III. Floods: A National Policy Concern

There are seven reasons for the growing concern about the management of flood hazards. These are:

- Repeated disasters from Hurricanes Camille (1969) and Agnes (1972) to recent dam failures and flash flooding have created and reinforced a national awareness of floods, and generated strong State and local political pressure for action. State and local interests are becoming more aware that the predominant measures of the past, physical flood control and disaster relief, are inadequate.
- Federal actions are directly or indirectly creating new legislation and regulation related to flood hazards management. A large number of programs, integrated in principle but not in practice, make up the complex of programs and policies for improving the management of natural resources, for the preservation of wetlands, and for wildlife conservation. Some programs, such as the Coastal Zone Management Act and the National Flood Insurance Program, have planning arrangements for both urban and rural areas.
- Structural or physical measures—in the form of levees, dikes, and dams—are increasingly seen as inadequate by themselves for a sound approach to flood hazards management that would both reduce risks and modify their impacts. Nonstructural measures, such as land use planning, are now becoming important complements to the physical approaches.
- Huge new catastrophes with extensive loss of life and property have become more likely as the population-at-risk increases.
- The political implications of adopting alternative strategies to the physical control of floods could be significant. A reduction in physical flood control measures implies a decrease in the direct economic benefits from construction and employment. Furthermore, adopting nonstructural measures to mitigate flood hazards implies new land use controls. These are widely perceived as being disadvantageous in the short term to some important local interests.
- Political boundaries are not respected by floods. Consequently, their effects and their management overflow the jurisdictions of States, counties, and local governments. This gives flood events a regional character and thus poses problems of intergovernmental coordination in the management of floodplains.
- New knowledge about the causes and effects of floods stimulates an interest in putting that new knowledge into effective practice.

THE PHYSICAL BASES OF FLOODS

The three principal causes of floods in the United States are the overflow of riverbanks, flash floods, and hurricane-induced surges of water. Numerous other phenomena can also *cause* significant flood problems. For example, seiches, which are surges of water that principally occur in lakes and large water bodies as a consequence of sharp changes in atmospheric pressure, do substantial damage in the Great Lakes region. In addition to Hawaii and Alaska, extensive coastal areas in the United States are subject to tsunamis, formerly called tidal waves.

Civil works, notably dams, may break, creating their own artificially induced floods. Flooding may also occur as a result of natural or artificially induced soil subsidence. Another manmade factor in flooding is back flushing through water conduits, especially in sewer systems.

Flood hazards may also originate from causes quite remote from the flood site itself. Land clearance of forests for farming may change the local ecology, thereby altering runoff water retention characteristics in a river basin. Depending on the size of the basin and the extent of the changes made, this may become a primary source of flooding.

A large part of the national shoreline is vulnerable to continuing erosion from flood-related events. Average annual losses exceed $300 million.[1] With the population continuing to move

[1] Gilbert F. White, and Eugene J. Haas, *Assessment of Research on Natural Hazards* (Cambridge, Mass.: The M.I.T. Press, 1975), p. 361.

toward coastal areas in greater numbers as trends indicate, coastal erosion will be responsible for a greater percentage of flood losses. (This particular hazard has its own set of problems, which are discussed in appendix A.)

When large areas of cities and suburbs are covered with concrete, asphalt, and buildings, a drainage problem is created because the soil's natural ability to retain water is sharply reduced. This can seriously aggravate flooding problems. A classic example is the so-called Four Mile Run in the northern Virginia area of suburban Washington, D.C. In part, as a result of extensive development, Four Mile Run experienced two officially designated flood disasters in 1970.[2]

Occasionally, a geophysical event is indirectly responsible for a flood disaster. For example, a landslide caused by heavy rains may, if it falls into an artificial lake, cause a wave to overflow the dam, and an earthquake may induce a landslide or cause a dam to fail. (Dam failures will not be given further consideration in this report since they are a subject of current investigation and appear to be receiving adequate attention.)

The principal sources of floods roughly in order of attributable losses are:[3]

- riverbank overflow,
- conduit backwater flood,
- groundwater flood,
- headwater flood,
- flash flood,
- subsidence flood,
- ice backup,
- debris backup,
- dam breakage, and
- geological sink flood.

THE GEOGRAPHIC SCOPE OF FLOODS

Flooding is primarily a problem in river valleys, on floodplains, in the coastal zone, and on the perimeters of large lakes. Unfortunately, historical necessity and esthetic appeal make areas prone to flood hazards among the most attractive in which to live or work.

The principal river basins and coastal zones that are subject to floods are shown in figure 2. Both rural and urban communities are vulnerable. Figure 3 represents a principal river basin in New York State. The historical pattern and frequency of flooding in that area are shown in table 2. This particular river basin illustrates a common pattern in the temporal distribution of floods, namely their relative infrequency. Between 1886 and 1972 there were 12 major floods due to heavy rain, snowmelt, hurricanes, or other causes. While their rare occurrence may remove floods as a source of constant concern to both residents and local governments, it necessitates bringing foresight in long-range planning to flood management.

THE COSTS OF FLOODS

It is difficult to calculate accurately the costs of flood hazards or of the measures taken to alleviate or moderate them. However, useful calculations can be made of the cost of prudent means for preventing or mitigating possible flood losses. Calculation can also give a sense of the magnitude of damage that floods have caused, and can be used to create an awareness of the role that current choices play in determining future losses. In the following sections patterns of loss of life and property, and of the geographic distribution of the costs of floods are reviewed.

National Exposure to Flood Hazards

Seven percent of the 48 contiguous States are in the 100-year flood zone. This means that these areas are subject to a flood of such severity that there is a l-percent probability of its occurring in any given year. Goddard cites, in addition, potential catastrophes existing in other areas of the United States:[4]

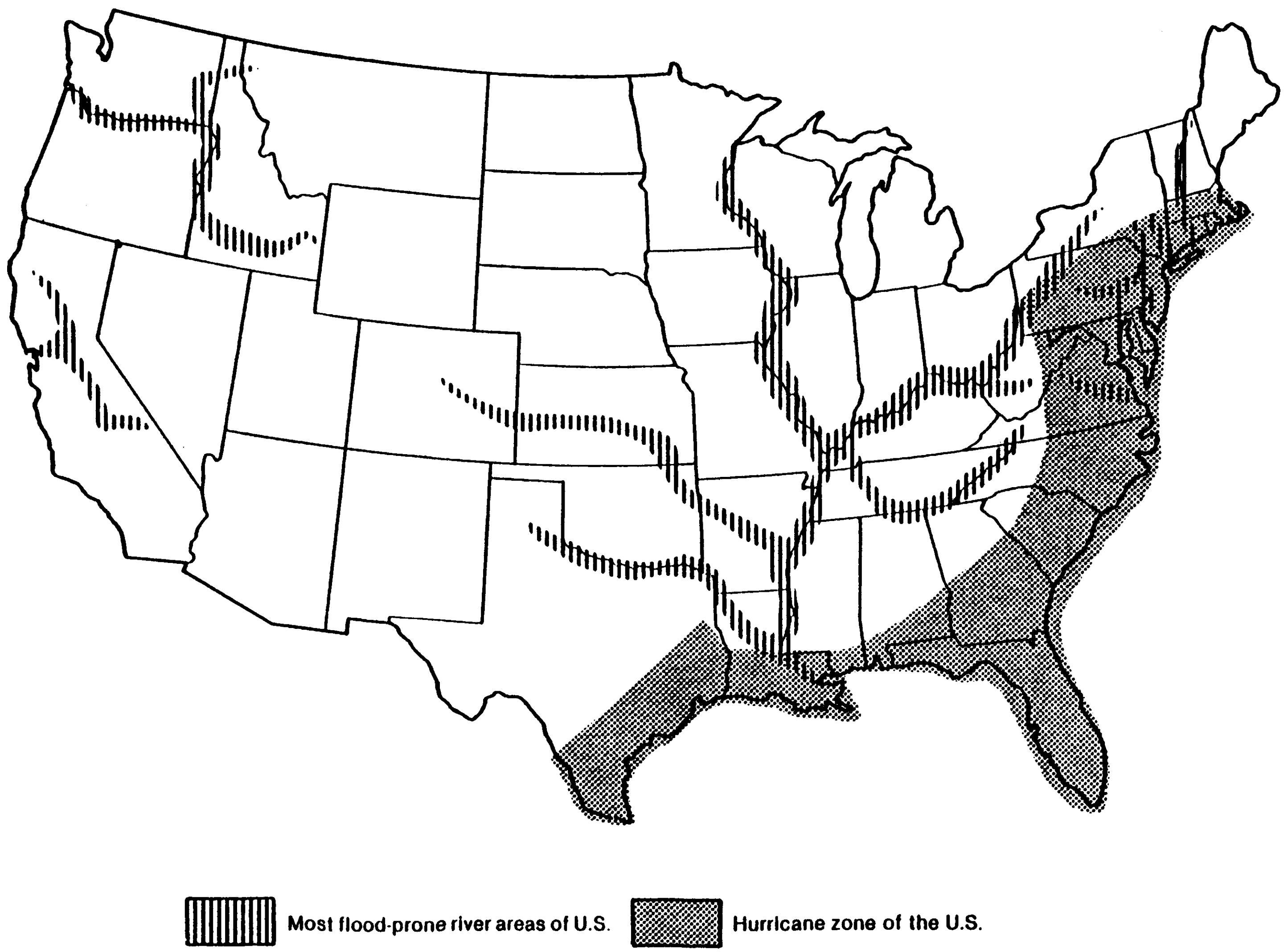
- Over 200,000 square miles are subject to inundation, an area equal to the combined size of California and Ohio.
- One-sixth of all urban areas are in the 100-year floodplain.
- There are more than 20,000 flood-prone communities in the United States, and 16,500 square miles of urban floodplain.
- There are more than 6.4 million single-family houses located in floodplains.

[2]Wesley Marx, Acts of God Acts of *Man (New* York: Coward McCann and Geoghegan, 1977), p. 46.

[3]D. Earl Jones, Chief, Field Services Branch, Office of Technical Support, Department of Housing and Urban Development, personal communication, 1978.

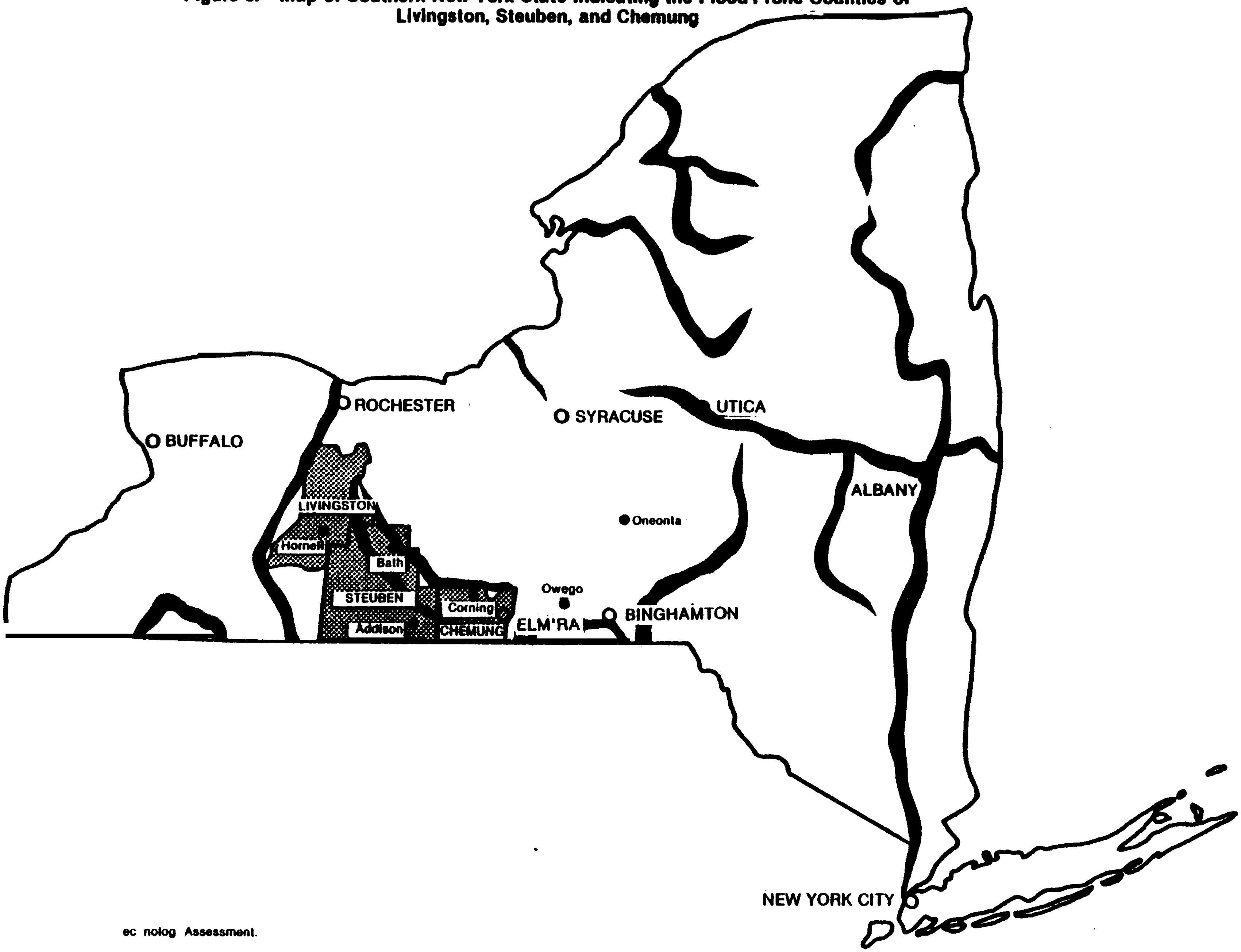
[4]James E. Goddard, "The Nation's Increasing Vulnerability to Flood Catastrophe," *Journal of Soil and Conservation*, March-April 1976, pp. 48-52.

Figure 2.—Most Flood-Prone Areas of the United States



SO R General Adjustment B "Nature's Destructive Forces," 1972.

Figure 3.—Map of Southern New York State Indicating the Flood-Prone Counties of Livingston, Steuben, and Chemung



ec nolog Assessment.

Table 2.-Frequency and Cause of Flooding Between 1886 and 1972 in the New York State Counties of Livingston, Steuben, and Chemung

Jan. 5-12, 1886
Elmira (snowmelt, heavy rain, ice)
June 1-2, 1889
Elmira (cause not stated)
Sept. 9-10,1890
South Canisteo, Schuyler, Chemung, Steuben Counties generally (heavy rain)
May 20-21, 1894
Elmira (heavy rainfall)
Aug. 8, 1917
Binghamton, Elmira (heavy rain)
Nov. 30,1927
Hornell, Addison, Corning (heavy rains)
July 1935
Elmira (heavy rains)
May 25-28,1946
Corning, Elmira (heavy rains)
Dec. 10-11,1952
Elmira, Oneonta (heavy rains, snowmelt)
Oct. 15,1954
Binghamton, Elmira, Hornell (hurricane rains)
Mar. 30-31, 1960
Elmira–small stream flooding (heavy rains, snowmelt)
June 20-25, 1972
Bath, Corning, Elmira, Owego (heavy rains)

SOURCE: N.Y.S. Climatologist's Records, U.S. National Weather Service, Cornell University, Ithaca, N.Y.

From: David W. Tregaskis, "Needed Changes in the National Flood Insurance Act to Reflect Farm Flood Loss Experience," Department of Agricultural Economics, Cornell University, April 1975, app. 2.

Commerce, transportation, safety, and the necessity for water for industrial processes or domestic use *are* all valid reasons for people to live and work in floodplains. Several of these historical reasons, however, have been largely superseded by national roads and pipeline systems. Furthermore, living near water is both esthetically and environmentally appealing. This attracts large numbers of vacationers and homeowners. It thus creates a long-term conflict with those who wish to convert the floodplain into common use open space or other low-density purposes.

By 1973, over half the floodplains in urban areas had been developed. j This covered an area of town and country totaling approximately 8,800 square miles (see table 3), which is 125 times the size of the District of Columbia.

Despite over four decades of public investments for controlling floodwaters and providing safety for those living near hazard areas, the population and resources at risk are greater than ever. Hood losses are increasing, and the very construction that has made floodplains safer in the short run has increased both the number of people at risk and the degree of risk they will face in the long run.

Costs—Annual and Cumulative Losses

Loss of life, which depends on the size of a flood, as fluctuated over the past four decades (see figure 4). In this period, about 4,000 U.S. residents have lost their lives in floods. The exact number is uncertain. The Red Cross and the National Weather Service, working with unpublished data, indicate the average annual loss of life to be 47.6 and 57.2 respectively; and unpublished Federal Insurance Administration (FIA) data indicate that in 1975 there were 89 lives lost. This appears minor in comparison with the 1911 Yangtze River flood in which 100,000 persons died or the repeated flood disasters in Bangladesh. By comparison with death tolls in the less well-developed countries, the loss of life in the United States is relatively insignificant. The U.S. flood in which the most lives were lost—6,000—was caused by the Galveston, Tex., hurricane of 1900.

The historical pattern of losses in severe individual floods is illustrated in table 4. The average number of lives lost in 77 major floods from 1913 to 1973 was 52; 14 involved no known loss, and the 4 worst took 467, 313, 237, and 187 lives. Some sense of the annual loss of life in relation to national development can be seen from figure 4, which shows the annual loss of lives for each $10 million of property damage.

Property Losses

Property losses are rising rapidly. Between 1953 and 1973, the annual property loss, according to one estimate, has risen from $1.5 billion to $3.8 billion (1973 dollars), and Federal outlays for disaster relief for that same period rose from $52 million to $2.5 billion (1978 dollars).

In the four decades since 1936, approximately $14 billion has been expended on flood control construction including dikes, dams, levees, channels, and sea walls. But there appears to be no clear relationship between that construction and any reduction in loss of life or property.

Coastal erosion, while not totally attributable to flood hazard conditions, is closely associated

[5]Ibid., p. 48.

[6]Ibid., p. 49.
[7]Ibid., p. 49.
[8]Ibid., p. 50.

Table 3.-Exposure to Floods of Selected Urbanized Areas

Urbanized areab(UA)	Totala Population (1000s)	Totala Area (sq. mi.)	Floodplain (FP) Total Area (sq. mi.)	Floodplain (FP) Total % of UAc	Floodplain (FP) Developed Area (Sq. mi.)	Floodplain (FP) Developed % of FPc
Asheville, N. C.	72.5	35.3d	1.6	4.4	1.0	65.0
Boise, Idaho	85.2	29.4	2.5	8.5	2.1	84.0
Boston, Mass.	2,652.6	664.4	62.4	9.4	11.9	19.1
Charleston,S.C.	228.4	99.2	39.8	40.1	21.2	53.3
Chicago, Ill.	6,714.6	1,227.2	131.8	10.3	75.1	57.0
Dallas,Tex.	1,338.7	674.2	146.1	21.7	28.0	19.2
Denver Colo.	1,047.3	292.8	30.6	10.5	19.1	62.2
Fargo, N. D.-Moorhead, Minn.	85.5	23.5	9.4	40.0	5.1	54.3
GreatFalls, Mont.	70.9	21.8	2.0	9.2	1.9	97.0
Harrisburg, Pa.	240.8	78.4	9.7	12.4	8.1	83.5
Lansing,Mich.	229.5	73.4	4.8	6.5	.9	18.8
Lincoln, Nebr.	153.4	52.1	13.8	26.5	6.9	49.6
Lorain-Elyria,Ohio	192.3	106.4	5.3	5.0	.6	11.3
Monroe, La.	90.6	40.1	32.5	81.0	26.8	82.4
Norfolk-Portsmouth, Va.	668.3	299.0	59.2	19.8	15.5	26.2
Omaha, Nebr.-Council Bluffs, Iowa	491.8	151.2	50.6	33.5	23.1	45.5
Phoenix, Ariz.	863.4	387.5	71.2	18.4	63.5	89.2
Portland,Oreg.	824.9	266.8	14.5	5.4	8.5	58.7
Reno, Nev.	99.7	37.5	2.0	5.3	.9	45.0
Richmond,Va.	416.6	144.6	12.9	8.9	1.7	13.2
St. Louis, Mo.Ill.	1,882.0	460.6	136.1	29.6	91.7	67.4
Salt LakeCity, Utah	479.4	184.3	12.9	7.0	10.1	78.3
SanJose,Calif.	1,025.3	277.2	80.0	28.8	67.9	84.7
Spokane,Wash.	229.6	77.8	1.9	2.4	.9	47.4
Tallahassee, Fla.	77.9	29.8	3.1	10.4	2.6	83.9
Texarkana,Tex.-Ark.	58.6	34.3e	4.7	13.8	2.1	44.2
Total	20,319.8	5,818.8	941.4	—	497.2	—
Average (weighted)				16.2		52.8

aNatural 100-year floodplain.
bEstablished and reported by U.S. Bureau of Census, 1970.
cBecause areas are rounded to tenths, some percentages may not agree.
dBureau of the Census limits, but revised measurements.
eIncludes the additional incorporated areas.

SOURCE: American Society Civil Engineers UWRRP Technical Memorandum No. 19.

with severe weather, particularly hurricanes. (See appendix A for additional discussion.) From $300 million to $400 million in property losses occur annually in the coastal zones due to erosion.[9] The Corps of Engineers reported in 1971 that 15,400 miles of U.S. shoreline experienced significant erosion with some 2,700 miles considered to be in critical condition.[10] In Michigan alone, with 3,000 miles of shoreline, property losses over a 3½-year period were approximately $47,000 per mile.[11]

There is as much as a twofold or threefold variation in the estimates of flood losses. This is due in part to the lack of systematic accounting, and in part to the methods used in calculating the value of flood losses. Replacement value and depreciation value give quite different loss estimates. One comprehensive systematic evaluation by Earl Jones of the Department of Housing and Urban Development (table 5) puts total flood losses at $2.8 billion per year.

In an independent study, John Wiggins puts the annual losses due to floods at $1.9 billion, based solely on losses to structures.[12] At least one-third more could be added on if losses of infrastructure, telephones, utilities, water and sewage systems, pavement, etc., were counted. This would bring the total to about $2.6 billion per year. Regardless of the method of calculation, it is evident that the losses are large, and that the chief cause is riverbank overflow, with somewhat less caused by backwater and groundwater flooding.

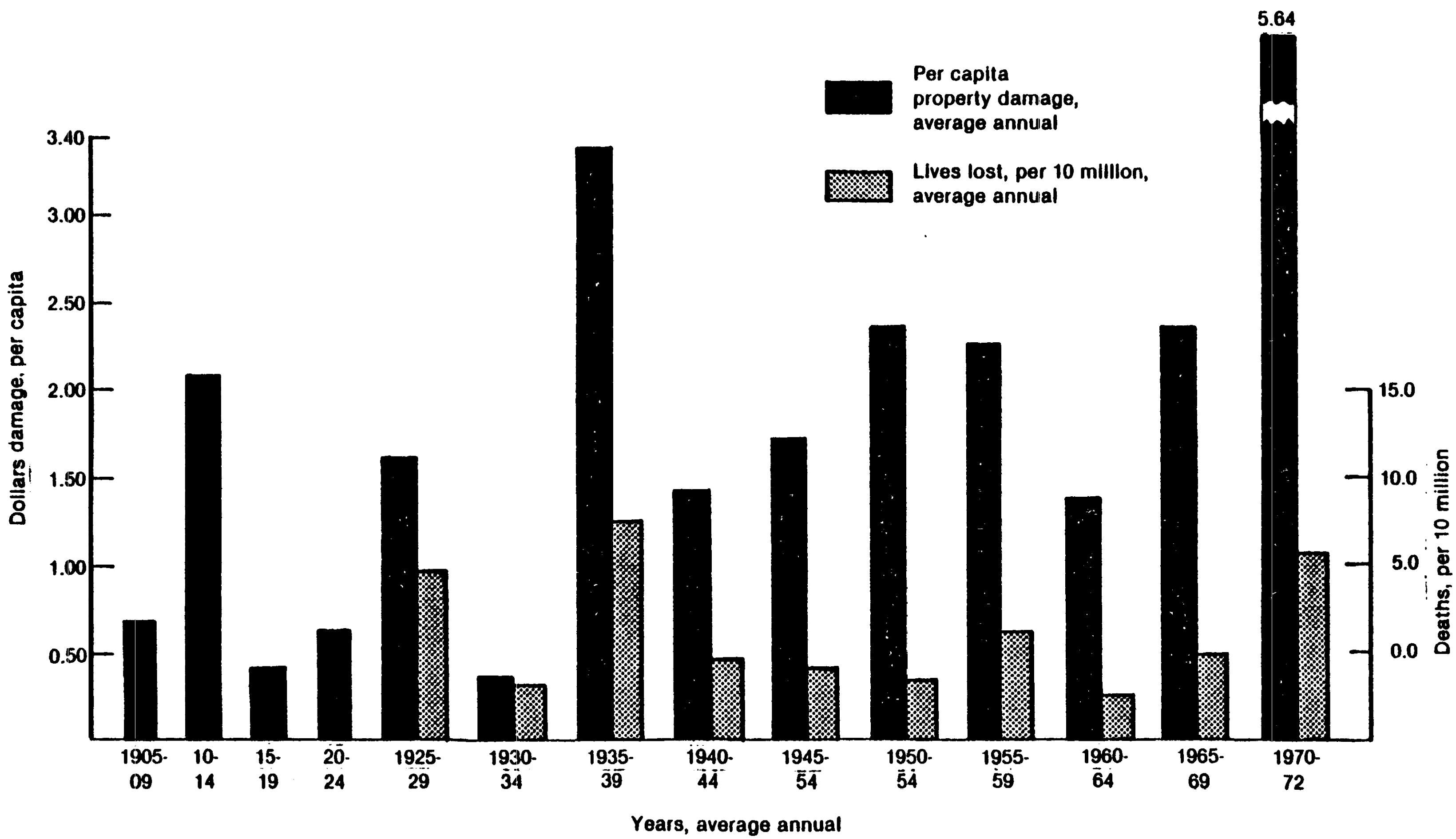
[9]Gilbert F. White and Eugene J. Haas, op. cit., p. 361.

[10]U.S. Army Corps of Engineers, *National Shoreline Study*, August 1971, from the abstract.

[11]John W. Armstrong, Director, Coastal Zone Laboratory, University of Michigan, personal communication, 1978.

[12]John H. Wiggins, *Risk Reduction Through Natural Hazards Research*, for the National Science Foundation, Apr. 21, 1976, from the executive summary.

Figure 4.—Losses in United States Floods, 1905–72



Damage figures in standard U.S. $, adjusted to base 1957–59 = 100

SOURCE: Gilbert F. White and Eugene J. Haas, *Assessment of Research on Natural Hazards*, University of Colorado, 1975, p. 256. From White, et al. 1958; NOAA 1971; 1972.

Table 4.-Losses in Individual Severe Floods in the United States Since July 1902
(Property losses in thousands of dollars)

Date"	Location	Lives*•	ProDerty
May-June 1903	Kansas, lower Missouri, and upper Mississippi Rivers	100	$ 40,000
March 1912	Lower Mississippi River	—	70,000
March 1913	Ohio River and tributaries	467	147,000
December 1913	Texas Rivers	177	9,000
June 1921	Arkansas River in State of Colorado	120	25,000
September 1921	Texas Rivers	215	19,000
Spring of 1927	Mississippi Valley	313	284,118
November 1927	New England Rivers	88	45,578
May-June 1935	Republican and Kansas Rivers	110	18,000
July 1935	Upper Susquehanna tributaries	52	26,000
March-April 1936	Rivers in Eastern United States	107	270,000
January-February 1937	Ohio and lower Mississipi River basins	137	417,685
March 1938	Streams in southern California	79	24,500
September 1938	Rivers in New England	—	37,000
July 1939	Licking and Kentucky Rivers	78	1,715
August 1940	Rivers in southern Virginia, the Carolinas, and eastern Tennessee	40	12,000
May 1942	Delaware and Susquehanna River Basins	33	13,000
July 1942	Upper Allegheny River and Sinnamahoning Creek Basins	15	10,000
November-December 1942	Willamette River	10	6,900
April-June1943	Maumee, Wabash, upper Mississippi Missouri White,and Arkansas River Basins	60	172,500
August 1943	Little Kanawha River	23	1,300
April-June1944	Upper Mississippi Missouri, Arkansas, Red, and lower Mississippi River Basins and eastTexas rivers	17	82,000
February-March 1945	Ohio River	18	30,000
May-July 1947	Lower Missouri and middle Mississippi River Basins	29	235,000
May-June1948	Columbia River Basina	35	101,725
May 1949	Trinity River	10	14,000
June 1949	Shenandoah and Potomac Rivers	11	8,850
June1950	Rivers in central West Virginia	31	4,020
June-July 1951	Kansas and Missouri b	28	923,224
April 1952	Red River of the North, upper Mississippi and Missouri River Basins c	11	198,000
April-May1953	Louisiana andTexas	12	38,959
June 1953	Northwestern Iowa	14	32,950
June 1954	Middle Rio Grande and lower Pecos Rivers	16	19,079
October 1954	Pecos River in New Mexico	13	1,783
March 1955	Ohio River Basin	15	14,396
August 1955	Hurricane "Dianne" floods in the Northeast d	187	714,079
December 1955	West coast rivers e	61	154,532
January-February 1957	Streams in southeastern Kentucky, southwestern West Virginia, and adjacent areas inTennessee and Virginia f	14	58,000
February 1957	Snake River and tributaries	—	20,500
April-June 1957	Rivers in Texas, Arkansas, Kansas, Louisiana, Missouri, and Oklahoma	18	105,000
June-July 1957	Wabash River and tributaries	—	63,000
June 1958	White and Wabash Rivers	—	63,000
July 1958	Flash flood on east Nishnabotna River (Iowa)	19	5,850
January 1959	Ohio River Basin	—	81,921
July 1961	Flash flooding on small streams in Charleston, W. Va.	22	3,238
March 1963	Ohio River Basin	26	97,600
June 1964	Montana	31	54,279
December 1964	California and Oregon	40	415,832
March 1964	Ohio River Basin	13	81,602
March-May 1965	Upper Mississippi, Missouri, and Red River of the north river basins g	16	181,325
May 1965	Brazos River	—	30,802
June 1965	South Platte River Basin	16	415,076
June 1965	Sanderson, Tex., flash flood	26	2,715
June 1965	Arkansas River Basin	16	58,340
April-May 1966	Sabine and Trinity Basins, Texas	14	20,100
June 1967	Platte River Basin in Nebraska	—	35,275
September 1967	Hurricane "Beulah" floods in Texas	—	98,239
August 1967	Tanana and Chena Rivers in Alaska	—	98,550
May 1968	Rivers in northern New Jersey	—	166,690
January-February 1969	Floods in California	60	399,233
March-April 1969	Snowmelt floods in upper Midwest h	—	151,000
July 1969	Northern Ohio	30	87,915

Table 4.-Losses in Individual Severe Floods in the United States Since July 1902, cont.
(Property losses in thousands of dollars)

Date*	Location	Lives**	Property
August 1969	James River Basin in Virginia	153	116,000
January 1970	Sacramento River Basin	18	38,120
September 1970	Arizona	23	5,000
October 1970	Puerto Rico	50	62,000
August 1971	NewJersey("Doria" rainfall)	-	138,700
September 1971	Southeastern Pennsylvania	13	19,010
February 1972	Buffalo Creek,W. Va.	125	10,000
May 1972	South-central Texas flash floods	18	17,500
June 1972	Black Hills of South Dakota	237	164,947
June 1972	Eastern United States (Hurricane "Agnes"floods)	105	4,019,721
Spring 1973	Mississippi system	33	1,154,770
May 1973	Flash flooding in mountains of North Carolina and southwest Virginia	12	29,485
June 1973	Connecticut Basin in Vermont, Connecticut, and New Hampshire	11	64,000
June 1973	San Jacinto Basin and small adjacent basins in southeast Texas	10	62,500

*The 1966 to 1972 Annual Issues of Climatological Data, National Summary (as well as various earlier issues) contain this table which lists additional significant severe floods during the period of record.
**No entry indicates that fewer than 10 lives were lost.
[a]Monthly Weather Review, January 1949.
[b]Technical Paper No. 17.
[c]Technical Paper No. 23.
[d]Technical Paper No. 26.
[e]Climatological Data, National Summary, December 1955.
[f]Climatological Data, National Summary, January 1957.
[g]Technical paper No. WB-3.
[h]NOAA Technical Report No. 13.
[i]Climatological Data, National Summary, October 1970.
[j]Climatological Data, National Summary, June 1972; Geological Survey Professional Paper 924.

Table 5.—Annual Property Loss Attributable to Floods

Source	Loss($)
Riverbank overflow	$I biilion
Conduit backwater flood	800 miilion
Groundwater flood	400 million
Headwater flood	250 miliion
Flashflood	200 million
Subsidence flood	70 miilion
Ice backup	20 million
Debris backup	20 miilion
Dam breakage	I0 million
Geological sink flood	I million
Total	$2.771 trillion

SOURCE: D. Earl Jones, personal communication.

The situation has been continuing to worsen, particularly with respect to the demography of urban, riverine, and coastal zone development. According to Gilbert White, the present rate of urban expansion into floodplains is between 1.5 to 2.5 percent annually.[13] This means roughly a doubling of the risks per generation. Encroachment on floodplains even occurs in areas with zero growth or declining population.

[13]Gilbert F. White, *Flood Hazard in the United States: A Research Assessment*, Monograph #NSF-RA-E-75-006 (Boulder, Colo.: Institute of Behavioral Science, University of Colorado), p. xviii.

Impending Catastrophes

Catastrophic floods are highly likely in more than one part of the United States. Galveston, Tex., Key Biscayne, Fla., Boulder, Colo., and Orange County, Calif., are examples of the many areas that are likely to experience flood disasters with possible losses of thousands of lives and billions of dollars in property damage. The tendency to think in terms of annual or average losses, which then become the sole criteria for planning, diverts attention from potential catastrophes.

The combination of unrestrained urban sprawl, expansion into coastal zones, and continued reliance on the engineering approach to floodplain management almost certainly presages catastrophic floods in the next several decades. The relatively small loss of life caused by floods in recent years belies the number of American cities and counties vulnerable to exceptionally high flood losses. The following potential disasters suggest the urgent need to move to more prudent management of flood hazards.

- **Colorado.**—According to a scenario proposed by Gilbert White, the city of Boulder faces a hypothetical catastrophic flood that could take over a hundred lives and cause $80 million worth of property damage.[14]

[14]Ibid., pp. 111-117.

- Florida. -In south Florida, floods accompanying a hurricane, according to White, could cause many deaths due to the vulnerability of bridges, causeways, and drawbridges to storm surges. Citing the transitory nature of Florida residents, he contends that a large part of its population has never experienced a severe hurricane. That ignorance could hamper evacuation and warning response:

  In sum, the total loss of life is high. A storm surge well in advance of the hurricane's center catches many still preparing to evacuate. Flooding of escape routes due co heavy rain exacerbates the severe traffic tie-ups which are normally expected with a large number of automobiles. (Rush hour traffic probably represents less than 25 percent of the traffic which could be expected with a warning to evacuate, and even this amount cannot be accommodated without major delays.) Warning and evacuation as they now are planned and proceed are inadequate responses to the posited threat.[15]

- California.–In 1 month in 1966, the Santa Ana River basin suffered two storms of such severity that each was likely to occur only once in 30 years. They caused $85 million in damage and qualified three counties for Federal disaster relief. The flood control system itself came close to failing. This compelled the Corps of Engineers to study what 'the post-disaster consequences would be if a storm of greater magnitude should occur. The study was referred to by the Corps as a "standard project flood." It is, however, a reasonable upper limit guideline for providing a high degree of flood protection to an urban area.

  According to its description by Wesley Marx:

  The corps exposed Orange County to a standard project flood on paper. River levees would breach. The junk autos needed to bolster levees in this situation simply do not exist, not even in auto-crazed southern California. Knotts Berry Farm and Movieland Wax Museum would be in 3 feet of water. Sleepy hamlets turned civic insomniacs—Anaheim, Garden Grove, Westminster, and Fountain Valley–would be wading in floodwaters. The Disney Matterhorn and freeway overpasses would be high ground. Rockwell International, McDonnell Douglas, Aerojet-General, and other corporations aiming for the moon would need hip boots. A naval weapons station would also be awash. Downriver, the oil town turned civic idol (proud Huntington Beach) would be calling for rowboats and seaplanes. Water would stand 2 to 10 feet deep over 156 square miles of the Nation's Fastest Growing County. Some 300,000 homes would be damaged. Total damage to homes, businesses and industries, transportation, work loss, and other economic entities would be an estimated $3 billion under 1974 conditions of development (the corps). This projected damage toll would equal that racked up by tropical storm Agnes, which performed over a much larger geographic area.[16]

The above forecasts of disasters that would be accompanied by a high loss of life and extensive property damage reflect the consequences of conditions typical of many American regions. Public policies that are largely limited to physical controls create a false sense of security which encourages the intensive development of vulnerable terrain.

The potential catastrophes described above have had very real, tragic precedents in recent history. On June 9, 1972, Rapid City, S. Dak., experienced the most destructive flash flood in the Nation's history. It took 231 lives and did more than $100 million worth of property damage (see table 6). Although the history of flooding in that area is well-documented, major floods had not occurred for five decades, and development took place unhampered by concerns about a flood hazard. Thus, it exemplifies the type of catastrophic destruction that could be experienced by other more densely developed areas as a consequence of an unusual flood-producing event, if floodplains continue to be developed without regard for the possibility of severe floods.

The flood history of Rapid City (see table 6), which was available to all of its flood planners, illustrates the consistent pattern of flooding that should have alerted them to the potentiality of a catastrophe.

Public policy in flood hazards management needs to be concerned with two types of flood risk. The first is a noncatastrophic flood. In this type, there is a slow and steady rise in losses. The second is the potential catastrophe, with enormous loss of lives and property.

[15]Gilbert F. White and Eugene J. Haas, op. cit., pp. 35-36.

[16]Wesley Marx, op.cit., p. 113.

Table 6.-Flood History of Rapid City, S. Oak.

Date of flood	Damages ($)	Loss of life
1.1878	?	1
2. 1883	'?	—
3.1885	25,000	—
4.1890	50,000?	—
5.1901	?	—
6. 1907	100,000+	4?
7.1909	?	—
8.1909	5,000	
9. 1910	?	
10.1910	?	—
11.1920	250,000+	
12.1926	7	
13. 1929	?	—
14.1936	?	
15.1942	?	
16.1949	?	—
17.1952	?	—
18.1962	?	
19.1972	100,000,000+	231

SOURCE: Gilbert F. White, Flood *Hazard in the United States: A Research Assessment* (Boulder Colo.: University of Colorado, 1975), p. 60.

ELEMENTS OF NATIONAL RESPONSE

Since the Lower Mississippi Flood of 1927, the Federal Government has been closely involved with the planning, design, funding, construction, and operation of flood control programs. Table-i -- describes the significant Federal responses since that year. From these it can be seen that specific disasters have provided strong incentives for new initiatives.

Between 1928 and 1968, the major emphasis was on the construction of massive engineering projects including flood control dams and reservoirs, widening and straightening channels, and local levees, dikes, and floodwalls. The intent in each case was to restrain floodwaters from affecting human activities and settlements. These meas-

Table 7.-Chronology of Major Floods and Public Response

Date	Major flood disasters	Significant events in national response
1927. .	Lower Mississippi— 1927 New England—1927	Mississippi Flood Control Act of 1928
1930. .		Tennessee Valley Authority Act of 1933 Report of Water Resources Committee of National Resources Board– 1934
1935. .	Kansas River– 1935 Upper Susquehanna—1935 Eastern United States–1936 Ohio/Middle Mississippi— 1937 New England— 1938	Flood Control Act of 1936 Flood Control Act of 1938
1940. .		Flood Control Act of 1944
1945. .		Publication of "Human Adjustment to Floods" by G. F. White—1945
1950. .	Kansas and Missouri Rivers—1951	President's Commission on Water Resources Policy— 1950 Watershed Protection and Flood Prevention Act of 1954
1955. .	New England—1955	Publication of *Floods* by Hoyt and Langbein— 1955 Flood Insurance Act— 1956
1960. .	Gulf Coast—1960 Southwest and Midwest—1961 Atlantic Coast—1962 Louisiana—1964	Floodplain Information Program, Corps of Engineers— 1961
1965. .	Upper Mississippi— 1965 Upper Mississippi— 1969	Southeastern Hurrican Disaster Relief Act of 1963 Water Resources Planning Act of 1965 HUD Study on Flood insurance—1966 Report of Task Force on Federal Flood Control Policy— 1966 Executive Order 11296-1966 National Flood Insurance Act of 1968
1970. .	Rapid, S. Oak.— 1972 Hurricane Agnes— 1972 Upper Mississippi— 1973	Flood Disaster Protection Act of 1973 Water Resources Development Act of 1974
1975. .	Mid-Atlantic—1975 Massachusetts Coast— 1978 Southern California– 1978	Executive Orders 11988, 11990–1977

SOURCE: Office of Technology Assessment.

ures have been accompanied, to a limited extent, by floodplain zoning to prevent downstream channel encroachment (a condition frequently required by the Corps of Engineers that appears to be more honored in the breach than in the observance.) Other measures that have been employed in rural areas since the 1930's include reforestation and soil conservation techniques. Whenever floods have occurred despite these measures, various forms of public and private disaster assistance have been supplied. The Federal share of this assistance has been rising sharply.

Since 1968, the emphasis in national flood policy has shifted towards an increasing reliance on nonstructural measures, such as flood insurance and land management, for averting severe flood losses and possibly redistributing their economic burden. The National Flood Insurance Act of 1968 (see chapter VII) established a program for insuring buildings and their contents against flood damage in both coastal and riverine hazard areas. The program requires the adoption by each community of local regulations that satisfy minimum national standards for floodplain management, as a prerequisite to the sale of insurance to property owners. Additional legislation during the 1970's has broadened the National Flood Insurance Program to require the purchase of insurance as a condition to the approval of federally related financing in hazard areas. Two Acts in 1974 authorized Federal cost-sharing for nonstructural measures (such as land acquisition), and required that efforts be made to mitigate disasters as a condition of Federal disaster assistance. These and other pertinent Federal laws are summarized below (see table 7):

- Federal Flood Control Act (33 USCA sees. 701a et seq.); **Flood Control Act of** 1936 (Public Law 74-738); Flood Control Act of 1938 (Public Law 75-761); and subsequent Rivers and Harbors Acts.

  These comprise the organic Federal law concerning the control of floods by means of structural projects: dams, channelization, local protection works, etc. Primary responsibility is assigned to the U.S. Army Corps of Engineers, with the Department of Agriculture assigned jurisdiction over small upstream watersheds with problems of erosion and runoff. The 1936 Act set forth the fundamental criterion that Federal funding is restricted to projects whose "benefits to whosoever they may accrue exceed their estimated costs."

- **Watershed Protection and Flood Prevention** Act **of 1954** (Public Law 83-566; 16 USCA, sees. 1001 et seq.).

  This Act established the "small watershed" flood management program of the U.S. Department of Agriculture Soil Conservation Service. The Service is authorized to undertake planning studies for watersheds of less than 250,000 acres and to implement flood control programs including land treatment, construction of flood detention reservoirs, and other measures.

- Water Resources Planning Act of 1965 (Public Law 89-80, 42 USCA 1962 et seq.).

  This Act established the U.S. Water Resources Council as an independent Federal agency responsible for the review and analysis of water resource issues and for the supervision of studies by river basin commissions. It also provided for the establishment of Federal river basin commissions, six of which are now in existence (New England, Ohio, Great Lakes, upper Mississippi; Missouri, and Pacific-Northwest.) This Act also authorized grants to States for water resource planning and studies.

- National **Flood Insurance Act (42** USCA sees. 4001 et seq.).

  Tide XIII of the Housing and Urban Development Act of 1968 (Public Law 90-448)

  Housing and Urban Development Act of 1969 (Public Law 91-152)

  Flood Disaster Protection **Act of 1973** (Public Law 93-234)

  This Act established the National Flood Insurance Program as a vehicle for promoting prudent management of floodplains, and for allocating some of the costs of flood losses to occupants of flood hazard areas through the mechanism of insurance. (See chapter VII.)

- **Water Resources Development Act of 1974, sec.** 73 (Public Law 93-251)

  This section requires those Federal agencies responsible for floodplain management to consider nonstructural alternatives to measures authorized in the Federal Flood Control Act. Federal agencies are authorized to participate in the implementation of such nonstructural alternatives at a level of 80 percent of total project costs or more.

- Disaster Relief Act of 1974, Sec. 406 (Public Law 93-288).

  This section requires as a condition of any disaster loan or grant made under this Act that the recipient shall agree that reconstruction thereby assisted shall conform to applicable building standards. States and local governments encompassing property eligible for disaster assistance shall evaluate the existence of natural hazards and shall adopt necessary measures to mitigate such hazards.

Following this overview of the historical and current basis for policy concerns, a framework for flood hazards management is considered in the next chapter.