NINE FALLACIES OF FLOODS *

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Abstract. A number of important misconceptions or fallacies stand in the way of a better understanding of the nation's flood problem. The fallacies are not universal, with many flood experts, decision makers, and sectors of the public escaping their seductive logic. But enough people do fall prey to these fallacies of floods so as to create obstacles to improved utilization of the lessons of experience. This paper uses three of these lessons to organize presentation of the nine fallacies:

- We know the wrong things *about the nature of the problem*.
  Fallacy 1: Flood frequencies are well understood.
  Fallacy 2: Damaging flooding in recent years is unprecedented because of 'global warming'.
  Fallacy 3: Levees 'prevent' damages.
  Fallacy 4: Flood forecasts are universally available.
- We don't know enough *about why and with what intensity we should act*.
  Fallacy 5: Societal vulnerability to floods is well understood.
  Fallacy 6: Data on flood casualties is a proxy for flood risk.
  Fallacy 7: Data on flood damages is a proxy for flood risk.
- We know enough *about what might be done*.
  Fallacy 8: Knowledge leads to action.
  Fallacy 9: The U.S. flood problem can be addressed without Federal leadership and support.

The purpose of raising the fallacies in this paper is to contribute to a systematic definition of the nation's flood problem.

1. Introduction

Flood policy in the United States is characterized by numerous assessments of society's response to particular events as well as periodic summaries of the common lessons distilled from those assessments.‡ A central theme running through this

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‡ Examples of assessments published in the aftermath of the 1993 floods in the U.S. Midwest include Changnon (1996), the Corps of Engineers Floodplain Management Assessment (FPMA, 1995), the Galloway Report (IFMRC, 1994), and the Department of Commerce's Natural Disaster Survey Report (DOC, 1994). More general reviews include Committee on Public Works (1959), Unified National Program reports (TFFCP, 1996; USWRC, 1976, 1979; ITFFM, 1986; FIFMTF, 1994), and the comprehensive Floodplain Management Assessment (FIFMTF, 1992).

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literature is that society has learned through experience what actions will lead to a reduction in vulnerability to floods, but that these 'thoughtful past recommendations of how to attain flood mitigation had never been adequately implemented' (Changnon, 1996, p. 312). The central thesis of this paper is that while experience has provided sufficient knowledge of steps necessary to begin to reduce society's vulnerability to floods, society lacks an accurate understanding of the nature of the flood problem itself.* Because decision makers lack knowledge of the policy problem, potential policy solutions developed by flood experts are often implemented unsystematically (if at all), overlooked in favor of false solutions, or without the leadership needed to ensure their success.

A number of important misconceptions or fallacies stand in the way of a better understanding of the nation's flood problem. The fallacies are not universal, with many flood experts, decision makers, and sectors of the public escaping their seductive logic. But enough people do fall prey to these fallacies of floods so as to create obstacles to improved utilization of the lessons of experience. This paper uses three of these lessons to organize presentation of the nine fallacies:

1. We know the wrong things *about the nature of the problem* (Fallacies 1, 2, 3 and 4).
2. We don't know enough *about why and with what intensity we should act* (Fallacies 5, 6 and 7).
3. We know enough *about what might be done* (Fallacies 8 and 9).

Of course, there are other fallacies of floods (and disasters more generally) which would expand the list presented here (e.g., Glantz, 1976).

The purpose of raising the fallacies in this paper is to contribute to a systematic definition of the nation's flood problem. It makes sense that effective actions in response to floods ought to be based upon an accurate and realistic definition of the problem. While this paper focuses on river floods (i.e., large-scale and flash) in the United States, the fallacies have potential broader relevance to the extent to which they influence policy in other flood-prone regions of the world. Simply correcting mistaken beliefs will not in itself 'solve' the nation's flood problem, but it can remove obstacles to the implementation of previously unseen or underappreciated policy alternatives. It is certain that the challenge of improving society's response to floods will face obstacles so long as these fallacies persist.

* One influential branch of the policy literature views policy solutions distinct from policy problems, with the two meeting only under certain circumstances. See particularly the 'garbage can model' of Cohen et al. (1972) and the policy and problem 'streams' of Kingdon (1984). A review of the problem definition literature is found in Pielke (1997a).

2. Flood Fallacies

2.1. FLOOD FREQUENCIES ARE WELL UNDERSTOOD

Flood experts use the terms ‘stage’ and ‘discharge’ to refer to the size of a flood (Belt, 1975). A flood stage is the depth of a river at some point and is a function of the amount of water, but also the capacity of a river channel and floodplain and other factors. Hence, upstream and downstream levees and different uses of floodplain land can alter a flood’s stage. A flood discharge refers to the volume of water passing a particular point over a period of time. For example, in 1993 St. Louis experienced ‘the highest stage we’ve ever had, but not the biggest volume’.

> We’ve had bigger flows, but the stage was different because the water could flow from bluff to bluff. Now we have communities in the floodplain. Every time you do something on a floodplain, you change the flood relationship. Every time a farmer plants a field or a town puts in a levee, it affects upstream flooding. That’s why you can’t really compare flooding at different times in history (G. R. Dryhouse quoted in Corrigan, 1993).

According to the World Meteorological Organization’s International Glossary of Hydrology, ‘flood frequency’ is defined as ‘the number of times a flood above a given discharge or stage is likely to occur over a given number of years’ (WMO, 1993). In the United States, flood frequencies are central to the operations of the National Flood Insurance Program, which uses the term ‘base flood’ to note ‘that in any given year there is a one percent chance that a flood of that magnitude could be equalled or exceeded’ (FIFMTF, 1992, p. 9-7). The ‘base flood’ is more commonly known as ‘the 100-year flood’ and is ‘probably the most misunderstood floodplain management term’ (FIFMTF, 1992, p. 9-7).

A determination of the probability of inundation for various elevations within a community is based on analysis of peak flows at a point on a particular river or stream. However, ‘there is no procedure or set of procedures that can be adopted which, when rigidly applied to the available data, will accurately define the flood potential of any given watershed’ (USWRC, 1981, p. 1). For many reasons, including limitations on the data record and potential change in climate, ‘risk and uncertainty are inherent in any flood frequency analysis’ (USWRC, 1981, p. 2). Nevertheless, quantification of risk is a fundamental element of flood insurance as well as many aspects of flood-related decision making.

In order to quantify flood risk, in the early 1970s the National Flood Insurance Program adopted the 100-year-flood standard (FIFMTF, 1992, p. 8-2). The standard was adopted in order to standardize comparison of areas of risk between communities. Since that time the concept of the N-year flood has become a common fixture in policy, media, and public discussions of floods. Unfortunately, ‘the general public almost universally does not properly understand the meaning of the term’ (FIFMTF, 1992, p. 9-7). Misconceptions about the meaning of the term creates obstacles to proper understanding of the flood problem and, consequently, the development of effective responses.

The 100-year standard refers to a flood that has a one percent chance of being exceeded in any given year. It does *not* refer to a flood that occurs 'once every 100 years'. In fact, for a home in a 100-year flood zone there is a greater than 26% chance that it will see at least one 100-year flood over a period of 30 years (and, similarly, more than a 74% chance over 100 years). The general formula for the cumulative probability of at least one flood of annual probability P is $(1-P)^N \geq C$ where N equals the number of years from now, and C is the cumulative probability over period N (P is assumed to be constant and events are independent from year to year). By choosing values for P and C one can compute the number of years that the cumulative probability (C) covers.

The concept and terminology of the '100-year floodplain' was formally adopted by the federal government as a standard for all public agencies in 1977 under Executive Order 11988. In 1982 FEMA reviewed the policy and found that it was being used in the agencies and, lacking a better alternative, concluded that the policy should be retained (FIFMTF, 1992, p. 8-3). However, despite the FEMA review, use of the concept of the 100-year flood is encumbered by a number of logical and practical difficulties (cf. Lord, 1994).

First, there is general confusion among users of the term about what it means. Some use the term to refer to a flood that occurs every 100 years, as did the Midwestern mayor who stated that 'after the 1965 flood, they told us this wouldn't happen again for another 100 years' (IFMRC, 1994, p. 59). Public confusion is widespread: A farmer suffering through Midwest flooding for the second time in three years complained that 'Two years ago was supposed to be a 100-year flood, and they're saying this is a 75-year flood, What kind of sense does that make? You'd think they'd get it right' (Peterson, 1995).

Second, the '100-year flood' is only one of many possible probabilistic measures of an area's flood risk. For instance, in the part of the floodplain that is demarcated as the '100-year floodplain' it is only the outer edge of that area that is estimated to have an annual probability of flooding of 0.01, yet confusion exists (Myers, 1994). Areas closer to the river have higher probabilities of flooding, e.g., there are areas of a floodplain with a 2% annual chance of flooding (50-year floodplain), 10% annual chance (10-year floodplain), 50% annual chance (2-year floodplain) etc., and similarly, areas farther from the river have lower probabilities of flooding. The '100-year floodplain' is arbitrarily chosen for regulatory reasons and does not reflect anything fundamentally intrinsic to the floodplain.

Third, the '100-year floodplain' is determined based on past flood records and is thus subject to considerable errors with respect to the probabilities of future floods. According to Burkham (1978) errors in determination of the '100-year flood' may be off by as much as 50% of flood depth. Depending on the slope of the flood plain, this could translate into a significant error in terms of distance from the river channel. A FEMA press release notes that 'in some cases there is a difference of only inches between the 10- and the 100-year flood levels' (FEMA, 1996). Further, researchers are beginning to realize an 'upper limit' on what can be known about flood frequencies due to the lack of available trend data (Bobée and Rasmussen, 1995).

Fourth, the 100-year floodplain is not a natural feature, but rather is defined by scientists and engineers based on the historical record. Consequently, while the '100-year floodplain' is dynamic and subject to redefinition based on new flood events that add to the historical record, the regulatory definition is much more difficult to change. For instance, following two years of major flooding on the Salt River in Phoenix, Arizona, the previously estimated 100-year flood was reduced to a 50-year flood (FIFMTF, 1992, p. 9-7). What happens to the structures in redefined areas? Any changes in climate patterns, especially precipitation, will also modify the expected probabilities of inundation. For example, some areas of the upper Midwest have documented a trend of increasing precipitation this century (Changnon and Kunkel, 1995; Bhowmik et al., 1994). Furthermore, human changes to the river environment, e.g., levees and land use changes, can also alter the hydraulics of floods. Finally, the extensive use of the term '100-year flood' focuses attention on that aspect of flooding, sometimes to the neglect of the area beyond the 100-year flood plain (Myers, 1994).

What can be done? Given the pervasive use of the concept of the '100-year flood' in flood insurance and regulatory decision-making it seems that adoption of an alternative concept is unlikely. Nevertheless, there are a number of steps that can be taken by those who use the concept when dealing with policy makers and the public. First, we need to be more precise with language. The FIFMTF (1992) recommends the phrase 'one percent annual chance flood' as a preferred alternative to '100-year flood', 'base flood', or 'one percent flood'. Another alternative is 'national base flood standard' which removes reference to probability (Thomas, 1996, personal communication). Second, when communicating with the public and the media, flood experts could take care to convert annual exceedances into annual probabilities. And third, policy documents could rely less on the '100-year flood' to illustrate examples and propose policies, and at the very least explicitly discuss floods of different magnitudes.

2.2. DAMAGING FLOODING IN RECENT YEARS IS UNPRECEDENTED BECAUSE OF 'GLOBAL WARMING'

The phrase 'global warming' refers to the possibility that the earth's climate may change because human activities are altering the composition of the atmosphere. Scientists first raised this possibility more than a century ago, and in recent decades policy makers have begun to express concern about the possibility of climate change. Possible changes that have been discussed in the context of global warming include increasing or decreasing tropical cyclone activity, increased spread of infectious diseases, change in mean global temperature and regional and local temperature variability, and a more active hydrological cycle, including the possibility of more floods (see IPCC, 1996a,b, on the science and impacts associated with climate change).

One result of scientific and political concern about the possibility of global warming is a frequent association by the media and the public of almost every extreme weather event with global warming. For instance, the cover of *Newsweek* from 22 January 1996 carried the following title: 'THE HOT ZONE: Blizzards, Floods, and Hurricanes: Blame Global Warming'. This article, and others like it, carry the implication that global warming is responsible for recent climatic extremes. In fact, it is essentially impossible to attribute any particular weather event to global warming. At the regional level scientists have documented various increasing and decreasing trends in the frequency or magnitude of extreme events, but are not able to associate those changes to global warming. Globally it is difficult for scientists to discern recent trends in extreme events. As the IPCC (1996a, p. 173) notes:

> Overall, there is no evidence that extreme weather events, or climate variability, has increased, in a global sense, through the 20th century, although data and analyses are poor and not comprehensive. On regional scales there is clear evidence of changes in some extremes and climate variability indicators. Some of these changes have been toward greater variability; some have been toward lower variability.

Does the lack of a linkage between extreme weather events and global warming mean that the public and policymakers need not concern themselves with climate change? On the contrary; there are many reasons for the public and policymakers to have an *increasing* concern about the impacts of extreme events. And this concern is largely independent of the global warming hypothesis, for the following reasons.

Current knowledge is limited as to the potential impacts of a changing climate on the number and intensity of hydrologic flood events (IPCC, 1996a; OTA, 1993; Dracup and Kendall, 1990). It is certain that for particular regions and communities the climate will change in some way or another. There will likely be some regions that experience more flood events and others that experience less. It will almost certainly be more straightforward to document these changes than to attribute them to specific causes such as human-caused global warming. For example, several regions in the Upper Mississippi River Basin have seen trends (at 80% and 90% confidence for different regions) of increasing precipitation since 1965 (Bhowmik et al., 1994). Meanwhile, the Colorado river basin has seen a decrease in streamflow over the latter two thirds of the twentieth century (Frederick and Kneese, 1990). Such 'winners and losers' have been documented in regions and nations around the world (e.g., Rao, 1995; Karl et al., 1995). In the United States (about 6% of the Earth's land surface), recent decades have seen an increasing trend (at various levels of confidence) in precipitation in certain regions and also streamflow (Kunkel et al., 1997; Karl et al., 1996; Lins and Michaels, 1994). But it is not clear that more precipitation (or changed frequencies of precipitation events) in the United States are the cause of the documented increase in losses in recent decades; other factors (such as human occupancy of flood plains, land use change, channel engineering, nonstructural mitigation policies, etc.) must also be taken into account to arrive at a final determination of the relation of climate and impacts.

There are at least three implications of the uncertain climate future for societal responses to floods. First, there is a continued need to document how climate has changed in the past. So much attention is focused on developing better predictions of the future that we often neglect the wealth of data about the past. Second, there is a need to systematically evaluate successes and failures in responding to past climatic extremes. While we do not know exactly what the future will bring, we do in many cases know that our responses to past events has been less than optimal. Thus, at a minimum we should take care to ensure that we are at least prepared to deal with the variability and extremes that have already occurred and been documented (Glantz, 1988). Finally, the uncertainty in the climate future underscores the need to better understand the societal dimensions of the climate threat and to take those adaptive measures that make sense based on our imperfect knowledge of the certain past and uncertain future. A first step in that effort is to better understand societal exposure to variability and extreme events.

No matter what the climate future holds, flood impacts on society may continue to get worse. A study conducted by the U.S. Congressional Office of Technology Assessment concluded that 'despite recent efforts, vulnerability to flood damages is likely to continue to grow' (OTA, 1993, p. 253). The study based this conclusion on the following factors, which have very little to do with climate:

1. Populations in and adjacent to flood-prone areas, especially in coastal areas, continue to increase, putting more property and greater numbers of people at risk,
2. flood-moderating wetlands continue to be destroyed,
3. little has been done to control or contain increased runoff from upstream development (e.g., runoff caused by paving over land),
4. many undeveloped areas have not yet been mapped (mapping has been concentrated in already-developed areas), and people are moving into such areas without adequate information concerning risk,
5. many dams and levees are beginning to deteriorate with age, leaving property owners with a false sense of security about how well they are protected,
6. some policies (e.g., provision of subsidies for building roads and bridges) tend to encourage development in flood plains.

At a minimum, when people blame climate change for damaging flood events, they direct attention away from the fact that decision makers already have the means at their disposal to significantly address the documented U.S. flood problem.

2.3. LEVEES 'PREVENT' DAMAGES

The United States, one flood expert has commented, has had an 'undying love affair' with levees (Tobin, 1995). Another flood expert has called the late-eighteenth/early nineteenth century policy of sole reliance on levees to control floods 'pernicious beyond belief' (Wright, 1996, p. 247). A levee is a structure built to keep water from inundating an area that would otherwise be flooded.* The United States is home to approximately 25,000 miles of levees – or enough to encircle the world at the equator (FIFMTF, 1992). The U.S. Army Corps of Engineers has been responsible for building more than 10,500 miles of levees. Levees built by other federal and state agencies, as well as by individuals, make up the remainder. The funding, design, construction, and repair of levees by the federal government is overseen by five federal agencies: USACE, Agriculture, National Resources Conservation Service,† Federal Emergency Management Agency (FEMA), Economic Development Administration, and HUD (Housing and Urban Development). The multiple agencies and their differing requirements and responsibilities 'confuses' the issue of levee systems (Tobin, 1995, p. 364). Local agencies and privately-owned levees further complicate the issue.

According to Tobin (1995, p. 365) levees can serve to actually *increase* the potential for flood losses. He calls this the 'levee effect' and defines it as follows:

> Once [a levee] has been constructed, however, the structure may generate a false sense of security to the extent that floodplain inhabitants perceive that all flooding has been eliminated. With the incentive to take precautions removed, few residents will be prepared for remedial action in the event of future floods. Even more costly, however, this false sense of security can also lead to greater development in the so-called safe areas, thus adding to the property placed at risk ... when the levee does fail, the increase in development can actually raise losses even higher than if no levee system had been constructed in the first place.

The 'levee effect' can increase society's vulnerability to floods in two ways: by creating a sense of complacency, which can act to reduce preparedness and by creating incentives to build structures in areas subject to flooding. Tobin observes that a comprehensive study of the 'levee effect' has yet to be undertaken.

The fallacy that 'levees prevent damages' is a subset of a much broader issue about the role of structural measures in flood mitigation. Structural approaches to flood control are characterized by attempts to keep high water from inundating public and private property and thus causing damage. Since the 1940s, beginning with the pioneering work of Gilbert White, floodplain management has increasingly included 'nonstructural' approaches that emphasize adjusting human behavior (see

* Both levees and floodwalls are defined as a form of 'dike' – a general term for 'longitudinal structures that serve to retain water' (FIFMTF, 1992, p. 12-27). This paper uses the more common term 'levee' to refer to all types of levees, floodwalls, and dikes.

† Formerly the Soil Conservation Service.

FIFMTF (1992), Chapters 12 and 15 for discussion). Issues of structural and complementing nonstructural approaches to flood mitigation go well beyond the scope of this paper. It is worth noting, however, that in spite of widespread agreement among flood experts that structural measures alone cannot adequately address the nation's flood problem, the proper role of structural measures has yet to be adequately defined. Lack of understanding of the 'levee effect' is a prime example of how an incomplete understanding of the role of structural and nonstructural measures in flood mitigation limits what can be authoritatively said with respect to the flood problem.

2.4. FLOOD FORECASTS ARE UNIVERSALLY AVAILABLE

The Unified National Program for Floodplain Management report asserted that 'regional warnings for floods and hurricanes are becoming universally available' (FIFMTF, 1994, p. 16). This stands in stark contrast to Changnon (1996, p. 309) who stated with respect to the 1993 Midwest flood that 'the flood condition pronouncements of the National Weather Service (NWS) and those of the Corps of Engineers for the St. Louis area were often inaccurate and sometimes controversial' (cf. Gruntfest and Pollack, 1994). As a consequence, 'these forecasts and pronouncements likely worked to the detriment of the strategies used to fight the flood, shipping alternatives, and other flood-impacted endeavors' (p. 27). Furthermore, even the Weather Service's self evaluation found 'substantial opportunities for improvements' (DOC, 1994, p. 2-1). More recently, residents of the Red River of the North basin have criticized the flood forecasts issued during the spring 1997 floods (see, for example, Glassheim, 1997). In short, in spite of the progress made over the last century in weather and flood forecasting, there remains considerable potential for improvements in flood forecasts. Further, there also remains a vast potential for improved use of those forecasts by decision makers (Pielke, 1999; Changnon, 1996; cf. Gruntfest and Pollack, 1994).

One potential area for improvement of flood forecasting lies with continuing improvements in 'Quantitative Precipitation Forecasting' (QPF), which is defined as 'the forecasting of the amount of rain or water equivalent of frozen precipitation that will fall over a particular area over a given period' (Schwein, 1996, p. 1). Such improvements have been described as 'steady, albeit slow' (Krzysztofowicz, 1995, p. 1143). The goal of using QPF in the flood forecasting process is to provide a longer lead time for flash flood and river stage forecasts. Of course, the success of this tool depends on large part upon the ability to forecast reliably the amount of precipitation that will fall over a particular watershed. To date, QPF has not been fully implemented. Results have been mixed in experimental uses of QPF with both improvements and degradation in forecasts. One review cites several studies of the use of QPF that show benefits to decisions associated with flood warning, reservoir control, and commercial navigation (Krzysztofowicz, 1995). According to Schwein (1996) a key to beneficial use of QPF in flood forecasting will be to train forecasters on how to interpret and use appropriately the additional information that is generated.

Other areas where flood forecasts might be improved include the use of advanced radar technologies to identify in real-time (as well as to forecast) areas of heavy rainfall, improvements to rainfall-runoff models, improvements in data collection with river basins using satellites, radiosondes, and ground stations (Krszysztofowicz, 1995). Of course, to be most valuable to society any scientific or technological advances in flood forecasting must be accompanied by commensurate ability to use those advances in the decision processes of warning and response. Growing evidence suggests that decision makers' ability to *use* flood forecasts has not kept pace with technical advances (Pielke, 1999).

2.5. SOCIETAL VULNERABILITY TO FLOODS IS WELL UNDERSTOOD

One of the goals recommended in 1994 by the Federal Interagency Floodplain Management Task Force recommended in its Unified National Program is to 'reduce by half the risks to life and property and the risks to the natural resources of the Nation's floodplains' (FIFMTF, 1994, p. 31). The Task Force recognized that in order to reduce risks by half, the dimensions of that risk must first be understood. Therefore, the Task Force recommended the compilation of an inventory of floodplain structures, areas for development, and natural resources by 2005. The reason that such an inventory is needed is the 'great uncertainty that exists in attempting to determine the total area of the United States that is subject to flooding' and 'there is no complete record of past flood damages in the United States' (FIFMTF, 1992, pp. 1-2 and 3-15). In short, we do not know with accuracy how many people inhabit and the quantity, value, and types of property in U.S. floodplains. Consequently, societal vulnerability to floods is poorly understood.

Societal Vulnerability

Once it was thought that a society's vulnerability to extreme weather and climate events was simply a function of an event's characteristics and incidence in places where people were at risk. This led to conclusions that a prediction of an extreme event, coupled with a technological or engineering solution (e.g., a levee system to prevent floods or an accurate forecast of a pending severe storm), would be sufficient to reduce vulnerability (Anderson, 1995). But as scientific and technical tools and techniques have advanced in recent decades, so too have losses of human lives and property because of the impacts of extreme events in the United States and around the world (Pielke, 1997b; White, 1994).* The implication of the twin trends of increasing technical sophistication and increasing losses signaled that vulnerability had more to it than implied by the perspective of nature-causing-disaster. There were obviously other factors at work.

* Loss of life was greater in the United States and worldwide in the early decades of this century.

A more accurate conception of societal vulnerability emphasizes the role that people play in creating their own vulnerabilities, as well as the role of others.* Anderson (1995, p. 45) summarizes a number of the factors responsible for human-caused-vulnerability.

> Whereas previous assessments focused on acts of nature that come from outside human agency, later assessments acknowledged that it is largely human actions, decisions, and choices that result in people's vulnerability to natural events. Choices about where to live (or, in some cases, the lack of choice due to political, economic, or social position), decisions about where to locate a chemical plant, and acts of cutting forests, farming marginal lands, or evading building codes are examples of how humans cause a 'natural' hazard to become a disaster. Humans make themselves – or, quite often, others – vulnerable.

A broad definition of 'vulnerability' seeks to capture an 'aggregate measure of human welfare that integrates environmental, social, economic, and political exposure to a range of potential harmful perturbations' (Bohle et al., 1994). An understanding of vulnerability requires integration of both its physical and societal aspects. As Chambers (1989, p. 1) notes that vulnerability has 'two sides', an 'external side of risks, shocks and stress ... and an internal side which is defenselessness, meaning a lack of means to cope without damaging loss'. Vulnerability to a climate- or weather-related event is thus a function of both society's exposure and of an event's incidence. Or as a 1966 Federal Task Force eloquently stated: 'Floods are an act of God; flood damages result from the acts of [people]' (TFFFCP, 1966, p. 14).

Flood events in recent years provide vivid evidence that people and property in the United States remain extremely vulnerable to floods. However, data is lacking (or unavailable) that would allow accurate and useful determination of the trends in and current level of societal vulnerability to floods. The 1992 assessment of floodplain management in the United States found that 'the actual amount of United States land in flood plains has not been clearly determined, nor has the amount of property and other economic investments at risk to flooding been firmly established' (FIFMTF, 1992, p. 3-1). A review of various estimates of floodprone regions in the United States shows considerable disagreement as to the areal extent of floodprone regions, the number of people who inhabit those areas, and the amount of property at risk to flooding. In 1942, Gilbert White estimated that 35 million acres of U.S. land was subject to flooding (White, 1945). In 1955, Hoyt and Langbein (1955) estimated that 10 million people live or work within the nation's 50 million acres of floodprone land. The 1955 estimate equates to 7% of the population living on flood prone regions which comprise about 3% of the United States land area. A 1978 study estimated that 4.5 million households were in flood hazard areas. A 1987 study classified about 94 million acres of land as

* For discussions of vulnerability see Palm (1990), Alexander (1991), and Burton, et al. (1993). More recently see Dow and Downing (1995).

U.S. floodplains containing 9.6 million households with $390 billion in property (FIFMTF, 1992, p. 3-2). (Table I summarizes these data on floodprone regions; see also Thompson and White, 1985). The wide disagreement among these data suggests a growing recognition of regions subject to flooding, but caution is advised in drawing definitive conclusions until more reliable data is available.

Population at Risk

A consequence of the lack of data on the areal extent of floodplains in the United States is that a difficulty exists in assessing trends in and current levels of population at risk to floods. Trends in population at risk to flood events are an important factor in any determination as to whether societal vulnerability to floods in decreasing, increasing, or remaining relatively constant. One can easily hypothesize that increasing population and urbanization in the United States has led to a commensurate increase in population at risk. Yet, one can also hypothesize that the various societal responses to floods may have more than compensated for population growth and in fact fewer people are today at risk to flood events. Currently, data is lacking to reliably assess trends in population at risk to floods events, and therefore it not possible to systematically assess whether societal vulnerability to floods has increased or decreased over recent decades.

Property at Risk

Accurate determination of property at risk to flooding faces many of the same obstacles facing accurate determination of people at risk to flooding. Table I summarizes the findings of the various studies (cf. Goddard, 1973, Table 5). The Table shows that there is relatively little systematic data collected on property at risk to flooding. Again, the lack of data limits what can be said about trends in vulnerability to flooding. It is likely that the Federal Insurance Administration, which operates the National Flood Insurance Program, has in its records data on property at risk to floods for the communities which it has worked with since the early 1970s. However, this data has seen only limited use, e.g., in determination of repetitive losses and substantial damages over 50%, and has yet to be systematically assessed from the standpoint of trends in societal vulnerability to floods.

Differences in the estimates of people and property at risk to floods are attributable to actual demographic changes, but also to differences in floodplain definitions, and simply that the data has not been collected and systematically analyzed. The data that does exist allows for only gross generalizations and thus limits what can be authoritatively concluded about trends in societal vulnerability to floods (cf. Changnon et al., 1983). An understanding of trends in societal vulnerability is one factor (along with trends in climate, policies, etc.) that would comprise an evaluation of the effectiveness of U.S. flood mitigation policies.

TABLE I

Summary of seven studies related to property at risk to flooding in the United States

Variable	Study						
	USDA (1967)	COE (1973)	ASCE (1973)	USGS (1974)	WRC (1977)	Sheaffer (1978)	FEMA (1989)
Areal extent of floodplain (sq. mi.)	209,619	201,780	–	–	218,750 to 281,250	–	146,600
Urban floodplain (sq. mi.)	4,413	5,269	16,500	–	5,470 to 8,590	–	–
developed (%)	–	–	53%	53%	–	–	–
Households	–	–	–	–	–	4.5 million (7.9% of U.S. total)	9.6 million
Property value	–	–	–	–	–	–	$390 billion

Sources: U.S. Department of Agriculture (1967). ‘National Inventory of Soil and Water Conservation Needs 1967’, Statistical Bulletin 461, (Washington, D.C.) and U.S. Army Core of Engineers (1973). ‘Water Resources Needs’, internal summary, EC 11-2-86, (Washington, D.C.) are summarized in ASCE (1973) (in references as Goddard, 1973). U.S. Geological Survey (1974). ‘Extent and Development of Urban Flood Plains’, Circular 601-J, (Washington, D.C.), Sheaffer and Roland, Inc. (1978). ‘Alternatives for Implementing Substantial Improvement Definitions’, Report to the Department on Housing and Urban Development (Chicago, IL), and Federal Emergency Management Agency (1989). ‘Flood Studies and Surveys: Historical Statistics’, unpublished 30 September are summarized in FIFMTF (1992). USWRC (1974).

A Prototype: the Scientific Assessment and Strategy Team (SAST)

In the aftermath of the 1993 floods the White House established a Scientific Assessment and Strategy Team (SAST) of scientists from various agencies 'to provide scientific advice and assistance to officials responsible for making decisions with respect to flood recovery in the Upper Mississippi River Basin' (SAST, 1994, p. xiii). One of the responsibilities given to the SAST was to 'organize the information in existing databases to aid in the near-term and long-term decision-making process' (SAST, 1994, p. 232). In its review of existing data on the floodplain the SAST found that 'some data vitally important to making informed management decisions on the floodplain were not readily available, or were not uniformly acquired throughout the floodplains or river basin' (SAST, 1995, p. 13).

As a prototype, the SAST has begun to collect, document, and distribute floodplain data for the Upper Mississippi River Basin. Some of the data collected by the Team includes: hydrology, land use/cover, soil, topography, vegetation, flood, agriculture, infrastructure, climate, biology/ecology, reservoir, etc. Data has been collected from federal, regional, state, and local organizations.* If the SAST is to contribute broadly to the U.S. flood problem by helping to fill the 'data gap' that it identified, then it must include societal data (e.g., demographics) in its mapping efforts. Further, its efforts must be evaluated from the standpoint of whether or not the information it collects is usable by decision makers. If the Team's work is judged by decision makers to be useful, then the SAST is a model that ought to be emulated for other U.S. river basins.

2.6. DATA ON FLOOD CASUALTIES IS A PROXY FOR FLOOD RISK

Due to the lack of systematic data on the number of people at risk to floods, trends in flood casualties, for which relatively systematic data is available, are sometimes used as a proxy for trends in population at risk. An assumption underlying many such analyses is that a rise in flood-related casualties is indicative of a rise in the number of people at risk to flood events. Unfortunately, at least three confounding factors limit the use of trends in flood casualties as a proxy for trends in the gross number of people who are vulnerable to floods.

First, many flood-related deaths are concentrated in single extreme events, like a hurricane or a severe flash flood. Second, society has taken many steps to reduce its level of exposure, with mixed results. This means that a moving baseline of exposure underlies any record of flood-related casualties. Consequently, there may be a number of trends within a trend record of flood casualties (e.g., level of exposure, success and failures of mitigation efforts, etc.). Finally, the data on flood casualties is generally not perceived to be accurate enough to lead to definitive causal conclusions (Richards, 1995, personal communication). The longest continuous record of flood casualty data is that of the National Weather Service (1903–present).

* Data and information on the ongoing status of the SAST can be accessed on the World Wide Web at http://edcwww.cr.usgs.gov/SAST-home.html.

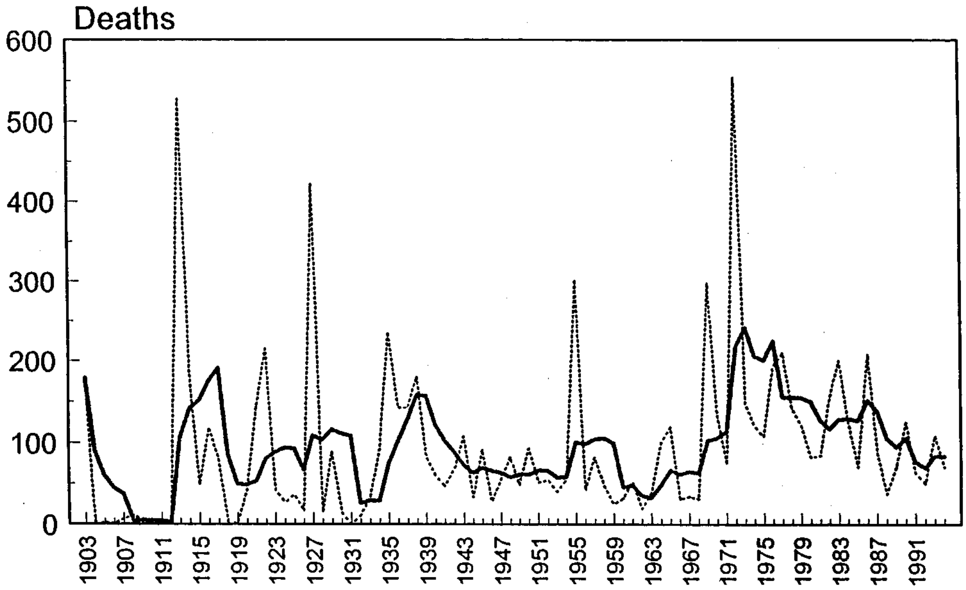

Figure 1. Flood fatalities in the United States: 1903–1994 (by year and five-year average).

However, there are different sources of data which have different numbers (e.g., Red Cross data in FIFMTF (1992) and Wood (1994)). For these reasons, trend data on flood-related casualties does not lend much insight into broader questions of factors which underlie trends on vulnerability to floods.

Figure 1 shows the data kept by the National Weather Service on flood-related fatalities in the United States from 1903–1994.* The data shows a downward trend in flood-related deaths since the early 1970s, but also an increased frequency of years with high deaths. Figure 2 shows the trend of flood-related deaths over a moving 25-year period beginning with 1927 (i.e., sum of 1903–1927) and ending in 1994 (i.e., sum of 1970–1994).† At this time scale, the more recent period contains more deaths (Wood (1993), using a different dataset finds a similar trend). However, this data must be viewed with caution, as it may be possible that part of the trend is due to better accounting in the more recent years. Of the annual deaths related to floods, 80–90 percent are caused by flash floods and 40 percent of these 'are related to stream crossing or highway fatalities' (Zevin, 1994, p. 1267).

In sum, available data indicates that flood-related deaths have increased in recent decades. However, because of the nature of the data, little can be said with authority about what the trend of increased deaths means from the standpoint of people at risk to floods.

* Data is kept by 'water year' which runs from October 1 through September 30 the following year. For instance, Water Year 1996 started on October 1, 1995 and ended September 30, 1996.

† A 25-year moving average is used because it is the approximate period between the most extreme flood events (as measured by economic impacts), e.g., 1903, 1927, 1951, 1972, 1993.

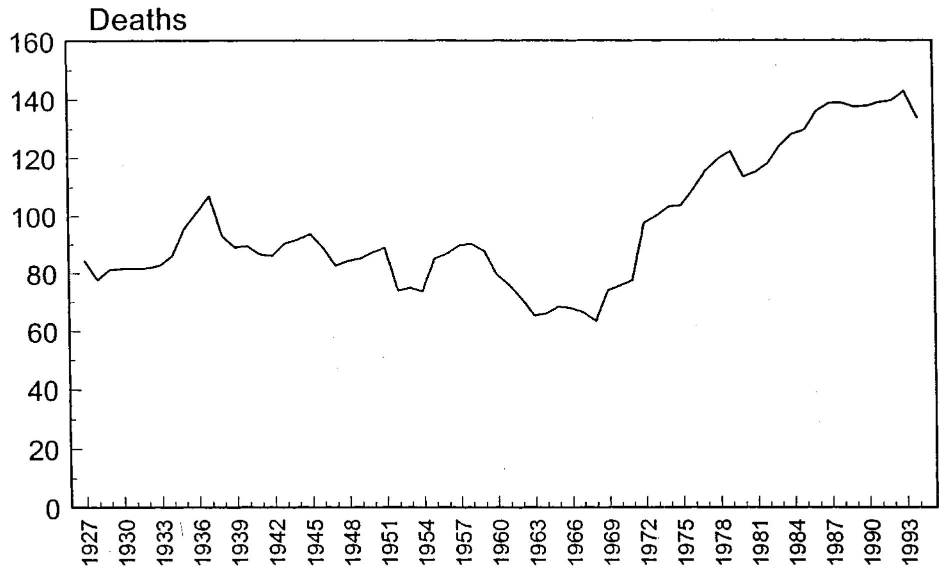

Figure 2. Flood deaths in the United States: 1903–1994; each point represents average annual deaths of previous 25 years.

2.7. DATA ON FLOOD DAMAGES IS A PROXY FOR FLOOD RISK

As in the case of trends in people at risk to floods, analysts have sought to use trends in flood damages as a proxy for trends in property at risk to floods. However, it is at least as difficult to form definitive conclusions about vulnerability from the damage data as it is from the casualty data. Flood damages occur every year in various places around the United States. Such damages, per se, are not sufficient evidence of a policy problem. As the Task Force on Federal Flood Control Policy noted in 1966 (p. 13), 'it may well be that the advantages of flood plain location outweigh the intermittent costs of damages from floods. Further, there are some kinds of activity which can only be conducted near a watercourse'.

Flood damages (or losses) have been defined as the 'destruction or impairment, partial or complete, of the value of goods or services, or of health, resulting from the action of flood waters and the silt and debris they carry. Easy to define, flood losses are difficult to set down in dollar figures' (Hoyt and Langbein, 1955, p. 77). Because of the methodological difficulties in assessing flood damages, as well as the limited data available, 'taking all in all, it is evident that any evaluation of flood damage is only a rough approximation' (Hoyt and Langbein, 1955, p. 79). Nevertheless, the historical record of flood damages provides some insight as to trends in flood impacts on society.

Figure 3 shows annual flood damages for the period 1903–1994 as tabulated by the National Weather Service (cf. F. Richards, personal communication). Figure 4 shows the same data from the standpoint of a 25-year moving average. The data

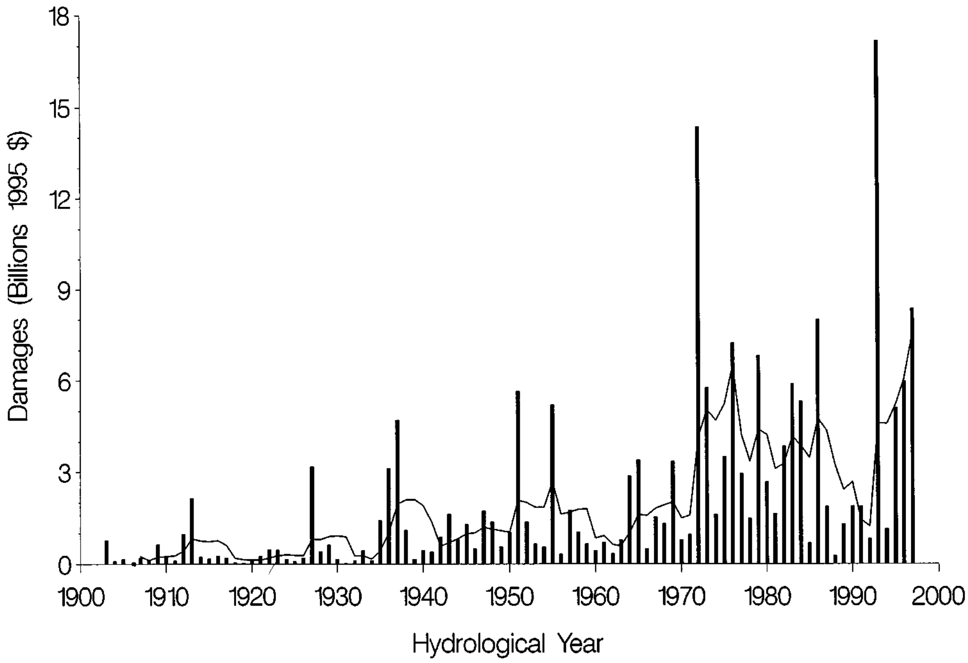

Figure 3. U.S. flood damages, 1903–1997, with 5-year running mean.

show that flood damages have been increasing steadily at this time scale (using constant dollars).

A pattern of climate underlies the trends in flood casualties and losses. For many years hydrological analyses assumed that climate of floods – the distribution of flood events around some central tendency – remained constant (FIFMTF, 1992). In recent years, scientists and policymakers have come to realize that we live in a climate that is changing in ways that are difficult to assess and predict (e.g., Karl et al., 1996). In other words, both the distribution of events and the central tendency may be changing in unpredictable ways. A consequence is that climate fluctuations such as those associated with El Niño events might be responsible for some of the variance in flood-related deaths and damages. This means that determination of vulnerability to floods must consider explicitly both physical and societal factors.

2.8. KNOWLEDGE LEADS TO ACTION

Those who study public response to natural disasters are well-versed in the persistence of this fallacy which really means: knowledge *by itself* is generally not sufficient for policy action. As Sims and Baumann (1983, p. 167) note in the context of public response to natural disaster, 'it doesn't necessarily follow that because information is given it is received or because education is provided there is learning'. Knowledge does not always lead to action, but only 'under highly specified conditions, and if properly executed, with certain target public, informa-

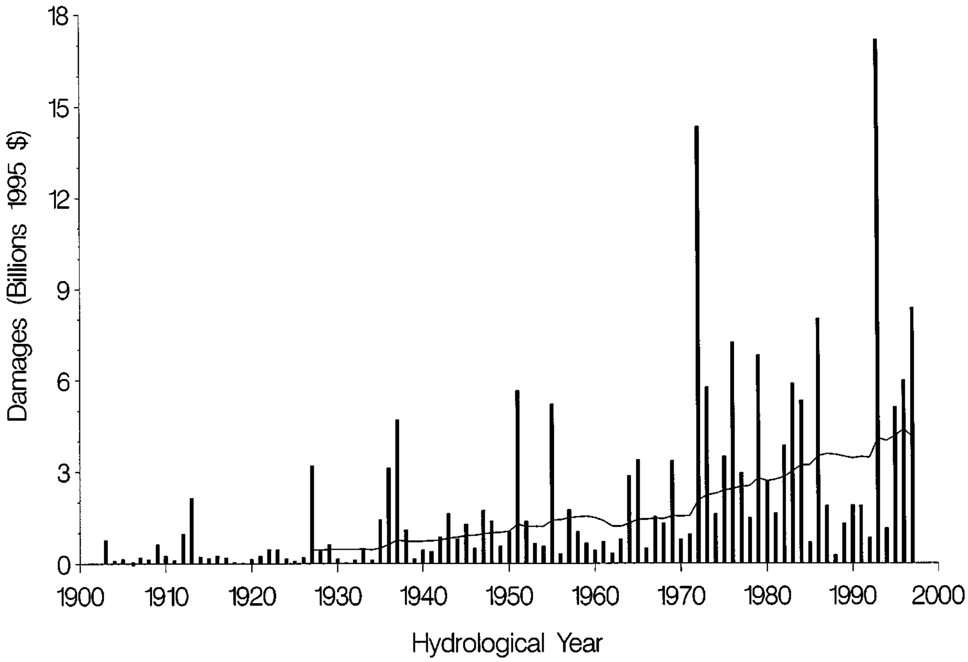

Figure 4. U.S. flood damages, 1903–1997, with 25-year running mean.

tion *may* lead to awareness and awareness *may* lead to behavior' (ibid., emphasis in original). The same phenomenon of knowledge *not* leading to action seems to occur not only with regard to public response to natural disasters but with policy makers as well.

Social scientists have explored many of the reason why 'policy happens' and have developed a robust literature (e.g., Olson and Nilson, 1982). From this body of theory and practice one point stands clear: knowledge of a policy problem or solution does not inevitably lead to effective policy action.

A number of scholars have explained the dynamics of the transformation of issues onto the public agenda as problems by drawing on an evolutionary metaphor (e.g., Carmines and Stimson, 1989). Issues emerge from a 'policy primeval soup' to occupy a place on the public agenda (Kingdon, 1984). Like their biological counterparts, issues 'compete' in a complex environment. In addition, social environments also have a 'carrying capacity' which limits the number of issues that can be considered at one time (Hilgartner and Bosk, 1988). For example, news stories compete for the finite amount of space on the front page of a newspaper, a congressional committee is limited by available time and staff to conduct hearings, and often budgetary considerations constrain the scientific community.

Issues 'evolve' according to a number of factors in its environment such as a prominent champion (e.g., the president) or a disaster (e.g., a flood) (see Carmines and Stimson (1989) for discussion). For instance, when President Clinton focused on health care shortly after his inauguration, it became an issue of national prominence because of his highly visible and influential position (compare Theodore Roosevelt's 'bully pulpit'). Similarly, most policies to deal with disasters are put in place in the immediate aftermath of an extreme event. According to Hilgartner and Bosk (1988), drama, novelty and saturation, and culture and politics also influence what becomes defined as a social problem and what does not.

A disaster or extreme event can serve to open a 'window of opportunity' for change (Ungar, 1995; Solecki and Michaels, 1994). At this time agents of change ought to be prepared with a well-defined plan of action. As Downs (1972, p. 40) notes, following a window of opportunity for change soon follows 'a prolonged limbo – a twilight realm of lesser attention or spasmodic recurrences of interest'. Consequently, those with an interest in improving policy outcomes with respect to floods ought to have a plan of action ready for when conditions do become favorable for policy change. But it is often the case that communities are surprised by floods, and are therefore unprepared to respond effectively (Solecki and Michaels, 1994). This means that efforts of flood policy advocates will be enhanced with an ability to recognize and capitalize on a window of opportunity. Thus, while knowledge of the flood problem is not a sufficient condition for action, knowledge is a necessary element of a rational plan put forward at the right time, to those with authority and interest to act. One example of this is that the recommendations of the IFMRC (1995) were in large part incorporated into the FEMA National Mitigation Strategy (FEMA, 1995). Here, knowledge plus the floods of 1993 began to stimulate broader policy change (Thomas, 1997, personal communication).

In the absence of an extreme event that mobilizes political action, policy for reducing a community's vulnerability to floods must meet several criteria in a business-as-usual environment (according to Nilson, 1985). First, the threat must be demonstrated (i.e., the problem must be defined). Second, potential responses must be shown to have a significant likelihood of being effective. And third, policy options must not be viewed to impose excessive costs or changes on the community. Many of the most effective mitigation actions are those which can be taken by the individual, such as a homeowner. Yet, studies indicate that neither improved awareness of hazards nor previous experience with hazards are sufficient to compel people to take actions to reduce their vulnerability (Sims and Baumann, 1983).

2.9. THE U.S. FLOOD PROBLEM CAN BE ADDRESSED WITHOUT FEDERAL LEADERSHIP AND SUPPORT

Recent trends in public and political opinion that government must be downsized and policy decisions ought to be increasingly made at the state and local level are counter to the needs of an effective response to the U.S. flood problem (cf. Wilkins, 1996). While most experts familiar with floods recognize this point, prevailing attitudes of the public and elected officials in recent years have emphasized limiting the role of the federal government in a range of areas. Responses to floods ought not be one such area. While it is at the state, local, and individual level that many decisions will be made to reduce vulnerability to floods, an effective long-term solution to the U.S. flood problem will necessarily require some form of coordination at the scale of the river basin. This is for the simple reason that no flood-vulnerable community can effectively address its flood problem without having its response affect other communities both up and down stream. As one assesses the interaction of communities, one finds that the largest unit of analysis that can be considered without concern for community interaction is the river basin, e.g., the Mississippi river basin. Consequently, coordination is required between communities within a particular basin or sub-basin: because communities and river basins span local, state, and federal jurisdictions, some form of regional or national level cooperation is unavoidable.

While cooperation, in theory, appears unavoidable, in practice it has in many respects been avoided. White (1991, VI-2) notes that ‘cooperation among the administrators of Federal programs, while generally cordial and helpful, has not yet yielded a genuinely unified effort. Lacking exemplary effectiveness at that level, State and local agencies cannot be expected to act in concord in meeting national goals’. A need for federal leadership in flood policy has been long recognized (e.g., CPW, 1959). Yet, although there has been progress with respect to responding to the U.S. flood problem, many observers continue to identify a need for improved coordination and leadership at the federal level (e.g., White, 1991; Myers and White, 1993; Kusler and Larson, 1993; Rasmussen, 1994; Galloway, 1995; Faber and Hunt, 1996; Wright, 1996).

Calls for changes in federal flood policy are seemingly paradoxical because they identify a need to be simultaneously more comprehensive and more localized, with a focus on individual and community responsibility (Kusler and Larson, 1993). The seeming paradox vanishes upon closer scrutiny: ‘individuals, not the government, must assume responsibility for their locational decisions, and future government policies must stand firm over time to seek such an approach’ (Changnon, 1996, p. 313). In important respects, the federal government establishes the context in which individual, local, state, and other public and private decisions related to floods will be made. For instance, recent claims that generous flood relief policies are ‘moving the country in the opposite direction from which many feel they should go’ point to the incentives toward abdication of individual and community responsibility that such policies create (Wright, 1996, p. 271). Just as policy can create an unhealthy context for flood-related decisionmaking, it can also create a healthy context, in which individuals and communities will strive to reduce their own flood vulnerabilities.

3. Conclusion: Implementing What We Know

How might the U.S. reach a healthy federal flood policy? Knowledge of what might be done is available, yet remains to be put to effective use. Not surprisingly, Gilbert White (1991) provides guidance in this regard worth repeating and difficult to improve upon:

First, 'unless a strong statement is made by the Congress on the ways in which the basic policies of the individual Federal agencies are to be related to the underlying aims in managing floodplain resources those policies will have little significance in the field where they influence or are constrained by State and local practices' (White, 1991, p. VI-3). White further notes there has not been legislation passed by the Congress stating clearly the overarching goals of U.S. flood policy. There is no lack of ideas for what such goals ought to be (recently, e.g., Myers and White, 1993; Kusler and Larson, 1993; FIFMTF, 1994; IFMRC, 1994; Shabman, 1994; Philippi, 1994/95; Faber and Hunt, 1996; Wright, 1996). A national debate, resulting in federal legislation delineating both the dimensions of the U.S. flood problem and the steps needed to address it, would be valuable both as an outcome and as a process. Such a debate would require leadership at the national level.

Second, 'floodplain policy changes must be taken in the context of broad environmental goals applied to local conditions' (White, 1991, p. VI-4). The federal role in flood policy is not to specify in great detail how individuals and locales are to respond to particular situations. Instead, it is to provide a common framework within which communities and individuals will be able to exercise choice. The federal government is needed also to coordinate the voluminous meteorological, hydrological, demographic, ecological, economic and other societal information needed to understand human occupancy of a river basin and floodplain. In addition, it is the federal government that has the ability to evaluate the interaction effects of communities acting in parallel and in series in a particular floodplain. Finally, it is the federal government that can establish and enforce statements of national interest in floodplain management. Policy change will not occur without broad support for a process of formulation, promulgation, and implementation of a overarching vision of federal flood policy.

Third, 'as new improvements are made in Federal programs, it would be important to craft them on an experimental basis with careful provision for evaluation as they are launched' (White, 1991, p. VI-3). The value of such experimental programs is well documented (see, e.g., Brunner (1996) for a discussion). 'Unfortunately, little formal recognition has been given to "what works" at the state level' (BTFFDR, 1995, p. 37). Thus, more attention needs to be paid to why certain flood policies succeed or fail with respect to addressing the U.S. flood problem. With the improved understanding gained from experience and practical knowledge, policymakers will be in better position to replicate successes and terminate failures.

Leadership, vision, and practical knowledge are easy to call for, but much more difficult to achieve in practice. However, without such an approach from national decision makers intent upon improving federal flood policy, it is likely that the United States will persist in a state of knowing what to do about floods, but not doing it.

We, as a society, have invested considerable effort and suffered much hard experience to learn the lessons of floods. The time is now appropriate to seek to ask and answer why those lessons have not always been effectively linked to policy action. Overcoming the obstacles to improved societal response to floods will be far more complex than simply exposing persistent misconceptions. Nevertheless, through a discussion of such fallacies, what they are, their deleterious effects, and why they persist, previously unseen opportunities for action may develop.

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