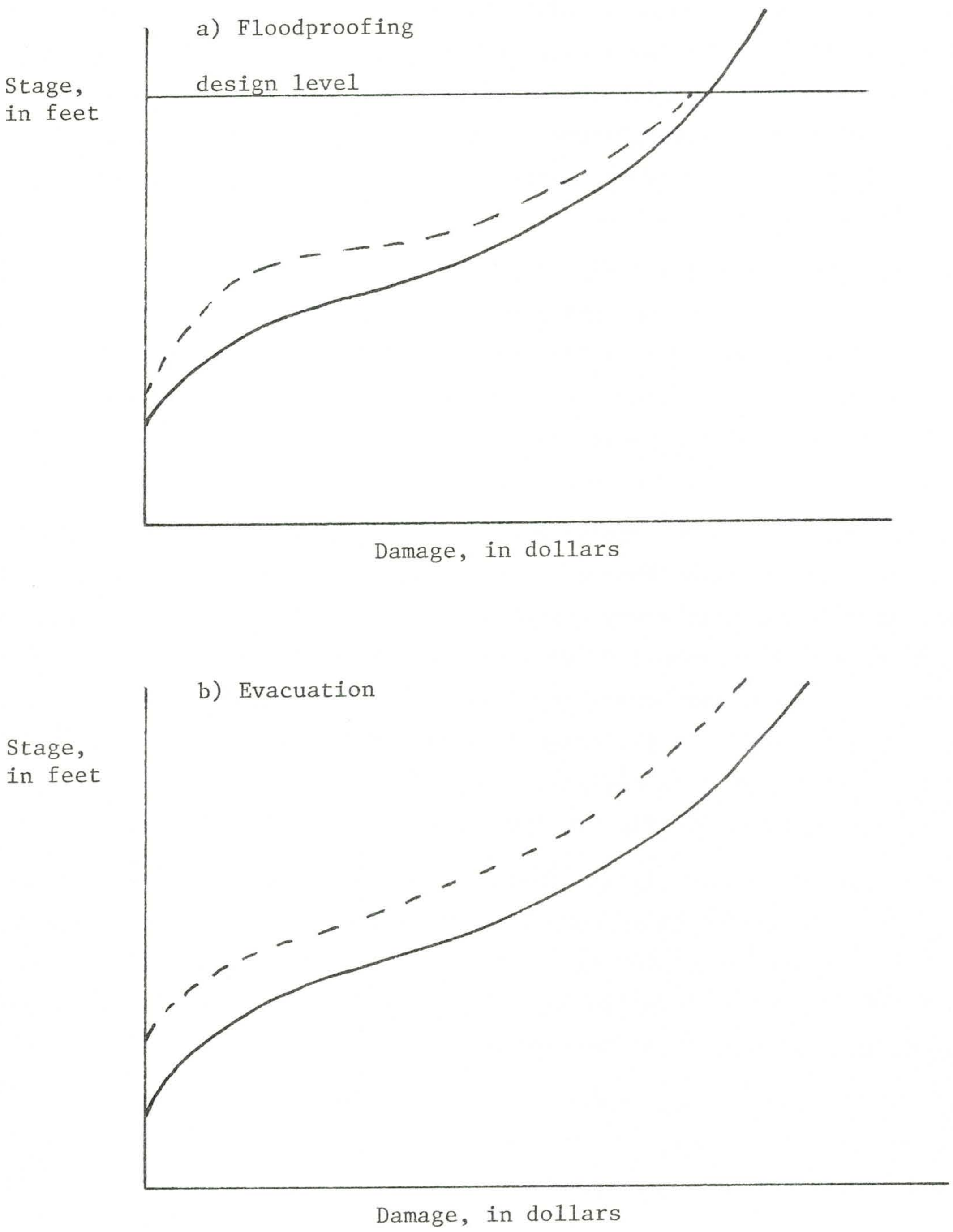
[4]This discussion is obviously of a very general nature. A problem remains and will be discussed below, i.e. what constitutes a program and how do we define the design level?

[5]See footnote 4.

Figure III-3

Modified Stage-Damage Curves



or purchase of the structures within a certain section or all of a floodplain. Nonstructural measures, however, do not fit this type of format as well as structural measures. For example, building a dam to provide 100-year protection will provide that protection to the control point or floodplain. This structural alternative is well defined and calculation of costs and benefits is straightforward. Now consider floodproofing: if the floodplain is a table top and development is randomly scattered throughout then the 100-year design level may correspond to raising each structure three feet. But if the floodplain is undulating, floodproofing to the 100-year level may imply raising some structures eighteen or twenty feet and others not at all. In most floodplains a uniform degree of protection is not possible due to the topography.[6]

An evacuation program could provide a uniform degree of protection by removing all structures, utilities and other damageable items from the floodplain defined by the design flow. Damages to substituted uses would remain, as would damages to structures above the design level. This program might not be the most efficient of the flood damage reduction alternatives and is almost surely to run head on into widespread local opposition.

A better approach to defining a nonstructural program would be to determine how various measures might be combined to take advantage of the complementary nature of the methods. In a more general sense, this is true not only of non-structural measures but of structural-nonstructural mixes as well. Here we limit the discussion to mixes of nonstructural measures. From an economic point of view the nonstructural program could be defined to consist of that mix of measures which would achieve protection to the design level at least cost. For example, for one subsection of the reach, floodproofing might provide the least cost alternative for existing structures, another subsection might require evacuation because floodproofing is not feasible or is too expensive, another might be regulated by a subdivision code which required floodproofing of any new structure, and still another might be zoned for open space. This least-cost combination may not correspond to the mix of alternatives chosen when all factors are considered--economic, social, and environmental.[7] In fact, the appropriate criterion would be to apply that measure to each structure which maximized net benefits. Political

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[6]Some studies have rejected floodproofing on the grounds that it does not provide uniform protection.

[7]The program could be developed using administrative decision rules such as: floodproof structures if raising four feet or less will provide the desired degree of protection; otherwise remove structures; zone undeveloped land.

exigency, rather than economic optimization, seems to be a determining factor here. It may turn out that some of the structures exhibit negative net benefits with any measure. Others may merit only marginal protection. It is unlikely that a public program which provided only slight protection to some structures and complete protection to others would be politically acceptable. With these comments and the caveat that a program keyed to providing least cost protection for a design level is not necessarily optimum, we move on. Once the mix of alternatives, the program, is selected the benefits are calculated as the difference between damages with and without the program.

To determine benefits, then, we must develop a modified stage-damage relationship for the program of nonstructural measures we have selected as an alternative. Conceptually, we know that the stage-damage function will shift up to the point where the design level is reached. However, little research has been performed which would define the magnitude or shape of this shift or the damage reduction capabilities of the nonstructural alternatives. James defines damages residual to implementation of the program to be:

> Damages which cannot be prevented by nonstructural measures. Urban examples include damages to yards, streets, and other outside property plus many kinds of indirect damage . . . it was assumed that an analysis of these kinds of damages showed them to equal one-sixth of the total. [James, 1965, p. 15.]

Modified damages would then be only one-sixth of potential damages to the design level and would return to the unmodified curve once the floodproofing was overtopped. [James, 1965, p. 15.] James is using a linear aggregated damage function which seems to be an oversimplification. This type of formulation is popular in the literature; see for instance Day [1969] or Willis and Alkiku [1974]. In the latter paper, benefits are defined to be

$$b_{pk} = a \cdot M_k \cdot d \qquad \text{(III.3)}$$

where b_{pk} is dollar damages to the k^{th} type of structure, a is the damage coefficient, M_k is the market value of a representative structure of type k and d is flood depth in feet defined as follows:

$$d = \begin{cases} d^*, \text{ if } p > d^*, \text{ and} \\ 0.1p, \text{ if } p < d^*. \end{cases}$$

Floodproofing is assumed 100% effective if p, the height of floodproofing, is greater than d*, the actual level of flooding. Otherwise the floodproofing is considered very ineffective. This approach would overstate the benefits of the floodproofing unless residual damages to the outside of structures is to be estimated separately.

Bhavnagri and Bugliarello [1966] approach the problem by dividing the floodplain into m steps or contours. Damages are taken as a function only of stage or depth on each step. A "Unit damage function," δ, is assumed to be a function of depth of flooding, Z, and to be the same for all establishments. This follows James in having a uniform damage function for each category of structure. Both the FIA and the Corps have stage-damage tables or functions for various types of structures. Table III-1 shows depth-damage curves for residential and small business structures. The damages are stated as percentages, or as dimensionless fractions. The damage susceptibility of the r^{th} structure on the j^{th} step is the "individual characteristic damage," K_{jr}, of the structure (in dollars). The market value of a structure and its contents is usually specified as K_{jr} for use with FIA or Corps tables. Damage to the r^{th} structure when flooded to height Z is

$$d(Z) = K_{jr}\ \delta(Z). \tag{III.4}$$

Total damage on the j^{th} step (flooded to height Z) is

$$d(Z)_j = \delta(Z) \sum_{r=1}^{n} K_{jr}. \tag{III.5}$$

The sum of all the individual characteristic damages for the j^{th} step

$$B_j = \sum_{r=1}^{n} K_{jr} \tag{III.6}$$

is the total damage susceptibility of that step. Total damages on the floodplain for flood level s_i are

$$D_i = \sum_{j=1}^{n} B_j\ \delta_{ij} \qquad i = 1, 2, \ldots, m \tag{III.7}$$

where,

$$\delta_{ij} = \delta(S_i - \theta_j) \tag{III.8}$$

in which $_j$ is elevation of the j^{th} step. Residual damages are accounted for in $\delta(Z)$.

Floodproofing is represented in this model in two ways. First, by excluding water from the structure, or by raising, the flood depth inside the structure is reduced, say from Z_1 to Z_2 in Figure III-4. This, in effect reduces the damages from $d(Z_1)$ to $d(Z_2)$ for the given flood. Floodproofing measures which reduce the vulnerability of the contents of structures reduces damages to $d'(Z)$ by changing the individual characteristic damage from K_{jr} to F_{jr}. The authors do not account for the fact the damage curve regains its usual shape once the design level of the floodproofing is exceeded.

Table III-1

FEDERAL INSURANCE ADMINISTRATION

September 1970
Depth-Damage Curves
Set A

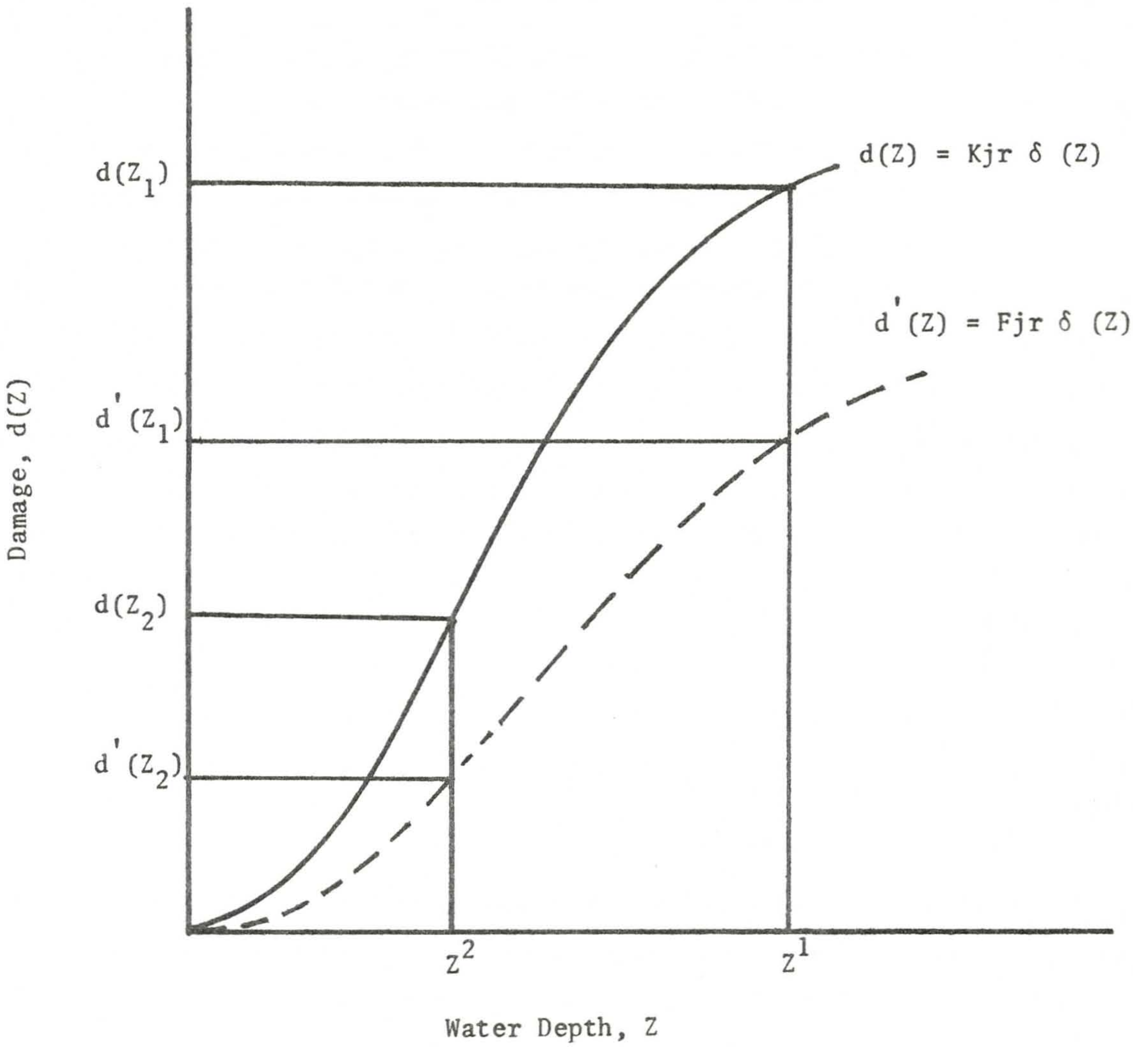
Structures--Residential and Small Business

	Curve No.						
	01	03	05	10	13	18	23
Depth in Feet	Damage in % of Total Value						
-3.0					.0	.0	.0
-2.0					3.	3.	3.
-1.0	.0	.0	.0	.0	6.	5.	5.
First Floor .0	8.	4.	3.	8.	10.	7.	6.
1.0	22.	10.	11.	50.	24.	14.	16.
2.0	30.	16.	20.	71.	31.	21.	22.
3.0	35.	20.	25.	82.	37.	26.	26.
4.0	39.	24.	29.	87.	41.	30.	30.
5.0	41.	27.	31.	89.	44.	33.	32.
6.0	44.	30.	33.	91.	46.	35.	35.
7.0	46.	32.	34.	91.	48.	38.	36.
8.0	48.	34.	41.		49.	40.	44.
9.0	50.	39.	46.		50.	44.	48.
10.0		42.	50.			46.	52.
11.0		45.	53.			47.	55.
12.0		47.	55.			48.	57.
13.0		49.	58.			49.	58.
14.0		50.	59.			50.	59.
15.0			60.				60.

Classification	Curve
One story, no basement	01
Two or more stories, no basement	03
Split level, no basement	05
One story with basement	13
Two or more stories with basement	18
Split level with basement	23
Mobile home, on foundation	10

Figure III-4

Two Methods of Floodproofing[8]



[Source: Bhavnagri and Bugliarello, D 66]

[8]The damage curves in the figure correspond to a unit damage function with form

$$\delta(Z) = \frac{2\pi Z}{10} - \sin\frac{2\pi Z}{10}. \qquad \text{(III.9)}$$

The most interesting aspect of this approach is the division of the floodplain into steps and analyzing each step separately. A similar approach is taken in the Cameron Run floodproofing study. There the modified damage function was calculated by shifting the first floor elevations of the floodplain structures in one-half foot intervals and recalculating benefits at each elevation. That is, flood damages are recalculated as if the flood depth had been reduced by one-half foot as in the Bhavnagri and Bugliarello discussion from Z_1 to Z_2.

Apparently there is no conclusive theoretical or empirical evidence which would help us to develop a "typical" modified stage-damage function for a floodproofed structure.[9] For our defined alternative, which includes floodproofing certain parts of the floodplain to specific heights, we will need to determine what damages will occur at various flood stages. Explicit account must be taken of damages residual to floodproofing measures (i.e. as defined above--those which cannot be prevented by floodproofing) and of the fact that once the floodproofing design level is exceeded the damage curve will regain or exceed its original level.

For evacuation the stage-damage curve is shifted by the amount of damageable structures and contents which are removed from the floodplain. For example, B_j would be reduced by the amount of the K_{jr}'s which are removed from the floodplain so that

$$B_j = \sum_{r=1}^{n} K_{jr} \tag{III.10}$$

where,

$$K_{jr} = \begin{cases} K_{jr}, & \text{for structures remaining;} \\ 0, & \text{for structures removed.} \end{cases}$$

Modifying the model of Bhavangri and Bugliarello to include different structural types and sections of the floodplain instead of contours, we redefine the damage to the r^{th} structure of type t flooded to height z as

$$d_{tr}(z) = \delta_t(z)\, K_{tr} \tag{III.11}$$

where a different function $\delta(z)$ is specified for each structural type t, $t=1, \ldots, m$. Total damage on the floodplain when flooded to elevation h is

$$D = \sum_{t=1}^{m} \sum_{r=1}^{n} \delta_t(z) K_{tr} \tag{III.12}$$

[9]This is an area where substantial research efforts are warranted. The Federal Insurance program should provide useful data as it develops.

where,

$$Z = h - g \qquad \text{(III.13)}$$

and g is the ground floor elevation of structure r. The value of n for each t is determined from floodplain maps or a survey.

In the planning process the number of calculations could be reduced by aggregating the structures into damage reaches, subreaches or sections. Each section s should contain homogeneous development of type t and be at a uniform elevation g. Damages for section s are

$$d_{gt}(Z) = \delta_t(Z)\overline{K}_{tg}n_g \qquad \text{(III.14)}$$

where,

$\overline{K}_{tg}$ = the average "individual characteristic damage" of structures of type t in section g, taken as market value here;

n_g = number of structures in section g;

g = 1, . . ., G.

The aggregate stage-damage function is determined by summing damages for each section at each stage. This defines damages for the "without" condition.

The with condition damages are determined by modifying either the unit damage function or by reducing the total characteristic damage ΣK. The program definition calls for separate actions on each section. Our hypothetical program calls for structural floodproofing on sections 1 through g_1, raising on sections $g_1 + 1$ through g_2, evacuation relocation on sections $g_2 + 1$ through g_3, and regulation of sections $g_3 + 1$ through G. Structural floodproofing modifies (III.14) to

$$d_{gt}(Z) = \delta_t^*(Z)\,\overline{K}_{tg}n_g \qquad \text{(III.15)}$$

where $\delta_t^*(Z)$ is defined by the damage reduction capability of the floodproofing until Z exceeds p, the design level of the floodproofing. At this point $\delta_t^*(Z) = \delta_t(Z)$. Raising modifies (III.14) to

$$d_{gt}(Z) = \delta_t(Z - p)\,\overline{K}_{tg}n_g. \qquad \text{(III.16)}$$

Evacuation-relocation modifies (III.14) to

$$d_{gt}(Z) = \delta_t(Z)\,\overline{K}_{tg}n^*_g \qquad \text{(III.17)}$$

where n^*_g represents the number of structures remaining on the section after evacuation.

Benefits are then calculated in the usual manner by aggregating the stage-damage functions from each section and converting these into damage frequency curves. The difference between the areas of the with and without damage frequency curves is the average annual damage reduction.

Measurement of benefits in this way would give an adequate representation of inundation reduction benefits. This approach, as well as most others currently used in this field, abstract from some important issues. The most obvious is the fact that no location or intensification benefits are estimated. This is a serious omission but, as explained above, cannot be accomplished here. Accurate assessment of inundation reduction benefits would be a major improvement in itself. A further omission is damages categorized as business losses, travel losses and other hardships which are directly or indirectly caused by the flooding. These should be evaluated as explicitly as possible for activities not directly inundated but may be included in the stage-damage function for those inundated. For example, we could estimate loss of production, clean up costs and lost sales which would result from a certain depth and duration of flooding and these could be incorporated in the stage-damage function. For the indirect losses we would need to know the interrelationships among producers.

Most of the other difficult questions which have not been answered about benefit estimation have to do with future time periods. For example, the Flood Insurance Act does not require that existing structures be floodproofed unless damages occurring in a future flood, or the cost of any remodeling, exceeds fifty percent of the value of the structure. If the nonstructural program does not recommend floodproofing or evacuation of such a structure then it will continue to exist, will age, will more than likely deteriorate and at some point in time be demolished or replaced. Since damages reduced include both those in an initial year and those in the future this chain of events will have some effect on the damage estimates. The question here is how the damages should be adjusted as the value of the structure depreciates. Related to this question is the question of how to handle the controversial "affluence factor." The affluence factor analysis is an attempt to capture the effect of the increasing wealth of consumers over time. Not only does the value of our goods increase with general price level but the holdings of households increase, also. As time passes, a greater proportion of households own a color television set, two automobiles, and etc. Engineer Regulation 1105-2-354 presents a methodology for the affluence factor which builds on a research effort to determine the relationship between values of structures, contents and personal income. The results indicate that only the contents of structures exhibit behavior which could be interpreted as growing affluence; structure values, apparently, decline as site values increase. The conclusion is that the rate of change of local real household income would be a reasonable proxy for the rate of change of local net real value of household content stock over time. This affluence factor is then applied to unit flood damages (i.e. an incremental unit flood damage is added) to obtain adjusted unit flood damages for projected conditions. A similar method could be used for projected benefits to existing structures which will depreciate over time due to age and exposure to flooding.

Other practical and theoretical questions remain concerning benefits in future time periods. One notable question which has produced many pages of debate in the literature concerns the appropriate discount rate to use in benefit-cost procedure. The same question arises in connection with nonstructural measures but since national policy specifies the discount rate to be used the question is beyond the scope of this inquiry.

The Flood Insurance Act specifies that floodproofing of future development is required so that a nonstructural program cannot claim benefits, from floodproofing unless it is beyond the 100-year design level. The nature of a nonstructural program then excludes many of those future benefits which help justify structural projects.

Flood Control Benefits and Flood Insurance Premiums

Flood disaster insurance is often suggested as a nonstructural alternative. Flood insurance does not produce any of the kinds of benefits discussed in the context of other nonstructural measures. No damages are prevented, no intensification is induced and no location advantages can be claimed. Essentially, flood insurance spreads the losses rather than reduces them. Flood insurance may, nonetheless, be an important flood control alternative. If the rates charged floodplain occupants are actuarial rates and therefore reflect their expected annual losses more rational behavior may result. Consumers will make their residential location decisions with full knowledge of the flood threat reflected through the premiums to be paid for flood insurance. Fuller information will lead to better location decisions since the flood insurance premiums will allow the flood risk to be explicitly accounted for in the profit calculus. Lind shows that flood insurance will lead to optimal results. The existing federal flood insurance program has subsidized rates but increased information and better location decisions should still result.

It has been proposed that the savings in flood insurance premiums be taken as a measure of the benefits from a flood control program. The reasoning is that by removing the flood threat, insurance is no longer necessary and so the premiums need not be paid. If the premiums are set actuarily then the savings in premiums is an indirect method of measuring the reduction in flood damages. Any load charge for administering the program would also be saved. This is only a benefit in the sense that the expense of a program required by law is no longer necessary. The benefits of the flood control program are limited to the damages actually prevented. Claims experience in the flood insurance program should prove to be a good source of data on actual damages from floods.

Chapter IV

TOOLS FOR EVALUATING NONSTRUCTURAL MEASURES

Chapters II and III suggest methodologies for evaluating the costs and benefits of nonstructural flood control measures. In these methodologies the evaluation problem is approached in a disaggregated form. The best evaluation tool to complement these individual unit data would consider each unit or structure as a separate case with the sum of these micro costs and benefits constituting the macro, or aggregate, value for decision making. However, since floodplains often contain large numbers of structures, and because they are usually linked hydrologically and economically with other floodplains within the basin, generalized and aggregated data must also be developed and used. Methodologies using average or representative values of unit costs are necessary in these cases. The accuracy implied by these procedures would be sufficient to make decisions for screening out the worst alternatives and to further evaluate the others.

Whether the analysis is with individual or aggregated data, computerized tools would facilitate the analysis. The type of tool selected will depend upon the analysis desired. Macro or system type tools link individual damage centers within a basin and provide a hydrologic, as well as, economic evaluation of the entire system of measures and damage centers and their interrelations. The micro type tools on the otherhand provide detailed hydrologic and economic information within a floodplain. Both are important and complement each other. A brief description of several of these analytic tools encountered during the course of this investigation follows.

HEC-5C - Simulation of Flood Control and Conservation Systems

This computer program simulates the flood control and conservation operation of a hydrologic system which can include structural and nonstructural measures. In its existing state, the nonstructural plans must be preformulated since only the aggregate of the costs and benefits is considered. This implies that the measure and its intensity must be selected outside the program. Any mixing of measures, for a given damage reach, is also performed outside the program. If data for different nonstructural alternatives are developed then HEC-5C can analyze each in the context of the system operation. Costs of nonstructural measures are specified as a function of the design discharges. The aggregated capital cost is entered to correspond with the design discharge. The costs of some nonstructural measures may not vary with channel discharges or with stage. However, by specifying costs at design discharge, or stage, we can adequately reflect the costs of a predefined program. If we were attempting to determine the best level of floodproofing for a given floodplain, a function which related costs to stage would be required. To determine net benefits we need to know the reduction in flood damages brought about by the measure. This is handled in HEC-5C in two ways. First, the modified damage function can be defined with the design discharge as the zero damage point. This implies that the nonstructural measure is completely effective up to the design discharge. The damage curve is truncated such that the design discharge becomes the zero damage point. The second is to completely redefine the damage function with a new set of data cards. The program requires that the upper limit of the measure be specified as a design discharge. As suggested in Chapter III this implies that the damage curve remains unchanged above the point where the protection provided by the measure is exceeded. The program is dimensioned so that nine different damage categories may be used.

The capability of HEC-5C for evaluating nonstructural measures is therefore primarily aggregate. Given the cost and damage relations of a prespecified plan, this can be evaluated with respect to other alternatives. The program was not developed to evaluate a floodplain on a unit by unit basis in order to determine the best mix of measures. The evaluation of such a plan, if necessary, can more effectively be done using other techniques.

The aggregate analysis capability of HEC-5C is essential to the evaluation of basin-wide and system mixes of alternatives. It is therefore complementary to any unit by unit analysis that is required for a specific damage reach.

Day-Weisz Model

Day and Weisz (1974) developed a linear programming model for floodplain management. The model is thorough and considers all alternatives. This model is reviewed elsewhere (Brown, et al., Models and Methods applicable to Corps of Engineers Urban Studies, 1974) so only a brief comment is necessary here. The main limitation of this model is that the cost and damage functions for nonstructural measures are linear while empirically the evidence suggests that these functions are nonlinear. For this reason and because we are here concentrating or developing an evaluation tool for nonstructural mixes, we find Day and Weisz less useful than other tools.

INTASA Simulator

INTASA has developed a computerized land use planning tool called the Simulator which is presently capable of economic evaluation of structural measures and land use regulations. The model is designed to assist the planner in rapidly and easily analyzing various alternative land use patterns. No explicit account is taken of floodproofing or relocation but it appears that these could be easily added to the model.

The model allows the floodplain to be divided into various subareas, parcels and reaches which will facilitate the selection of a nonstructural plan. Flood damage zones are such that flood characteristics can be assumed uniform. These are developed by first dividing the floodplain into reaches where the difference in stage of floods is approximately the same. Then each reach is divided into zones where the depth of any particular flood is approximately the same throughout using ground elevations and stages of sample floods or flood contours. Site development zones are determined such that site development and construction costs are relatively uniform within each zone. Parcels are defined as the smallest land use units and are selected based on uniformity of flood damages, site development costs and amenity values. These definitions and the detail of floodplain representation they imply would facilitate the introduction of floodproofing, evacuation and mixed measures into the model. Categorizing structures at similar elevations, of similar structural facility types and in the same site development cost zone within the same floodproofing cost range will allow for the application of those procedures suggested in Chapter II.

Depth-damage curves are required for each activity/structure type. Damages are expressed as a fraction of the value of the unit; the same curve applies to all structures within an activity/structure type. Modified stage-damage curves could be developed for the various nonstructural measures with further research and with data developed within the framework of the flood insurance program. The calculation of average annual damages reduced for floodproofing by raising is facilitated by the requirement that the height above ground level at which zero flood damage occurs be specified. This height could be shifted up to represent the effect on damages of raising the structure. The model is developed so that situations which differ in one or more parameters may be compared. Some modifications to allow for explicit analysis of nonstructural measures need to be made and so the Simulator is recommended for further study.

HEC DAMCAL

A computer program is currently being developed at the Hydrologic Engineering Center that makes economic analyses as part of a larger data management strategy. The main strength of the program lies in its ability to handle data. Location, elevation and structural (or land use) types are input along with damage functions for various activity types. The locations are mapped using a grid which allows for relatively small cells that may contain as few as one structure. The effects of varying land uses and hydrology can be determined in detail by overlaying the modified land use map and recalculating flood damages. Since the structures and land uses are categorized by type and elevation, the effects of floodproofing certain sections of the floodplain could be easily calculated. Many combinations of floodproofing and relocation could be evaluated with the resulting damage function modifications useful for input into other analysis programs. If cost functions, or tables, could be specified for floodproofing and evacuation of various structural types at various stages then aggregate costs could also be determined. The program has potential for evaluating changes in zoning or other planned and unplanned land use changes. The floodplain data is stored in computer files as a grid map with changes in the grid map easily made.

Some Observations

The best tool for detailed evaluation of nonstructural measures should have, in the author's opinion, the following capabilities: (1) It could handle mixed nonstructural measures and structural/nonstructural mixes as well. This is necessary to allow the most efficient measure to be applied to each unit within the floodplain. (2) The tool should be able to identify the most efficient measure to be used at a specific point within the floodplain. At times efficiency will be sacrificed for other goals and so the tool should be able to handle other decision rules for selecting the appropriate measure for each unit of the floodplain. (3) In order to evaluate the alternatives, the tool should have the capability to use micro cost and damage functions defined for different types of development at different elevations. In the cases where we are unable to evaluate each unit separately, samples of structures can be used to represent various categories of development in a section, grid cell or damage reach. (4) Finally, the tool should have the capability to aggregate the information in (1) through (3) into macro cost and damage functions for input into HEC-5C or similar aggregate model, to perform the hydrologic and economic analysis of the entire system.

In line with the methodologies for measuring costs and benefits developed earlier the mechanics of using this evaluation tool would follow these procedures. The floodplain would be defined in spatial units small enough to contain one structure or a small number of structures of one category. Second, the number and category of structures in the floodplain would be determined. Third, define the plan formulation rules. These could take two forms: (a) choose the most efficient method or, (b) criteria such as, if floodproofing to a height (h) less than six feet gives the design level protection (say, 100-year) then floodproof to height h, otherwise relocate the structure; regulate all undeveloped areas in the floodplain to exclude damageable development. Fourth, evaluate the costs of the plan by applying cost equations or tables of costs to the structures. Statistical sampling in each floodplain would increase the accuracy of the estimate. Fifth, determine damages before and after using damage functions developed for each category of structure. More data is needed which will help determine the damage reduction capabilities of the various nonstructural measures. Finally, aggregate the costs of the different measures included in the plan and aggregate the various damage relations.

Chapter V

SUGGESTIONS FOR FURTHER RESEARCH

This study has developed some basic procedures for measuring the costs and benefits of floodproofing and relocation for flood damage reduction. Many questions remain unanswered or only superficially addressed. One of the most important of these is the measurement of intensification and location benefits from the nonstructural measures. The requirement that these benefits be measured and that nonstructural measures be evaluated on an equal basis with structural measures makes it mandatory that the concepts be thoroughly investigated in the context of nonstructural measures. A second important area of investigation is the specification of modified damage functions. Experience with these measures is inadequate to provide an accurate assessment of the damage reduction capabilities of the measures. A cooperative, consistent and thorough data gathering effort within the Corps of Engineers would provide much needed information to help guide future studies. This leads directly to a third area of potentially fruitful research. The development of a data bank within the Corps of Engineers with data input from all studies investigating nonstructural measures could progress from suggestions made in earlier chapters. Surprisingly, many district offices were unaware of the work which their counterparts were performing in other areas of the country. Obviously, much of the information reflects local conditions but the data could still prove useful, especially if a consistent methodology were used to develop the various estimates. A final area of suggested research is the whole question of land use regulations in floodplain management. A particularly interesting area is that of the Flood Insurance Act and its implications for land use regulations. It is not clear that the Act has provided the most efficient utilization of land use regulations. Benefit costs and other considerations should determine how and how much regulations should be used.

APPENDIX A

Cost Estimates for Nonstructural Measures in Corps Reports

In the interest of providing information about the methodology used by the Corps of Engineers for evaluating nonstructural flood control measures, this Appendix summarizes much of the information gathered in this study. Two trips were made to visit and gather information from various Corps offices which have recently considered nonstructural measures in floodplain management plans.

The trips were successful in gathering a reasonably large volume of information. To maintain consistency with the main report the discussion is arranged by measure. First, the measurement of the cost of floodproofing, evacuation-relocation and regulation is discussed. Little information or material was gathered on the measurement of benefits.

The insights gained from the conversations and meetings are not limited to those reported here. Much was left out which was not specifically relevant to the study topic. Some of the ideas not reported here will hopefully be pursued at a later date.

Floodproofing

In the following discussion the organization is by district rather than project because of the similarities in methodology for measuring costs within any one district. In some cases projects are not specifically identified due to the preliminary nature of the studies and therefore of the material gathered.

It is interesting to note that the different measures take various forms in the several districts. For example, as shall be seem below, floodproofing for residential structures was seen to be limited to raising in some districts while others considered only more conventional sealing and installation of gates. In any case, the chosen methodology is seen to be determined by factors such as: characteristics of flooding and the floodplain, integrity and characteristics of the structures and density of development. The data shown is in each case the data considered most useful for the study of the evaluation of the three nonstructural measures.

Baltimore District

In the Lock Haven Flood Protection Project Survey Report it was found that "the depth of flooding and the degree of development preclude the use of floodproofing and zoning as an immediate total solution to the flooding problem in Lock Haven" (Lockhaven, p. 18). However, in Appendix J a detailed evaluation of floodproofing costs is undertaken. Cost estimates are made for six residences, five commerical and three industrial structures. These structures are said to be sample typical of the development in Lockhaven. Floodproofing costs are not developed for public services since these sustained little damage in recent floods.

The method chosen for residential floodproofing is to seal the structure to the first floor level by exposing, cleaning and waterproofing with gunite the existing walls. The first floor level was chosen because it is typically two to three feet higher than the surrounding elevation and because the structures were judged incapable of withstanding the hydrostatic forces caused by deeper floods being excluded from the interior of the structure. Table A-1 shows a detailed cost estimate for one typical residence. Figure A-1, also taken from Appendix J of the Lockhaven report, plots the floodproofing costs against the size of the structure.[1] At the Baltimore district it was found that size is more important than market value in determining the costs of floodproofing a structure.[2]

Each of five commercial structures is analyzed in detail and costs of floodproofing are determined. Itemized costs for a typical commercial structure are shown in Table A-2. Detailed analysis and costing was undertaken for three industrial concerns. The measures taken are unique to each establishment and are too detailed and complex to be reproduced here.

Another report, in its early stages in the Baltimore District, will thoroughly consider floodproofing. The type of floodproofing to be used will again be of the contingent type, i.e., gunite sealing and closure structures on low windows and openings. In both these studies only floodproofing of existing structures is considered.

The information presented in the Lockhaven report will be useful in the evaluation of nonstructural measures because costs are related to particular structures and sizes of structures. These costs will be applicable to other projects where the method of floodproofing is sealing and structures are

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[1] It is not clear why the curve is given this particular shape.

[2] Personal communication with Baltimore district personnel.

Figure A-1 Relation Between Floodproofing Costs and Size of Structure

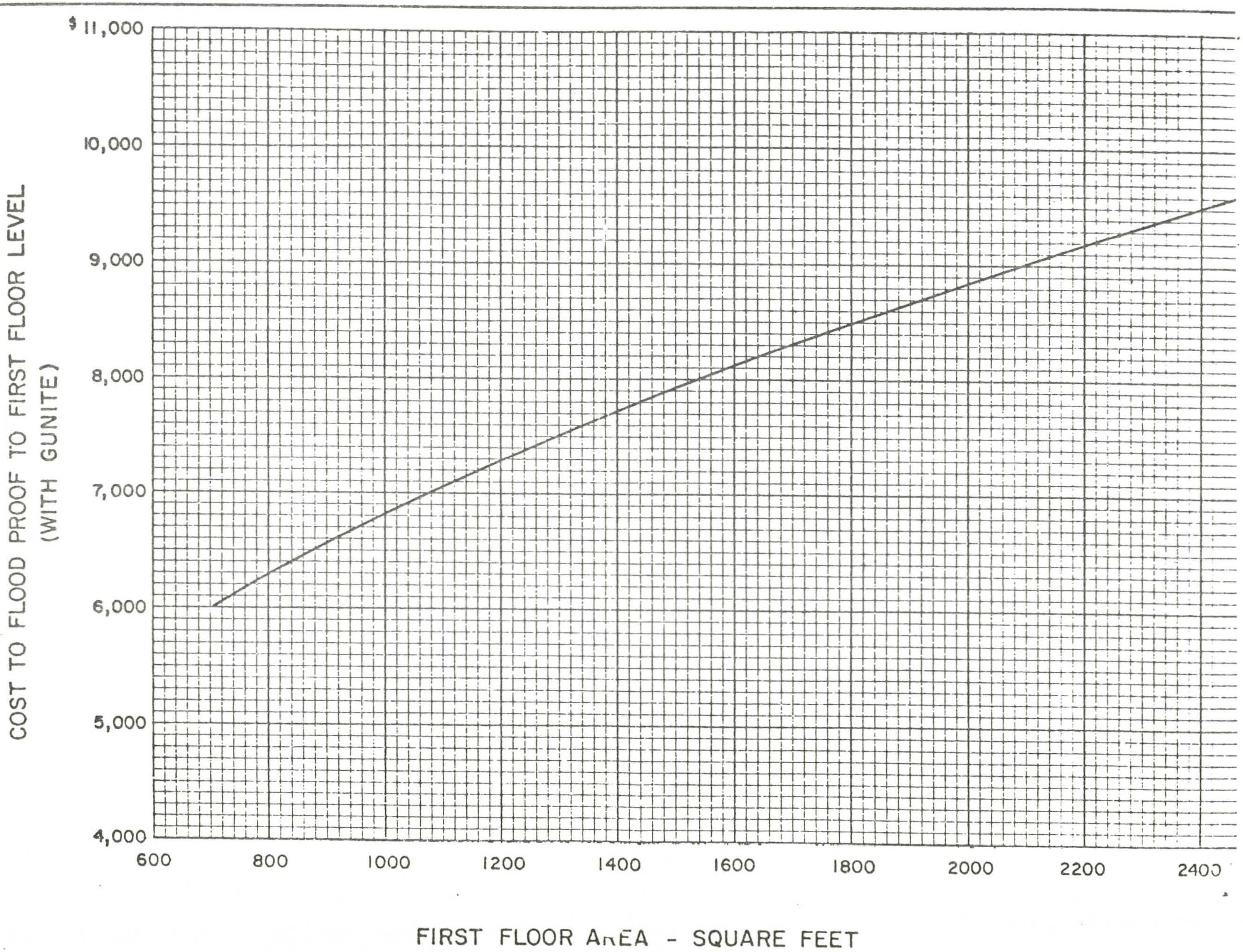

TABLE A-1

Detailed Cost Estimate Typical Residential
Cost for Using Existing Foundation, Repair and Waterproof

1.	Excavate	$ 225.00
2.	Drain Title	326.00
3.	Sandblast	192.00
4.	Concrete Floor (Interior)	650.00
5.	Block Closures (Windows, etc.)	53.00
6.	Gunite 20x40x8 @ 2.13/sq. foot	3,000.00
7.	Backfill and Compact	104.00
8.	Grading and Seeding	150.00
9.	Closures for outside door 3'x10" Passage	150.00
	Subtotal	$4,850.00
	Actual Labor	1,044.00
	25% Contingencies	261.00
	Total	$1,305.00
	Material and Subcontractor	3,806.00
	25% Contingencies	851.50
	Total	$4,657.50
	Labor and Material 30% Subcontractor overhead and Profit	$1,788.75
	Billing Cost	$6,751.25

Source: Lock Haven Flood Protection Project Survey Report, Appendix J, Table 3, page 13.

TABLE A-2

Itemized Cost, Typical Commercial
Floodproofing Cost

1.	Repair section of wall on the south side of the building where plumbing is exposed. Labor and material		$ 650.00
2.	Parge and Waterproof		
	Medusa Portland White Cement w/cretite adatitive, 22 bags @ $6.39 bag		140.58
	22 gals cretite @ $5.00/gal		110.00
	Labor		500.00
3.	3 3' x 7' block windows in rear		
	33 8" concrete blocks @ $.23 ea., 33 per window x 3		22.77
	Labor @ $.40 per block x 99		39.60
	Brick facing @ $100 p/m, 140 per window x 3		50.00
	Labor A $120 p/m		60.00
4.	Outside entrances on sidewalk		
	2 4' openings (aluminum shields as designed)		1,000.00
5.	Concrete basement floor 2,700 s.f.		
	25 yds. concrete 3,000 lb. mix @ $26.85 per yd.		671.25
	Labor @ $.40 per s.f. x 2,700		1,000.00
6.	Front door closure		2,000.00
	Labor		500.00
7.	(3) Rear door closures @ $234.00 ea.		702.00
	Labor		400.00
			$6,020.00
	Contingencies		$3,000.00
		25%	748.00
			$2,278.20
		25%	570.00
	Overhead and Profit		$7,344.20
		30%	$2,203.26
	Total		$9,547.46
	Approximate cost per building		$9,600.00

Source: Lockhaven report, Appendix J, p. 21

similar to those in the Lockhaven report. After adjustments for regional and time differences in prices the Lockhaven costs will provide a reasonable figure for comparison purposes with local estimates.

Buffalo District

Three studies in the Buffalo District consider floodproofing. In the first study, averages were used to represent floodproofing costs. Unfortunately the backup data for these costs were not available. The following cost estimates were used:[3] $600 per residence where work is confined to blocking window openings, providing check valves and raising vent outlets; $6,700 per unit where there are structural weaknesses of basement walls of flood levels higher than basement walls so that it would be necessary to build new walls. Included are costs of replacing sidewalks, floors, integral garages and shrubbery; $8,400 per unit for commercial structures. Check valves are required on all structures because much of the flood damage in this basin is caused by storm sewer backup. In a floodproofing and evacuation plan presented in the same study residential protection is provided by waterproof man hole covers and sewer cutoff valves. The costs are as follows: $495 per manhold and $250 per residence for cutoff valves.

In the second study, floodproofing is by raising for residential structures and by structural improvement for commercial structures. Estimated costs[3] of floodproofing used in this study are shown in Table A-3. Cost estimates for floodproofing were based on previous Corps projects.

The third study considered floodproofing for two types of residential structures--permanent residences and cottages. The estimated costs[3] are $5,700 and $3,200 respectively. These costs include: closing opening; raising vents; installing check valves; replacing basement walls; raising garage floors, driveways, sidewalks; adding fill; and structural modifications to buildings. Commercial structures were not analyzed because they are few in number and incur only minor damages at the stage of flooding considered. Estimated costs in these reports are not stated in detailed form.

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[3]Supplied by Buffalo District Personnel.

TABLE A-3

Estimated Costs of Flood Proofing

1. Raising residential structures above flood plain elevation

	Quantity	Unit Cost	Total
Raising house	6	$3,500	$21,000
Additional foundation	6	1,500	9,000
Total	6	$5,000	$30,000

2. Flood proof businesses

	Quantity	Unit Cost	Total
Estimated Average Cost	20	$7,000	$140,000

3. Total cost of flood proofing $170,000

Source: Supplied by Buffalo District Personnel

Los Angeles District

Two methods of floodproofing were considered in several studies undertaken by the Los Angeles District. The first method involves raising the house, hauling in fill and replacing the house at an elevation above the design flood level. The second method involves constructing concrete walls contiguous to the structure and fitting necessary openings with waterproof gates. Another version of the second method would have the concrete walls surrounding all the houses on the one block.[4]

In the Calleguas Creek report both kinds of floodproofing are considered, i.e., contiguous walls and raising on fill. The contiguous walls would have the advantage of not diverting flood flows or worsening the overflow situation. Commercial, industrial and institutional structures would be floodproofed with ring levees. Considerable problems are encountered with this alternative both from an operational and esthetic standpoint [p. 29]. The first group of problems arises because the measure is a contingent measure and requires placing gates at each of the openings on receipt of warning. Warning times are short

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[4] Personal communication with Los Angeles District Personnel.

on Calleguas Creek, evacuation is expensive and upsetting and the reaction of property owners to warnings cannot be guaranteed. The second group of problems arises because a change in the esthetics of a residential property is being imposed on a property owner which may be entirely unacceptable to him. Due to these serious problems this alternative was not considered desirable and no costs were shown.

The second floodproofing alternative at Calleguas Creek was to jack and raise structures using fill to put the residence above the 100-year floodplain. Since this measure is permanent none of the operational problems of the contiguous walls are encountered. In addition, esthetic effects would more easily be softened by proper grading and landscaping. However, evacuation problems and residual damages would remain. Costs are estimated at $600,000 in the Simi Valley and $440,000 in Mooreparks. The costs are not detailed and the number of structures is not indicated.

Computation sheets for two studies were provided by the LA district personnel. The first study considers both contiguous floodwalls and raising on fill. A large number of pages of information were provided for this study. Only a few representative pages. or calculations, will be reported here. The floodwalls were designed of concrete block seven feet high but with three feet above ground. A five foot wide footing would be provided for strength and to help prevent seepage. The cost of the wall was estimated to be $48.00 per lineal foot which includes excavation and backfill. Relocation of underground utilities would escalate the cost by approximately ten percent. For determining total costs of this alternative the cost of floodproofing residential buildings was estimated to be $7,187 per acre. It was also calculated that there are approximately four houses per acre in this area so the cost per house is about $1,797. The type of housing or of floodproofing measure is not indicated.

Table A-4 shows estimated costs for floodproofing existing residential structures by raising on fill. This alternative involves jacking the structure and moving it, placing fill and a new foundation on the building site and returning the structure to the site. As can be seen from the table other incidental costs are also included. The cost of fill in (e) of table A-4 is determined by adding costs of hauling to costs of the fill itself. A revised estimate of the cost of fill was determined to be $3.50 per cubic yard because the haul

TABLE A-4

Floodproofing by Raising on Fill

a.	Provide temporary housing family of four - 2 mos. @ \$250/ mo.	\$ 500.00
b.	Move furnishings to warehouse and return, \$500/house/move	1,000.00
c.	Disconnect existing utilities: sewer, water, gas and electrical	500.00
d.	Raise structure and move (1500 ft^2 x \$3.00/ft^2)	3,000.00
e.	Place four (4) feet of compacted fill (area top of fill, 45'x45' = 2025ft^2; volume of fill including 20% shrinkage 500yd^3 x \$1.50/yd^3)	750.00
f.	Install new utilities; sewer, water, gas and electrical. 4 items @ \$150 each	600.00
g.	Construct new footings and stem walls (foundations) 1.0ft^3/LFx1500/27=55yd^3, 55yd^3x\$30/yd^3=1650 use	1,600.00
h.	Construct ramp to move existing structure to new site	200.00
i.	Move structure to elevated site 1500ft^2 x \$2.00/ft^2	3,000.00
j.	Remove access ramp	200.00
k.	Landscape 2500 ft^2 x \$0.05/ft^2	125.00
l.	Stone revetment of slopes 1.0' thickness 1.0'x11.0x210'/27 = 86yd^3 x \$12.00/yd^3	1,030.00
	Total	\$12,505.00

Source: Provided by Los Angeles District Personnel distance was increased due to the large volume of fill material required.[5] In the same study the increased cost of constructing new residential structures with floodproofed design was estimated to be \$10.00 to \$12.00 per square foot as shown in Table A-5. Estimated residential building costs at the time of this study are \$15 per square foot. Floodproofed construction would cost approximately seventy-five percent more.

In the second study floodproofing costs were estimated for precast floodwalls constructed to the level of the 100-year and standard project floods. Floodproofing by raising was not considered feasible since the estimated costs would be five times as great as using floodwalls and greater than the damages prevented. A considerable volume of data was provided for this study but only two tables will be reproduced to facilitate comparison with other studies. Table A-6 shows estimated costs for floodproofing a typical residence with precast concrete walls. (Estimates are also provided for cast-in place walls which are considerably more expensive). The costs of raising a typical structure to provide the same protection as the floodwalls are shown in Table A-7. The total cost of raising the structure varied between 56.0 and 90.5 percent of the property value.

In this study an attempt was made to use James' [1972] equation for estimating annual costs of floodproofing. The cost equation[6] is

$$C_p = K_p((\frac{A}{p}, i\%, N) + M_p)UM_s hA \qquad \text{(A-1)}$$

Where:

C_p = discounted average annual cost of floodproofing structures;

K_p = average initial cost of floodproofing structures per foot depth per dollar of market value of structures;

$(\frac{A}{p}, i\%, N)$ = capital recovery factor based on project discount rate, i%, and measure life, N years;

M_p = annual maintenance cost expressed as a fraction of first cost;

U = fraction of floodplain in urban development.

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[5]Personal communication with Los Angeles district personnel. The costs include pressurizing water and sewer systems and any revetments.

[6]James, 1972, p. 984.

TABLE A-5

Estimated Cost increases for Floodproofed Construction (Residential)

1.	Cast in place piling	0.60/ft^2
2.	Elevated building site	1.50/ft^2
3.	Reinforced concrete block or reinforced concrete tilt up construction	8.00/ft^2
4.	Steel window and door shutters	1.25/ft^2
	Estimated unit cost increase	$11.35/ft^2

Source: Los Angeles District personnel.

TABLE A-6

Cost to Floodproof Typical Residence (200 lin. ft.) to a Height of 3 Feet with Precast Floodwalls

Description	Quantities	Labor Unit Cost	Labor Total Cost	Material Unit Cost	Material Total Cost
1. Precast concrete wall panels class "A"	(200)(1.0)/27.7= 11.1yd^3	5.00	55.50	20.00	222.00
2. Footings-class "A" concrete	(200)(1.5)/27= 11.1yd^3	5.00	55.50	20.00	222.00
3. Forms	(200)(6.0)=1600ft^2	0.30	480.00	0.20	320.00
4. Excavation	200 (1.5)/27= 11..yd^3	6.00	66.60		
5. Reinforced Bar Steel	200(9.8)=2940lb.	0.10	294.00	0.10	294.00
6. Subtotals			951.60		1,058.00
7. Supervision-basic labor (10%)			95.20		
8. Subtotal			1,046.80		
9. Fringe benefits (16.5%)			172.50		
10. Small tools (3%)			31.70		
11. Subtotal-Labor			1,251.00		
12. Sales tax (5%)					53.00
13. Subtotal-Materials					1,111.00
14. Subtotal-Labor + Materials					2,362.00
15. Prime contractors overhead, profit, bond (16%)					378.00
16. Total Construction Cost					2,740.00
17. Average unit cost $2740.00/200 lin. ft. = $13.70/lin. ft.					

Source: Los Angeles District personnel.

TABLE A-7

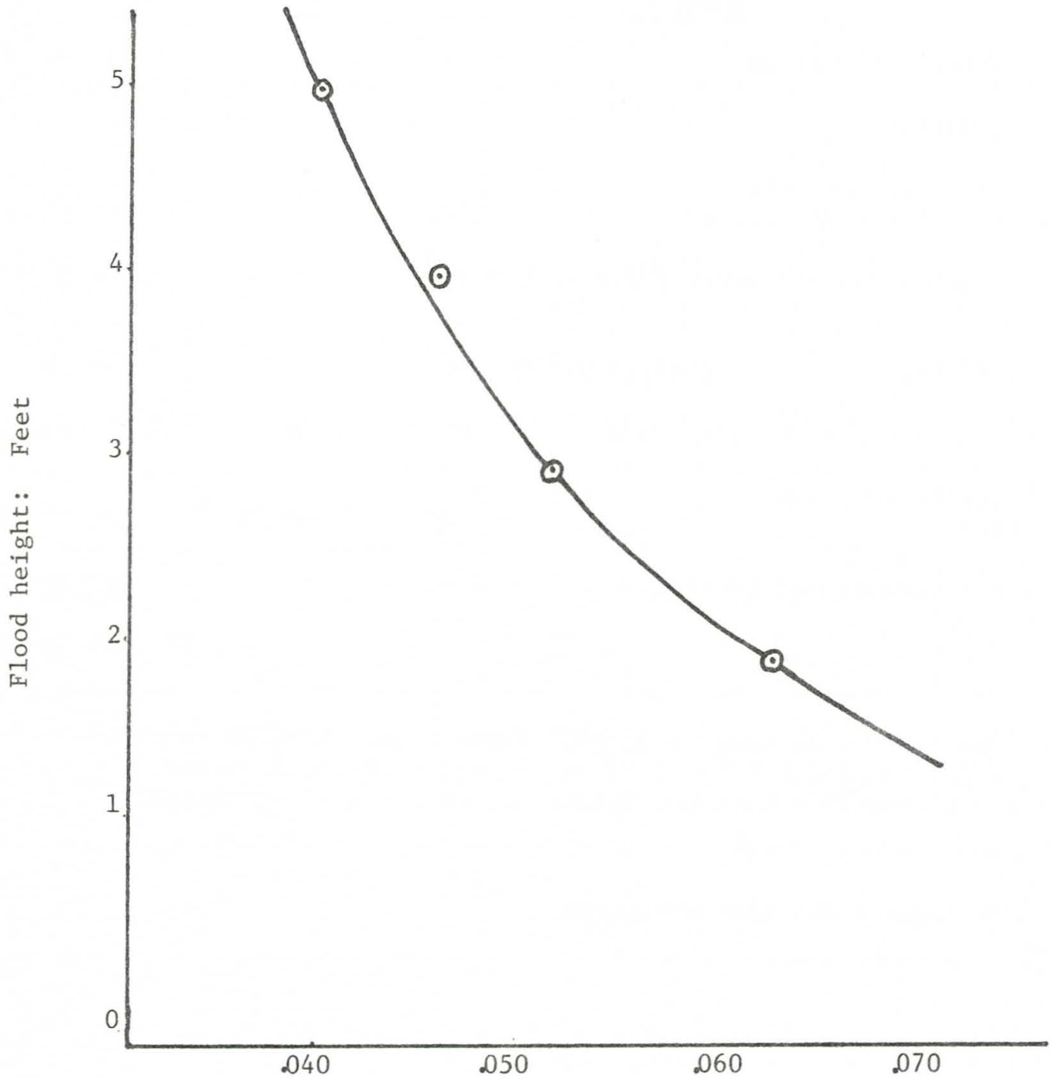
Floodproofing cost--Raising First Floor Elevation of Typical Residence 3 Feet

Description	Quantity	Unit	Unit Price	Cost
1. Moving, jacking & timbering		L.S.[1]		$ 2,500.00
2. Raising foundation				
a. cast-in-place concrete wall: labor & materials		L.S.		3,510.00
b. back fill under structure	(92.6)(3.0)= 278	yd^3	$6.00	1,670.00
3. Grading yard-fill	(185)(3.0)=555	yd^3	5.00	2,770.00
4. Replace lawn and trees	5000	ft^2	0.50	2,500.00
5. Replace Concrete sidewalk and driveway	3.33	yd^3	90.00	300.00
6. Sewer & Water service modifications		L.S.		300.00
Total				$13,550.00

[1]Basic moving cost of an average 35'x40' frame house is $2000 to $2500 which is approximately 10% to 12.5% of the value of the structure. This cost was assumed constant within range of 2' to 5' elevation.

Source: Los Angeles District personnel.

Figure A-2: Values of K_p



$$K_p = \frac{\text{Construction cost per foot flood height}}{\text{Market value of structure}}$$

[Source: Plotted from a like figure provided by Los Angeles district personnel.]

M_S = market value of structures to be floodproofed, in dollars per development acre;

H = average design flood depth, in feet; and,

A = design flood area, in acres.

The interesting parameter for this study is K_p because it expresses costs as a percentage of structure value when height is specified. James [1972] used a value of \$0.04/ft for K_p which was determined "by designing flood proofing for a group of representative structures and plotting cost per dollar of structure market value versus design flood depth. Term K_p is the slope of the best fit line through the origin." Results from the Los Angeles district study are shown in Figure A-2. The numbers in this figure are based on cost estimates for using precast concrete walls.

These studies provide useful comparison estimates for various kinds of floodproofing measures. Adjustments would need to be made for unique characteristics of the Los Angeles area and for other regional and time differences in costs.

Missouri River Division, Omaha

In the Wears Creek, Jefferson City, Missouri study[7] floodproofing is considered but rejected without the calculation of costs. Reasons for the rejection include the following [p. D-8]: 1) Many of the buildings in the floodplain were found to be structurally unsound and could not be rehabilitated; 2) Other buildings were in such poor condition that the cost of raising or protecting them exceeded their value; and 3) the existing structures were not compatible with the planned development and would not serve to attract developers to the area. The floodproofing alternative was defined to consist of such measures as raising existing and future facilities, waterproofing others and protecting roads and utilities (D-8).

A second study[8] considered floodproofing which consisted of sealing basements of residential structures or raising them if flood stages exceeded the first floor level. For nonresidential structures floodproofing would consist of floodwalls for stages up to three feet and raising for stages in

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[7] Performed by the Kansas City District.

[8] Personal communication with Missouri River Division personnel.

excess of three feet. First costs are not shown for the floodproofing alternative and the annual costs are stated in aggregate and are therefore not useful for this study. In the discussion of the general applicability of floodproofing in the studied floodplain the opinion is expressed that owners are reluctant to floodproof where flash floods occur. In general, on this type of floodplain, floodproofing is only considered attractive when the areas are being redeveloped.

In the Committee on Environmental Planning Report on the Boulder Creek Flood Control Plan floodproofing is suggested as an alternative. No cost estimates are developed but in the Appendix prepared by the university of Colorado it is suggested (Appendix, p. 10) that an average of 3-5% of the cost of the building can be used to estimate full floodproofing cost for a structure. This estimate corresponds closely to the value of K_p in James [1972].

New England Division

In the New England River Basin Commission's Report on Flood Damage Reduction [Second Draft] flood proofing is considered and evaluated. Cost estimates are stated in the aggregate and therefore are of little use to this study. Follow-up communication may provide more detailed backup data.

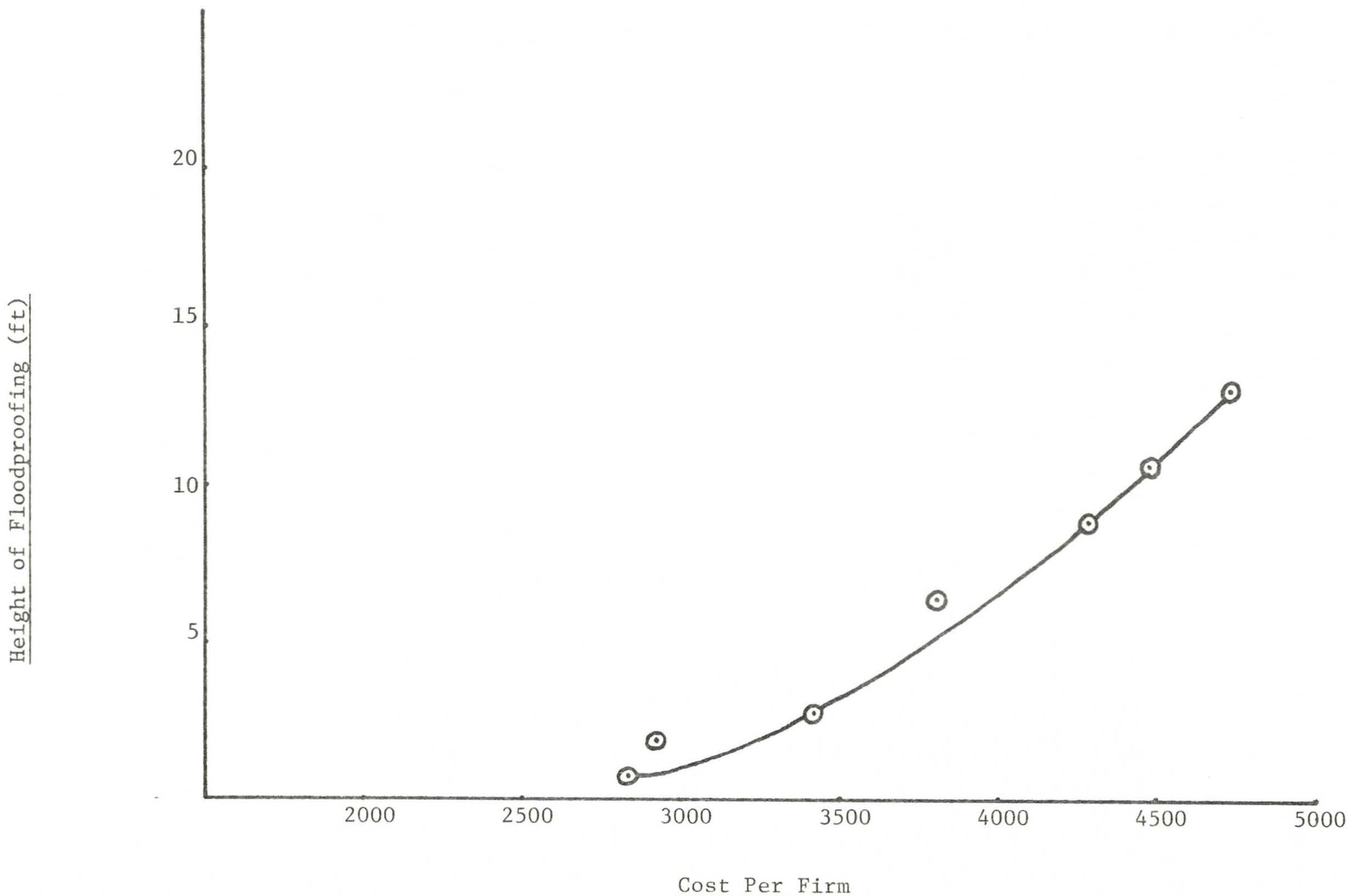
Norfolk District

The James River Basin, Richmond, Virginia, report considers floodproofing and suggests three criteria for preliminary investigation of this alternative [D-18]:

1. Only buildings of masonry construction can be floodproofed.
2. Three feet is the maximum height of floodproofing.
3. Buildings constructed with a concrete slab foundation can withstand the pressure resulting from three feet of water.

In the study area of Richmond the buildings are predominantly commercial or industrial. The suggested means of floodproofing is either concrete ring walls or waterproofing. It is not clear from the report how the cost estimates are developed but it is estimated to cost $4,000,000 to floodproof forty buildings to the 100-year flood level and $14,000,000 to floodproof eighty-one buildings to the SPF level. Backup data were provided by personnel of Norfolk district office. Table A-8 shows cost estimates for various sizes of commercial and industrial establishments. The costs were developed by updating estimates from the Buena Vista report. The box in the table shows how costs were calculated for structures in the Small 1 category. The other costs were

Figure A-3: Floodproofing-Commercial Cost Per Firm



[Source: Norfolk district personnel]

developed by multiplying the Small 1 costs by ratio of the size of the structures to the size of Small 1 structrues. Figure A-3 shows the cost per firm plotted against height of floodproofing.

Backup data for the Buena Vista report showed that calculations of residential floodproofing costs were based on costs determined for several houses examined in the Tug Fork report which were considered typical of structures in Buena Vista. These costs were updated and averaged to develop a new cost curve. The calculation is based on the assumption that all the houses are of frame construction and cannot be effectively sealed and therefore the method of floodproofing must consist of raising the structures such that the first floor elevation is above the design flood. The average cost of raising is plotted in Figure A-4.

St. Paul District

Several studies in the St. Paul District consider floodproofing. In all but one costs are either stated in too aggregated form for our purposes or are not stated at all. In each case where costs are stated they are found to be quite large in relation to benefits.

One study developed unit costs for floodproofing. The method of floodproofing was not apparent from the material.[9] Unit cost estimates are: $4000 for protection against basement flooding; $4500 for protection against first floor flooding below two feet; $5000 for protection against first floor flooding in excess of two feet; $21,000 for commercial and industrial buildings; and, $25,000 for miscellaneous commercial structures. These costs were developed from two sources. The first was updated cost estimates from the Prairie du Chien report which showed $3400 cost for floodproofing residences with basements; $2700 cost without basements; and $20,500 cost to floodproof businesses. The second was cost estimates developed in an earlier study and showed $5,000 for homes and $24,000 for other structures.

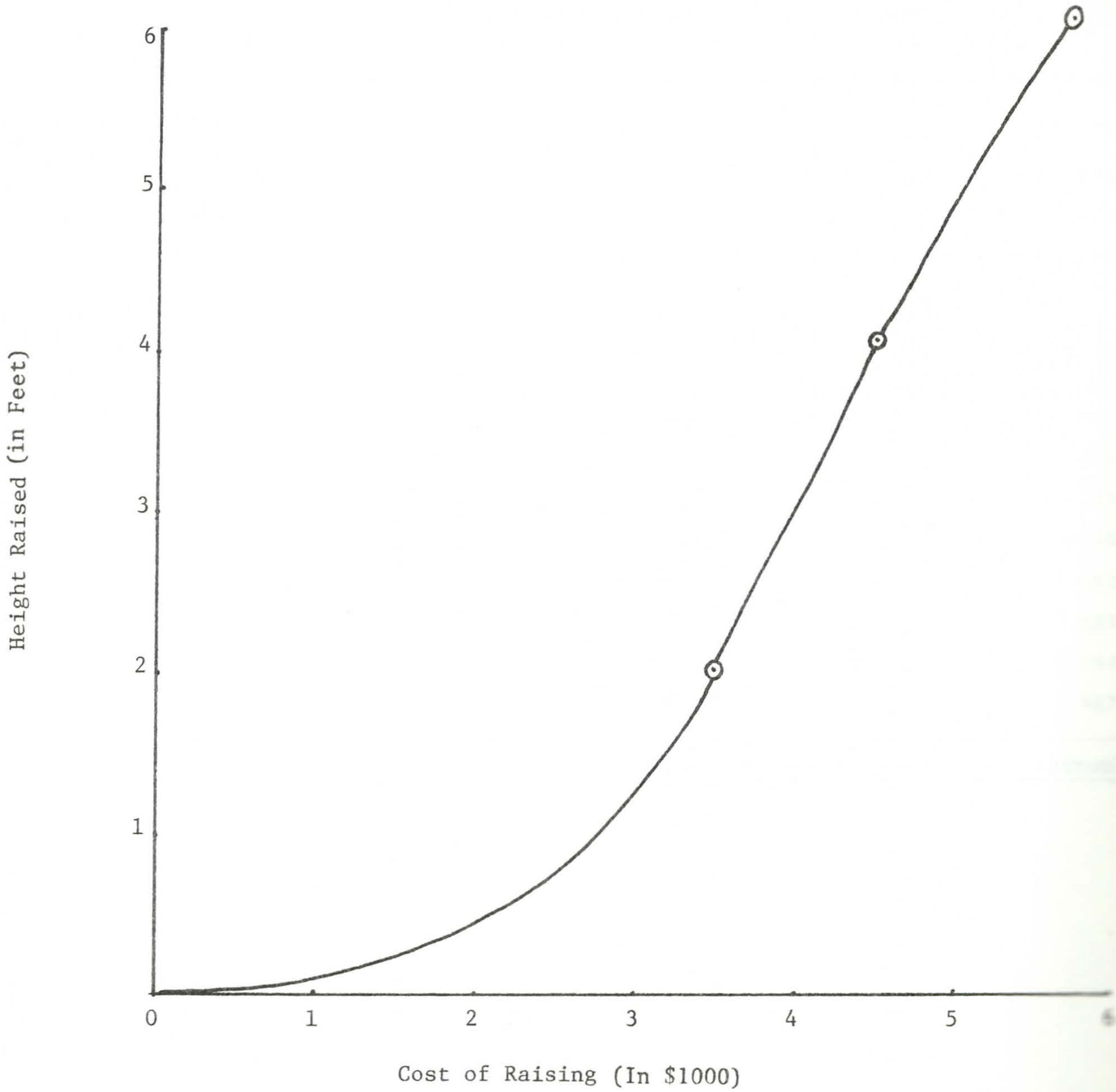
Other Agencies and Offices

The American Institute of Architects examined flood damage reduction by the use of elevated residential structures. The designs and costs are for new construction and take several forms including the use of wood pole, wood pile and concrete pier construction. Average unit costs are developed for

[9]Provided by St. Paul District personnel.

Figure A-4

Average Cost of Raising Homes in Place
at Buena Vista



[Source: Information provided by Norfolk district personnel.]

TABLE A-8

Cost of Floodproofing Commercial and Industrial by Sealing
(Concrete floors)

Type	Size	Cost
Small 1	6250 sq. ft.	$18,730

12 windows @ 3'x6' ea. 12/18.$1.80		390
4 doors 10'x10', 400x$6.10	=	2440
Sealing	=	15000
Sump pumps 3 @ $300	=	900

Type	Size	Cost
Small 2	7500	22,475
Medium 1	15,625	46,825
Medium 2	18,750	56,250
Large 1	30,000	90,000
Large 2	50,000	150,000
Large 3	75,000	225,000
Large 4	90,000	270,000

Source: James River Basin, Richmond, Virginia the various designs as shown in Table A-9. The cost of conventional versus elevated foundations are shown in Spring 1975 prices. Figure A-5 shows a comparison of the costs of several foundation types including slab on site raised with fill.

The Fulton Business District Flood Proofing Study suggests a plan of improvement consisting of floodproofing the three city block study area by using waterproofing compounds and flood walls. Table A-10 shows detailed cost estimates for a wall to protect against the 100-year flood. Cost estimates for other wall heights are also presented.

In an investigation called "Prudent Construction in the Flood Plain," Sumrall investigates various methods of building structures above expected flood heights. Table A-11 shows the cost of fill for various heights assuming typical one story construction.

The preceding pages have presented an objective survey of material gathered concerning floodproofing costs. Of the three nonstructural measures being considered floodproofing is the most straightforward and amenable to evaluation.

The information should be useful to Districts considering floodproofing as an alternative. Comparison of a District's cost estimates with those made in other studies will provide a check on the reasonableness of the estimates.

TABLE A-9

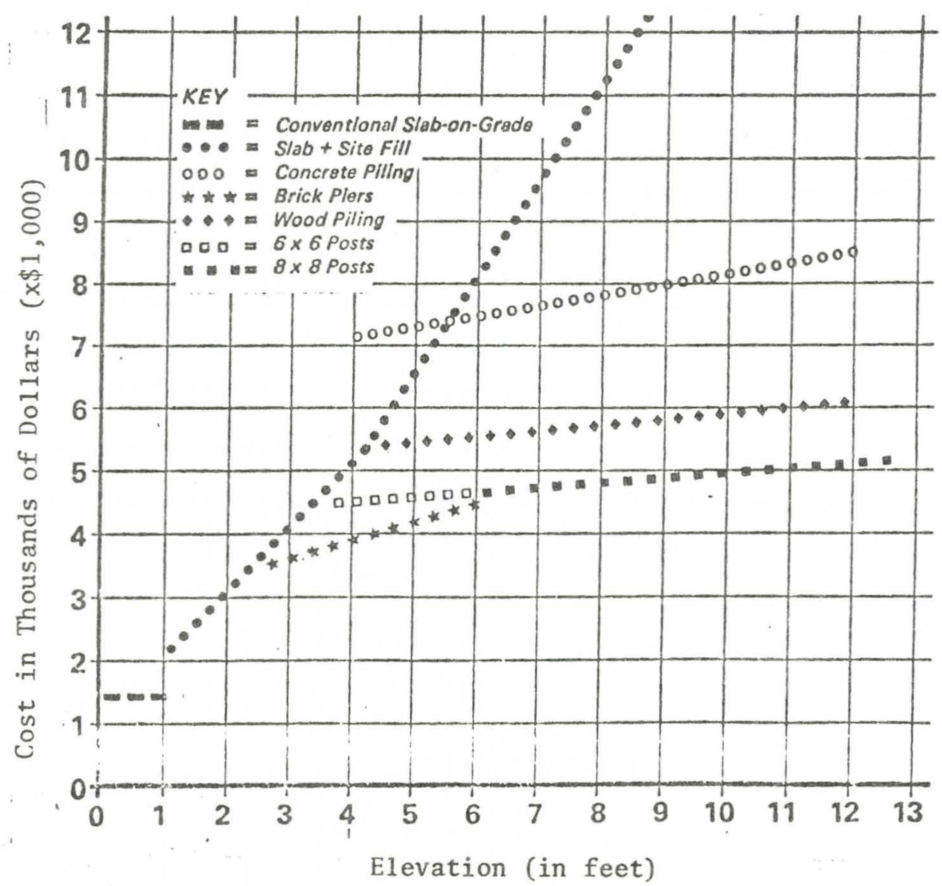
Foundation Cost Estimates
for New Construction

Conventional Foundations	Costs
Slab-on-grade	$1.27 per square foot
Crawl space	$1.95 per square foot
Basement	$3.49 per square foot
Elevated Foundations	
Wood pole	$3.35 per square foot
Wood pile	$3.05 per square foot
Concrete Pier	$3.59 per square foot

Source: AIA, Elevated Residential Structures, p. 4-3

Figure A-5

Cost Comparison of Foundation Types
for a Specific House in Louisiana



[Source: AIA, Elevated Residential Structures]

TABLE A-10

Floodwall
Cost Estimates - Average Wall Height, 3.4 Feet
100-year Frequency

Item	Quantity	Unit Cost	Total
Relocations	unit	$14,000	$14,000
Utilities	contingencies 25%		3,500
Construction			
Break out	1,385 yd^2	3.75	5,194
Foundations and sidewalk	16,425 ft^2	1.30	21,353
Flood wall	3,010 ft^3	3.34	10,053
Brick Veneer	5,740 ft^2	2.50	14,350
Waterproofing	2,300 ft^2	.35	805
Sandblasting	1,250 ft^2	.40	500
Gates	21 - 4.5 feet	425.00	8,925
	10 - 6 feet	500.00	5,000
Sidewall repair	unit	1000.00	1,000
	contingencies 25%		16,820
Pumps			
Sump pumps	7	1000.00	7,000
	contingencies 25%		1,800
	Project subtotal		$110,300
	E&D 14%		17,500
	S&A 8%		10,000
	Total		$137,800

Source: Fulton Business District Floodproofing Study, Table 1, p. 7

TABLE A-11

Cost Estimates for Earthfill

Flood Elevation	Cost of Earth Fill
2.0	$ 0
2.3	130
2.6	280
2.9	450
3.2	640
3.5	840
3.8	1060
4.1	1320

Source: Sumrall, p. 4

Evacuation - Relocation

Permanent evacuation is a rather drastic action which cannot often be seriously considered because of the far-reaching economic and social impacts. However, in particular floodplains, evacuation may prove to be the best choice. The evaluation of this alternative, as well as of the other two, is now required by Section 73 of the Water Resources Development Act of 1974.

Buffalo District

Three studies in the Buffalo district consider evacuation as an alternative flood damage reduction measure. In the first, flood plain evacuation is combined with flood proofing. The plan involved evacuation of residences subject to direct overbank flooding and floodproofing of commerical buildings and residences subject to sewer backup. The estimated costs of these measures are stated in aggregate terms based on average costs. Most of the backup data were not available. Detailed cost estimates are given for removing structures and landscaping. These estimates are shown in Table A-12.[10] Some of the houses to be evacuated (20%) would be sold to private investors who would move them away.

In the second study[10] the proposed plan of improvement calls for evacuation with floodproofing and land use control measures. The evacuation would be accomplished by purchase or relocation of all structures which do not meet the land use criteria for floodway and floodplain areas. The plan of improvement includes grading and landscaping of new building sites, constructing foundations, connecting utilities, demolition and debris removal for buildings purchased rather than relocated. Table A-13 shows estimated costs for moving an average structure. The relocation costs of residents are shown in Table A-14.

This floodplain is well suited for an evacuation plan for several reasons.[10] First, the efficiency of city services would not be reduced through loss of tax base, loss of patronage or overloading. Less than 5% of the population of the city would be affected by evacuation and approximately one-forth of structures affected would be relocated within the city on undeveloped land. Sufficient vacant land is available within the city so that this is not a constraint. In addition, any loss in city tax revenues will likely be offset by reduced recurring expenditures on evacuation, repair of streets and utilities and clean up costs incurred as a direct result of flood conditions in the evacuated areas. Not all urban floodplains would exhibit characteristics so favorable for evacuation.

In the third study,[10] evacuation was found to be not feasible. Costs were estimated to be $10,000 per residence which includes: cost of conveying property to the government; moving and related expenses; supplemental housing payments; land acquisition and demolition of structures. The $10,000 cost was considered conservative.

Los Angeles District

In the immediate Los Angeles area many of the floodplains are heavily and densely developed. The economic and social costs of an evacuation-relocation plan would be very large. In the Calleguas Creek report the evacuation-relocation alternative was rejected because of the heavy existing development and

> Because of the lack of community support for any structural alternative which called for relocation of homes, nonstructural alternatives which proposed significant relocations were considered unacceptable. [Calleguas Creek, p. 30]

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[10] Information provided in personal communication with Buffalo District personnel.

TABLE A-12

Cost Estimates of Removing Structures and Landscaping

Item	Number	Unit Cost	Volume/Structure	Total Cost[3]
Demolition	815 houses	$ .11 cu. ft.	10,125 cu. ft.[1]	$ 907,700
Debris Removal	815 houses	2.00 cu. yd.	113 cu. yd.[2]	184,200
Basement Fill	865 houses	3.60 cu. yd.	233 cu. yd.	726,000
Seeding	254.5 acres	800 acres	--	203,600
Total				$2,201,500

[1]Average size house was estimated to be 1-1/2 stores and 36x25 feet

[2]Seventy percent of house volume is air space, thus thirty percent of the volume would be solid debris.

[3]Rounded

Source: Buffalo District personnel

TABLE A-13

Estimated Costs for Moving an Average Structure[1]

	Quantity	Unit Cost	Total Cost
House Moving			
Brick & Frame Construction	39	$7500	$292,500
Mobil Home	55	250	13,750
Foundation	39	1300	50,700
Grading, Topsoil, Seeding	39	600	23,400
Utilities and Services			
Streets	39	300	11,700
Curb & Gutter	39	200	7,800
Sewer & Water	39	1200	46,800
Power & Telephone	39	400	15,600
Land (relocation site)	45 acres		100,000
Contingency			75,000
Total			$637,250

[1]Estimates were obtained by updating data for the Prairie du Chien, Wisconsin project via ENR Construction cost index.

Source: Buffalo District personnel.

TABLE A-14

Relocation Cost of Residents

	Quantity	Unit Cost	Total
Moving and related expenses	200	$ 700	$ 140,000
Supplemental housing payment	200	7,000	1,400,000
Cost of conveying property to government	200	300	60,000
Total	200	$8,000	$1,600,000

Master plans for land use in the Calleguas Creek floodplain call for continued development to take advantage of existing services and to preserve agriculture and open spaces outside the area [Calleguas Creek, p. 30]

Missouri River Division

In the Wears Creek report[11] evacuation is considered. The floodplain is located in downtown Jefferson City and permanent evacuation would be a costly and disruptive measure. Total estimated cost is $6,285,000 (details are not provided). The city has established redevelopment goals for this part of the city and evacuation would greatly suppress the future growth of the commercial area thereby conflicting with the city's goals. The increase in available open space would not offset the loss in projected enhancement of the area [Wears Creek, p. 23].

New England Division

In the Flood Damage Reduction Study performed by the New England River Basin Commission evacuation is considered. Here it is labeled acquisition and redevelopment. It is suggested that beach acquisition "does not stand up under scrutiny as a significant flood reduction measure in this region." (p. 35). The flood damage reduction benefits are trivial when compared with costs. Costs are estimated to be $7 million a mile [p. 37]. In this region, evacuation could more easily be justified as a recreation measure rather than

[11] Kansas City District.

a flood damage reduction measure [p. 38].

Norfolk District

Evacuation to both the 100-year and standard project flood elevations were considered in the James River Basin study. The evacuated floodplain would be used for parks, open space and any use that would not interfere with flood flows or result in material damage during flood periods. Several problems which would arise due to evacuation are discussed in the James River report. One problem would be the loss of employment and tax revenues to the city of Richmond due to the fact that some businesses would cease operations and others would relocate outside of the city. Another would be the disruption of normal activities in the floodplain. This would be weighed against the alleviation of the disruption and destruction caused by flood waters.

Cost estimates are shown in Table A-15 and are based on: "...the cost of acquiring all lands and improvements; the cost of razing existing structures, including clean-up and disposal; and the cost of moving stock and equipment to a new location." A 90-day period of transition is assumed and fair market values are used. Back up data and computation sheets were provided by Norfold District personnel. These costs may be useful here but are in very aggregated form. Demolition costs are stated separately and shown in Table A-16. The Uniform Relocation and Assistance Act [P.L. 91-646] allows for extra payment to upgrade housing facilities. This is recognized in this report by the addition of $10,000 to the costs of purchasing the land and improvements. In another study, house moving costs were estimated to be $6000 per house.

St. Paul District

Information supplied on five studies indicates that in each, evacuation was considered as a nonstructural alternative. In each costs are stated as totals and the backup data is not evident. Some of the objections to the evacuation are as follows: unacceptable impact on wildlife habitat, not economically feasible, not socially acceptable (major disruption of existing physical, social and cultural relationships), completely unacceptable to local interests, and agricultural damages would not be appreciably reduced.

In a sixth study evacuation is more thoroughly investigated. Table A-17, A-18 and A-19, taken from this study, are examples of the calculations made. Table A-17 shows the cost of developing alternative sites for the evacuated residences, Table A-18 shows estimates of moving costs for various market value ranges of houses and Table A-19 presents details on how the cost for one such range is calculated. Substandard houses (in the $5000 to $10,000 range) would be replaced with new structures [P.L. 91-646] at a cost of $20,000.

In a seventh study, evacuation costs are based on those used in the sixth study. Unit costs are shown for moving various commercial structures and these are listed in Table A-20. Other costs, such as landscaping, are stated in aggregate terms.

TABLE A-15

Total Evacuation Costs

Item	Cost
Initial Costs - 100-year elevation	
294 buildings	$ 86,000,000
Initial Costs - Standard project	
flood level 360 building	$133,000,000

Source: James River Basin Study, Tables D-8 and D-9

TABLE A-16

Demolition Costs

Type of Establishment[1]	Average Demolition Cost
Small Commercial	$1500
Medium 1 Commercial or Industrial	10000
Medium 2 Commercial or Industrial	12000
Medium 3 Commercial or Industrial	15000
Large 1 Commercial or Industrial	22000
Large 2 Commercial or Industrial	30000
Large 3 Commercial or Industrial	40000
Large 4 Commercial or Industrial	50000
Residential	Not applicable

[1]Sizes are as in Table A-8 of this report

Source: Norfolk District personnel

TABLE A-17

Improved Lot Cost [1]

Item	Cost
Residential street, 30 feet wide with curb and gutter and allowance for side street	$1,460
Land	1,330
Waterline	760
Sanitary Sewer	360
Storm Sewer	760
Boulevard landscaping	100
Sidewalk	400
Total	$5,170

[1]Apparently an average size lot.

Source: St. Paul District personnel.

TABLE A-18

Estimated Moving Costs
for Residential Structures

Market value of structure	Average Moving Costs[1]
$10,000 to $15,000 range	$14,600.00
$15,000 to $20,000 range	15,500.00
$20,000 to $40,000 range	17,700.00

[1]See Table A-19 for detail and conditions

Source: St. Paul District personnel

TABLE A-19

Moving Cost for Typical Residence - $15,000-$20,000 Range

Item	Cost
1. Moving including disconnecting utilities, lift, move (less than 5 miles over good road), set down and connect	$ 3,680
2. Utilities within the basement including soil pipe, water pipe, hot water heater, electric, gas lines, furnace and duct work and chimney	1,550
3. Foundation including excavation and backfill, 12-inch block wall w/waterproofing, 4-inch slap, footings, steel and windows	2,800
4. Site work including sanitary service, water supply, topsoil, sod, driveway and sidewalk (on lot)	2,300
5. Improved lot (see Table 17)	5,170
Total	$15,500

Source: St. Paul District personnel.

TABLE A-20

Moving Costs - Commercial Properties

Type of Establishment	Average Unit Cost
Retail Stores	$23,000
Service Stations	20,000
Bars and Restaurants	17,000
Garage and Light Industry	25,000
Public Services	25,000
Other	20,000

Source: Personal communication with St. Paul personnel

In discussion with personnel of the St. Paul District it became clear that the Uniform Relocation and Assistance Act (P.L. 91-646) would have a definite impact on the calculation of evacuation costs. The impact comes in the determination of whether a particular structure will be moved or, purchased and demolished. Apparently the interpretation of the law is that the owner has the right of choice. Since these options vary in cost, the mix will determine the cost of the program. In some of the studies an attempt is made to predict the mix and to come up with a reasonable estimate of the total costs. Without interviews at the planning stage this is probably the best that can be done.

Land Use Regulation

Determining the costs of regulating the floodplain is more difficult than determining the costs of floodproofing and evacuation for several reasons. First, the physical and tangible costs of instituting and administering the regulatory program are probably quite small. Second, the costs of the regulatory program for the floodplain are difficult to separate from the other regulatory costs incurred at the local level. And third, the less tangible costs which come about because income is foregone due to the regulations are difficult to measure. For these reasons, and because the task of measuring regulatory costs has remained relatively undefined, we find that few estimates of the costs of regulatory programs have been made.

Many studies consider floodplain regulation and some recommend management of the floodplain as a required supplement to whatever plan is proposed. However, most of the studies which recommend regulation as a supplement assume that benefits of such a supplemental program clearly outweigh the costs.[12]

Because examples of cost estimates for regulation are few the following will not be divided by district or office. Only examples which are considered particularly relevant to the evaluation of regulatory programs will be reported. In some cases the relevance is only potential and will need to be pursued further.

In the Middle Fork Snoqualmie Joint Study[13] one proposed alternative is flood plain management. Land use in the floodplain would be managed so that no residential or commercial construction would be permitted in the floodway. Construction would be allowed in the floodway fringe subject to floodproofing regulations [p. 18]. The average annual cost of this program is estimated to be $360,000. Details of this estimate are not presented.

In the Calleguas Creek Study [L.A.] one reach had only one significant development--a sewage treatment plant already floodproofed. The recommended plan for this reach is floodplain management, i.e., county management of the standard project floodplain so that no development or construction would take place that would interfere with the safe conveyance of the SPF flood. Since no benefit from flood control is claimed for this reach the estimated costs are allocated to recreation. Average annual costs are estimated at $40,000 but this is primarily for the operation and maintenance of the recreation facilities.

In another study[14] underway in the LA district average annual costs of a floodplain regulation program are estimated and are divided

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[12] This, at least, appears to be the case because the program is not directly evaluared.

[13] Performed jointly by the Seattle District Corps of Engineers and the Washington State Department of Ecology.

[14] Personal communication with LA District personnel.

into five categories: net loss in tax revenues[15]; flood damages[16]; alternative site costs; additional subdivision and building cost; and, loss in net income. These costs are for ordinances prohibiting land developments in an area of approximately 8990 acres. Administration of the program may be included under additional subdivision and building costs but this is not clear.

In a study provided by the Missouri River Division zoning costs were defined to consist of an economic loss which would occur when the market price of land falls because of the restriction on the use of the land posed by the zoning; and, an annual administrative cost of enforcing the zoning regulations. The change in land prices depends upon the amount of land zoned in relation to the amount of land which can be absorbed in the lower use. In a relatively developed reach the land price is estimated to be reduced by 25% from the present average price of $4,500. Total annual costs are $39,000 for the 100-year flood. Administrative costs are estimated by calculating what the cost would be if a single agency performed all the regulatory costs. The single agency, patterned after existing flood plain management agencies, would consist of an administrator, lawyer, engineer, a secretary and two draftsmen. The annual costs would be $99,500 (for the 100-year flood) including salaries, fringe benefits and operating expenses. Actually, eight different agencies would be involved in the regulatory program involving approximately 785 undeveloped acres and 1540 total acres.[17]

In the Flood Damage Reduction Study performed by the New England River Basin Commission the regulation of land use is included in some of the plans evaluated. Costs are presented; e.g., $9,320,000 for regulation in the riverine environmental plan [p. 48], but it is difficult to tie these to acreages or particular components of the cost of regulation. Presumably the costs of added infrastructure to serve the alternative locations and an estimate of locational benefits foregone are included in the reported costs since the neglect of these is emphasized in the body of the report [p. 25].

Several of the St. Paul district studies include an estimate of costs for the floodplain regulation alternative. In each case the cost is given in a large table of costs and benefits and the backup data or methodological approach is not

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[15] Costs (in thousands) are: $9,107, $1,559, $189, $1,445 and $1,207 respectively for the five categories.

[16] It is not evident why these are included in costs.

[17] It is not clear from the report exactly how many acres are involved.

explained. In three of the four studies first costs are estimated at $100,000. Annual cost estimates vary from $36,000 to $71,000. These numbers may become more meaningful when the studies are more completely compared in terms of acreage, number of structures and jurisdictions involved.

In the backup material provided for one study in progress a thorough examination of the cost estimate is given. First costs are estimated to be $100,000 with $40,000 for initially setting up the program and $60,000 for the floodplain information study. These costs reduce to $5700 when the capital recovery factor for 5-5/8 percent discount rate is applied. Annual administrative costs, including processing applications, field inspections, and etc., are estimated at $20,000 annually. There are additional costs implied by the application of the regulations to new construction. Given present population trends roughly two new houses per year will be built within the area governed by the regulations. Costs of complying with the regulations are estimated at $2000 per house. Four houses per year will be replaced with extra costs of compliance at $5000. Approximately six farmsteads will be replaced per year, again with extra costs of compliance set at $2000 per farmstead. Annual costs of compliance are therefore $24,000. Costs of compliance for new businesses are estimated at $1000 per year (assume one new business every two years). Total annual costs are estimated at $50,700.

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This report evaluates three nonstructural flood control measures: floodproofing, evacuation-relocation and land use regulations. Floodproofing is an adjustment to a structure or its contents, or both, such that either water is kept from the structure or the damaging effects of water entry are eliminated or reduced. Evacuation-relocation involves the physical and permanent evacuation of activities and people from the floodplain to sites where the flood hazard is lower. Land use regulation attempts to direct future land use in such a way that it is consistent with (Continued)

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the flood hazard. Estimates of the cost of floodproofing would be made by examining different designs for each structure and choosing the least expensive to add into the total cost. Two distinctive cost categories can be considered for evacuation-relocation: (1) physical costs of carrying out the program, and (2) loss of income occasioned by the relocation of the activity away from the location chosen in the market. The measurement of the costs of land use regulation requires projection of future development which will occur in the floodplain and determining what costs are incurred by excluding this projected development from the floodplain. These three measures create inundation reduction benefits by lowering the damage susceptibility of individual structures or of the aggregate of structures on the floodplain. Intensification benefits occur when an activity is allowed or induced, to intensify its operation as a result of a flood control program. Tools for evaluating non-structural measures include (1) Hydrologic Engineering Center (HEC)-5C-Simulation of Flood Control and Conservation Systems; (2) Day-Weisz Model; (3) INTASA Simulator; and (4) HEC-DAMCAL. These tools are either computer programs or linear programming models