Reducing Flood Losses

Is the 1% Chance Flood Standard Sufficient?

Report of the 2004 Assembly of the Gilbert F. White National Flood Policy Forum

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Foreword

A fundamental goal of the Association of State Floodplain Managers Foundation is the furtherance of research and education in support of efforts to reduce flood losses and improve the management of floodplains throughout the United States. Facilitating the identification of gaps in knowledge and its implementation is one means by which the Foundation seeks to fulfill this mission. The Gilbert F. White National Flood Policy Forum thus was initiated by the Foundation in order to periodically convene experts in floodplain management to explore pressing issues in the field and set out ideas for resolving them. From these Forums, which the Foundation will host periodically, we hope will grow a broader and deeper understanding of what it is that we still need to know, how we better can apply what we already know, and what paths may still be unexplored in our attempts to move toward more sensible uses of our nation's floodprone lands. Only with that sort of clarified understanding can we move forward with needed research, policy modifications, and other actions.

The first Assembly of the Forum tackled the question of the sufficiency of the 1% annual chance flood standard, which is the basis for most floodplain management* today, both here and abroad. The 1% standard is not just an issue for the National Flood Insurance Program. Probability-based flood standards—including the 1% chance frequency—underlie floodplain management at all levels of government. Any improvements to the standard or its use will require the full participation of all stakeholders in these flood-related programs. For its inaugural Assembly of the Gilbert F. White National Flood Policy Forum, it is hard to imagine that the ASFPM Foundation could have selected a topic more complex or more universally applicable than the question of the sufficiency of that fundamental premise of the nation's floodplain management programs. What role has the 1% standard played in shaping the face of floodplain management as we know it today? How can we improve upon the results that we are seeing? Is there a better way?

It is essential that these difficult questions be tackled, particularly when, as in this case, little expert discussion of the issue has taken place even though decades have passed since the standard was instituted. Further, because use of the 1% standard is so widespread, it will take concentrated effort by all the players—at all levels of government and the private sector—to move successfully toward any shifts in thinking, policy, or legislation that may be needed.

As a way of approaching an analysis of the sufficiency of the 1% standard, in this report we have adopted a formulation of science-based policy analysis forwarded by Gilbert White and his two perennial colleagues, Robert W. Kates and Ian Burton, in a recent issue of

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* As explained in the Introduction, "floodplain management" is used in this document in its broadest sense, as a term that encompasses efforts to reduce flood losses, protect resources, and maintain natural floodplain functions.

Environmental Hazards. With regard to the apparent failure of hazards management to reduce losses worldwide, they asked:

> Is the knowledge still insufficient, sufficient but not used, used but ineffectively, used but with an unanticipated lag in taking effect, or used with positive results that have simply been overwhelmed by increased vulnerability due to population growth, economic expansion, or other factors?
>
> *(White et al., 2001)*

Their five questions are a thoughtful and useful way of breaking down an analysis of the 1% flood standard—or any standard. In this report, the discussion of the Forum participants on these issues and others is summarized. We hope practitioners, policymakers, researchers, and others involved in floodplain management today find it useful and illuminating.

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Acknowledgments

The first annual Assembly of the Gilbert F. White National Flood Policy Forum, and this report of its discussion, were the products of the dedication and diligence of numerous people and organizations. For their cooperation and support of the concept of an annual gathering of this type, and their efforts in making it happen, the ASFPM Foundation expresses its appreciation to William Hooke, American Meteorological Society and the Disasters Roundtable, and to William A. Anderson, The National Academies.

The planning, background work, synthesis of the Forum, and this report were done by a team led by Larry Olinger, President of the ASFPM Foundation and Larry Larson, Executive Director of the Association of State Floodplain Managers, and made up of Michael Armstrong, ICF Consulting; Gerald Galloway, Titan Corporation; Jacquelyn Monday, JLM Associates, Inc.; Doug Plasencia, AMEC Earth and Environmental; and Ed Thomas, Michael Baker, Inc.. In addition, Chad Berginnis, Ohio Department of Natural Resources; Dennis S. Mileti, University of Colorado; and David Ford, David Ford Consulting Engineers, Inc. lent their expertise both in speaking at the Forum and shaping its substance. The burden of logistical support was borne by Patricia Jones Kershaw of The National Academies and Diane Brown of the Association of State Floodplain Managers.

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Finally, gratitude is due to Gilbert White for his early and ongoing inspiration, for his belief in the importance of convening groups like this to deliberate policy issues, and for his willingness to lend his name to the Forum.

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Executive Summary

The 1% annual chance flood standard has been used for nearly a century as the basis for many structural and non-structural floodplain management approaches. It is widely supported and thoroughly institutionalized as the foundation for these efforts throughout federal, state, and local government in the United States, and is also used extensively abroad.

However, the effectiveness of the standard in helping to bring about sensible use of floodprone lands, minimize losses, and protect resources has never been thoroughly evaluated. This is so in spite of regularly expressed concerns about the adequacy and appropriateness of the 1% chance flood standard, and in the face of indicators that there may be a better approach:

- Floods appear to be getting bigger and causing more damage than anticipated. Nationwide flood losses continue to rise.
- The expected flood depths and the extent of flood reach as depicted on maps are regularly demonstrated to be inadequate in specific situations.
- Numerous localities use a higher level of protection than the 1% chance standard, add margins of error, and apply tighter land use restrictions in order to reduce their flood losses.
- Advanced technology, modeling, and computing capabilities call into question the wisdom of clinging to a standard designed in an earlier era.

To examine the usefulness of the 1% standard, therefore, the ASFPM Foundation convened a group of about 75 experts in floodplain management at the first Assembly of the Gilbert F. White National Flood Policy Forum in September 2004. They considered the standard's applicability in increasingly complex situations, whether today's science can provide a better approach, and what counterproductive impacts may have ensued during the years of the standard's implementation.

The Forum concluded that the 1% chance flood standard, although in hindsight perhaps not a perfect choice, has nevertheless stood the test of many decades of use in a varied and changing nation. Determined efforts have been made at all levels and sectors to implement the standard and associated practices and, not surprisingly, these have met with varying degrees of success, depending on the circumstances. There are areas in which specific scientific and technical knowledge are still lacking, and filling those gaps could help improve implementation. Forum participants also observed that the nation has changed and grown rapidly and that in some ways it has not been possible for the policies and practices associated with the 1% standard to keep pace.

The Forum noted positive results from use of the 1% chance standard; some apparent shortcomings in the standard and its use; and some broad approaches and specific actions that could be taken to help address deficiencies in floodplain management.

Encouraging Outcomes from Use of the 1% Standard and Associated Practices

- The single, prescriptive standard has satisfied our social needs for uniformity, administrative ease, and a baseline for equity.
- In 20,000 communities, flood hazards are being managed. There are 4.5 million flood insurance policies in force (covering an estimated 40–55% of floodprone structures nationwide).
- Within the mapped 1% annual chance flood area, homes and other buildings constructed since regulations began are safer and in post-disaster surveys have been found to sustain less damage.
- As an unanticipated benefit of the decision to manage development in the 1% chance floodplain (and restrict development in the floodway), tens of thousands of acres of riparian land have been protected and their resources thereby preserved.
- The 1% annual chance standard is well institutionalized, supported by a body of case law, and integrated into federal, state, and local floodplain management initiatives. While there is support to reduce annual flood losses (currently about $6 billion), there is no overwhelming cry for reform of the 1% annual chance flood standard itself or the framework that has been established around it.
- Technological advances made in communications, cartography, computing, modeling, and other fields have enhanced and simplified many aspects of floodplain management, especially mapping and information dissemination.
- Costs for flood protection, flood damage, and flood disasters are being spread more widely among states, localities, individuals, and the federal government.
- About 1,000 communities, representing about 2/3 of the flood policy base nationwide, are going beyond the minimum requirements of the NFIP, as evidenced by their participation in the Community Rating System. Many of them are exceeding the 1% standard in some way.

Shortfalls in the 1% Standard Approach

- As noted above, flood losses are rising, perhaps for reasons related to the 1% annual chance standard.
- Because of the standard, in many parts of the country development has tended to cluster just outside of the 1% floodplain boundary, an area not free from flood risk and possibly subject to considerable risk now that watersheds have been urbanized and runoff thereby increased.
- Natural floodplain resources and functions are ignored in the delineation of the 1% chance floodplain, so their protection is a hit-or-miss proposition within the existing framework.

- There is a “gray area” of uncertainty surrounding the calculation and the mapped floodprone zone, resulting from inadequate data, lack of consideration of changing and future conditions within watersheds, and oversimplified assumptions. Because of this uncertainty, there is considerable doubt whether management practices are actually being applied to the entire 1% floodplain.
- The 1% annual chance standard has not lent itself to ready integration with water-related programs based on other types of standards, such as those for water quality or resource management.
- As a means of communicating flood risk, the 1% chance floodplain has been problematic. Both the concept and terminology are confusing and inaccuracies have undermined the credibility of the maps and the program operations.
- The “in or out” nature of the prescriptive standard too often triggers misunderstanding, denial of the flood risk, or attempts to have a property “removed” from the 1% floodplain.
- The 1% annual chance standard is inadequate when applied to levees, considering the potentially disastrous impacts associated with failure of those structures.

Action Needed

Options

Forum participants discussed an array of approaches to remedy noted deficiencies in floodplain management related to the 1% standard. Those approaches centered around the six options listed below. The Forum did not recommend any one option, although it was noted that nothing should stand in the way of improving the existing approach (the second option, below) even if more dramatic changes are made later. The options are listed from least amount of change to most.

1. Bring the 1% Standard Approach up to the 1% Standard. This would require an investigation of the level of protection that is actually being used on the ground (many experts suspect it is often actually much lower than the 1% standard). Based on those findings, a decision would be made whether to adopt that standard or make appropriate corrections in calculations and implementation to make sure the 1% annual chance standard is being met.

2. Enhance the Existing 1% Standard Approach. Improvements could be made in the policies, regulations, and implementation of the 1% annual chance standard to make it more accurate and effective at achieving its goals. The most badly needed are integrating the protection of natural resources and functions; eliminating the 1-foot rise allowed in the floodway; using future-conditions hydrology; and establishing a new levee standard.

3. Adopt a Two-Tiered Standard. This would keep the 1% annual chance standard for the bulk of activities to which it is now applied, but would add another, higher level of protection for certain important uses and facilities.

4. Use A Vertical Standard. Under this approach, flood insurance would become mandatory for every building in the country. The elevation of each building (or lot) would be compared to the flood elevation at the site. Insurance rates would be based on the flood level, the size of the building, and the amount of coverage. Protective measures (as used in the NFIP today) would be imposed for buildings within a certain vertical distance of the flood elevation.

5. Apply a Benefit/Cost Model. Each proposed activity in a floodprone area would be analyzed for the probability of flooding at that site, the consequences of flooding to that activity, and the uncertainties associated with those estimates. Whether or not to proceed, and what protective measures would be needed, would be based on that analysis.

6. Take an Incentive-based Approach. Standards would be abandoned and market incentives would be used. This would involve re-delineating the floodplain from the current 1% annual chance area to something larger. Development of the area would have to bear the costs of flooding by itself, leading to more sensible uses such as agriculture, sequestering carbon, filtering pollutants, providing wildlife habitat, and conveying and storing normal and extreme flows.

Data, Policy, and Research Needs

Whether or not a fundamental shift is made in use of the 1% annual chance standard, Forum participants agreed that a number of issues need further attention now if progress is to be made in managing floodplains. The highest priorities for enhancing the amount and quality of data available, improving existing policies and programs, and obtaining further fundamental knowledge are listed below.

- Obtain more and better stream gage data, both in terms of geographic areas covered and time periods.
- Establish a uniform method and associated management techniques for using future conditions within a watershed, e.g., ultimate build-out vs. a number of years into the future, or how to quantify the benefits of flood protection.
- Use management techniques and develop maps based on future-conditions hydrology at the local level. At the state and federal levels, encourage or require localities to base their maps, engineering, and planning on future conditions.
- Examine the role of levees in floodplain management, and particularly with regard to the 1% standard. Evaluate existing levees and develop uniform procedures for certifying levees as being capable of providing a specified level of protection.
- Establish an appropriate policy for coastal A-zone designations and associated development standards.
- Quantify both the accuracy and effectiveness of the 1% annual chance standard in specific riverine and coastal situations, such as the hurricanes of 2004.

- Investigate techniques for better communication of the probability of flooding, flood risk, expected damage, impacts of changing conditions in watersheds, and other issues.
- Determine how residual risk could be incorporated into floodplain management programs and policies.
- Determine what effect the 1% standard and associated practices have had on the protection of natural functions and resources of floodplains.
- Conduct hydrologic research (1) to improve algorithms and methods for rainfall/runoff modeling for traditional and special hazards applications; (2) to determine the applicability of the Bulletin 17B guidelines for flood flow frequencies ; and (3) to estimate flood frequencies for watersheds that are urbanizing and/or have flood control works in place.
- Quantify the economic costs and benefits of application of the 1% annual chance standard, including public and private property damaged and protected, loss of life, cost of repair and reconstruction, insurance coverage, lost opportunity, environmental costs and benefits, disaster relief, and other factors.

Introduction

About the Gilbert F. White National Flood Policy Forum

The ASFPM Foundation has established a periodic gathering of leading experts in flood policy and floodplain management to facilitate national discussion of important floodplain management[*] issues. These Forums develop policy and research recommendations and establish an ongoing record of flood policy issues and directions for the future. The Forums have been named in honor of Gilbert F. White, the most influential floodplain management policy expert of the 20th century. The Forums are not only a tribute to his work, but also a recognition of the success of his deliberative approach to policy analysis and research.

Periodically the Forum explores one pressing national flood policy issue by assembling and facilitating a dialogue among topical experts who represent various stakeholders from government, industry, and academia. The goal of each Forum is to recommend research and policies that will reduce the human casualties and economic losses associated with flooding, as well as protect and enhance the natural and beneficial functions of floodplains.

The discussions and recommendations for action and research formulated at each Forum will be summarized and distributed as a report by the ASFPM Foundation. It is anticipated that policymakers and their constituent groups will review these reports to determine which actions could be undertaken to reduce flood losses in the nation. Furthermore, it is expected that these reports will provide the basis and priorities for conducting the research necessary to improve policy or program implementation.

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[*] Throughout this report, the ASFPM Foundation uses the term “floodplain management” to refer collectively to all the activities undertaken and decisions made both to reduce flood losses and to protect and restore the natural resources and functions of floodplains. This includes structural and non-structural measures, flood loss reduction efforts, insurance, flood mitigation, watershed-based planning, and many other approaches. The intent is to focus attention on improving many aspects of the relationship between human activity, the flood hazard, and the floodprone lands, rather than simply on minimizing property damage. This is consistent with the *Unified National Program*’s broad use of the term “floodplain management” as the process of working to achieve the “wise use of the nation’s floodplains.”

The 2004 Assembly of the Forum

The first assembly of the Gilbert F. White National Flood Policy Forum was held September 21-22, 2004, at The National Academies in Washington, D.C. It addressed the adequacy of the 1% chance flood standard that is widely used as a basis for floodplain management throughout the United States. The assembly comprised about 75 nationally known experts in all aspects of floodplain management. These experts applied their knowledge and experience to a fresh consideration of the appropriateness and sufficiency of the existing 1% standard in furthering national goals and in providing a basis for effective flood hazard management. Over 40 invited papers on this topic were collected (see the supplemental materials published separately), grouped into four broad perspectives: (1) history of the 1% standard; (2) implementation of the standard and associated practices, (2) impacts of science, engineering, technology, and tools; and (4) societal considerations. These four categories also framed the background presentations and discussion at the Forum assembly.

Why Examine the 1% Chance Flood Standard?

The United States and much of the developed world use the 1% chance flood standard as a basis for identifying, mapping, and managing flood hazards. Agencies like the U.S. Army Corps of Engineers, Natural Resources Conservation Service, Bureau of Reclamation, Tennessee Valley Authority, and others have used this standard for design of structural and nonstructural flood control projects for close to a century. For several decades, the National Flood Insurance Program and most states and local governments have used the 1% chance flood as a minimum standard for floodplain management, mapping, and mitigation.

The 1% annual chance base flood standard (100-year flood) was established at the recommendation of a group of experts convened by the U.S. Department of Housing and Urban Development when it was charged with administration of the new National Flood Insurance Program (created with the 1968 passage of the National Flood Insurance Act). The 100-year flood level was selected because it was already being used by some agencies, and because it was thought that a flood of that magnitude and frequency represented both a reasonable probability of occurrence and loss worth protecting against and also an intermediate level that would alert planners and property owners to the effects of even larger floods.

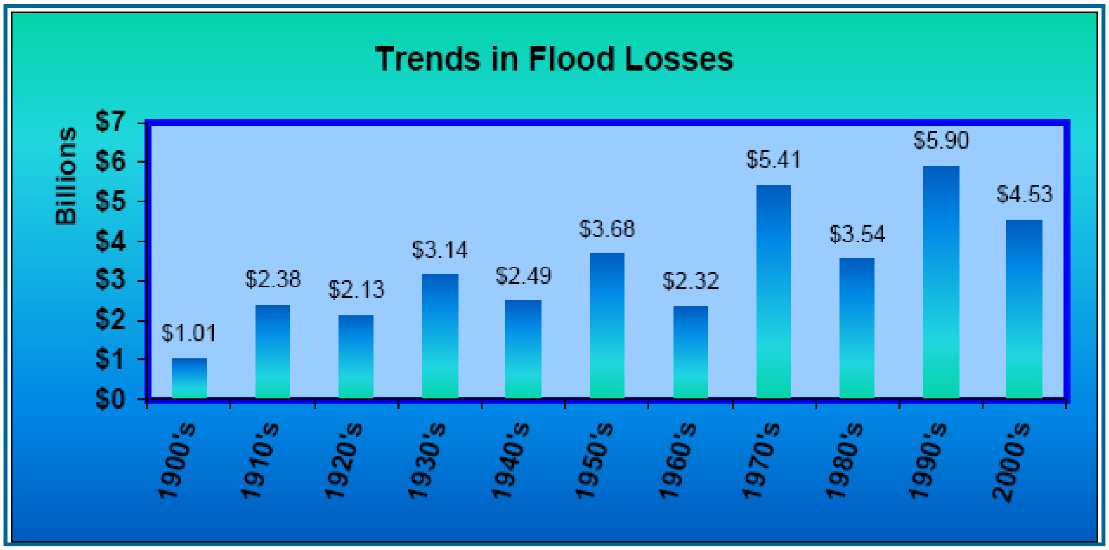
In passing the National Flood Insurance Act of 1968, Congress intended continuing studies of flood hazards to provide for a constant reappraisal of the NFIP and its effect on land use requirements. In the intervening years, ways to improve upon the 1% chance standard were occasionally considered, including a 1976 National Academy of Sciences study of incorporating expected probabilities into the flood studies conducted for riverine communities (National Academy of Sciences, 1976), and a 1983 report by the Presidential Task Force on Regulatory Relief, which concluded that no better alternatives to the standard were available and that there was no justification for the expense of converting to another standard (see Federal Emergency Management Agency, 1983). Both of these efforts were undertaken in response to fairly narrow concerns: the first was brought about by controversy over the uncertainties in data on flood discharges, and the second was part of the Reagan Administration's initiative to reform regulatory programs.

In addition, the 1% chance standard has been variously reviewed, challenged, criticized, and supported by bodies representing both Congress and the Executive Branch, by independent organizations, and by those that are affected by the implementation of the standard. Among them, these efforts presented an array of possible solutions. They offered alternative standards, from 50-year to 500-year; argued that the 1% standard does not adequately reflect the nation's flood risk; warned that changing the standard would be counterproductive; suggested that flood risk should be measured on a geographic basis, subject to local conditions and hazards; and raised concerns about the effect any change would have on communities protected by 1% structures, such as levees. No conclusive recommendations for change were made.

One compelling reason, therefore, for examining the 1% chance flood standard now is that, after about a century or so of using it for structural projects, and about 35-years of experience in using it for insurance and regulation, there has been no serious attempt to evaluate the standard itself or consider whether it is helping to meet national policy goals—as good practice would dictate and Congress clearly expected. An independent assembly of the nation's floodplain management experts, aimed at examining whether the 1% chance flood standard is still a solid basis for mapping, management, and other activities, has been overdue. It should be noted that an evaluation of the National Flood Insurance Program, being conducted by the American Institutes for Research under contract to the Federal Emergency Management Agency, is now underway and one component of that broad study is an examination of the 1% standard (American Institutes for Research, 2004). The conclusions from that effort, combined with insights from this Forum, should help resolve questions about the appropriateness of the standard, possible alternatives to it, and additional approaches.

A second reason for examining the standard is that concerns are continually expressed about the adequacy and appropriateness of the 1% chance flood standard.

- Floods appear to be getting bigger and causing more damage than anticipated, making it seem as though a higher standard should be used.
- The calculated expected flood depths and the extent of flood reach as depicted on maps are regularly demonstrated to be inadequate in specific situations, making a range of protection seem more sensible than a single level.
- There are numerous examples of localities' using more accurate techniques, raising the protection level, adding margins of error, and applying tighter restrictions in order to reduce their flood losses—all suggesting that the existing standard may be insufficient in a number of ways.
- Advanced geospatial technology, modeling techniques, and other tools not even dreamed of three decades ago call into question the wisdom of clinging to a standard that was designed without the luxury of those abilities.



- Recent successes in using accurate, cost-effective methods to collect site-specific elevation data raise the tantalizing possibility of not using a single standard at all, but rather establishing protection techniques on a case-by-case basis.

Most tellingly, despite all the effort nationwide to stem them, flood losses continue to rise, approaching an average of $6 billion annually at the turn of the millennium—suggesting that improvements need to be made in one or more aspects of the nation's approach to managing its flood hazards, if such costs are to be minimized.

Part 1

How We Got Here

The 1% annual chance (or 100-year flood) standard was the product of well-reasoned professional judgments, given the experience and circumstances within the nation when the standard was agreed upon, in the late 1960s. Part of the motivation for setting a standard was to establish a zone within which some of the burden of flood protection and relief could be shifted away from the federal government. Under the newly proposed scheme of flood insurance in exchange for land use regulation, communities would bear the costs of administering actions to keep development out of the flood zone (or protecting it, if inside) and individuals and the private sector would share the costs of damage, through insurance.

But if the nation wanted to manage activity within the "flood hazard area" in that way, such an area had to be defined. If national programs for this purpose were to emerge, questions of fairness and administrative simplicity had to be considered. At that time, it was not feasible to conduct a full economic analysis of whether the 1% chance flood was the level that would meet all these criteria. The judgment of the experts was that it was a good place to start.

> *The 1% chance flood standard was a compromise from the beginning.*

Thus it was known from its beginning that the 1% annual chance standard was a compromise: scientists were not completely happy with it, and neither were politicians, as can be seen in the historical interplay (summarized below) of repeated Congressional or Executive calls for additional study and scientific investigations to verify or re-verify the underlying methods and assumptions. Several views of the genesis of the 1% annual chance standard are presented in the background papers prepared by Robinson, Reuss, Sheaffer, Krimm, Reilly, Dawson, and Platt (available as part of the supplemental materials to this report). A historical view of some earlier standards and approaches can be found in the paper by Reuss in the supplemental materials. Important ideas from all those papers, and from the Forum, are presented below.

History of the 1% Chance Flood Standard

Floods are part of American history. One need only look at the serious floods that took place in the Mississippi Valley during early part of the 20th century to see the mindset that prompted determined work to control floods. In that period, with many lives lost, widespread economic damage, agricultural failures, and precious little disaster assistance, the goal was to do as much as could be done to keep the water away from people, with whatever style and size of flood control structures were available at the time.

River engineering was not new then, of course. Throughout the 19th century and even before, flood control efforts were undertaken by levee districts, other public groups, and private landowners. By 1824 the U.S. Army Corps of Engineers was made responsible for maintenance of river channels and harbors for purposes of navigation. After the Civil War Congress took a greater interest in flood forecasting and warning by authorizing federal agencies, including the Corps and the U.S. Geological Survey, to begin stream gaging, and by charging the U.S. Forest Service to conduct watershed studies of the relationship between timber harvest and water flow.

Full-fledged federal commitment to flood control began with the passage of the 1917 Flood Control Act, in response to disastrous floods on the Mississippi River. A series of flood control acts over the next several decades gradually widened federal responsibility for flood control to all navigable rivers in the United States, and assigned it to the Corps of Engineers. During the 1930s, 1940s, and 1950s the flood control arena expanded to include the Tennessee Valley Authority, the Bureau of Reclamation, the U.S. Department of Agriculture, and the Soil Conservation Service. Several states had independent programs in their own jurisdictions.

Although the programs from the early part of the 20th century did include flood loss reduction techniques besides flood control structures, including watershed-wide analysis and evacuation, the bulk of the effort was dedicated to structural measures. Congress authorized millions of dollars worth of projects to build reservoirs, flood control dams, channel modifications, and other structural measures.

As the nation's approach to flood management was coalescing, so were techniques both for calculating the size of the structures needed and for making decisions about the size of flood that should be anticipated (and, theoretically, controlled). A usual approach was to rely on historical information; it made common sense to try to provide protection to at least the size of flood that had happened once and surely could happen again. Engineers at the turn of the century began applying probability principles to flood problems, suggesting that frequency was essential to determining the magnitude of the maximum flood for a river, and using empirical data to buttress that concept. "Duration curves" were developed to show a particular percentage of time during which a given discharge would be equaled or exceeded.

The California Department of Public Works published a bulletin in 1923 in which it plotted the probable frequency of floods occurring in 100 years for 140 rivers in the state. This became a popular and enduring way of characterizing flood threats. Later it was suggested that the term "1% flood" be used instead of "100-year flood," but as modern floodplain managers know, this terminology has persisted, to much confusion.

Agencies involved in flood control found that combining frequency analysis with experience, historical high water levels, newly developed methods, and common sense was more effective than simple reliance on the engineering formulations. In designing its projects, the Corps routinely added a percentage factor as a "measure of safety" to the discharge arrived at through the frequency analysis. Later (with the availability of significantly better hydrological data by the mid 1930s) the Corps shifted to an approach developed by the Miami (Ohio) Conservancy District that calculated the discharge likely during a "standard project storm" (based on historical records and rainfall and runoff data). The TVA found that local officials and state planners were more receptive to predicted flood levels that had a relationship to a previously recorded flood, and this led to that agency's procedure for calculating a "regional flood."

Probability analysis became the norm for predicting the amount of flood flow and for specifying the return frequency of a given amount of flow. However, it continued to be criticized, particularly for the calculation of very rare floods (1,000-year or larger), because of the comparatively short period of record available.

All these calculations were geared mostly toward determining the logical size of a flood control structure. Construction of and reliance on dams, reservoirs, levees, and channel modifications were widespread and publicly accepted solutions, but not everyone was thinking that way. Geographic research at the University of Chicago had led to the formulation of an approach that focused on working with the way in which people use the land—including floodprone land—rather than just trying to protect everyone from what Nature could do. In his 1942 dissertation, Gilbert F. White wrote, "The solutions [to flood losses] will not involve a single line of public or private action but will call for a combination of all eight types of adjustments, judiciously selected with a view to the most effective use of floodplains." The eight adjustments he referred to were land elevation, flood abatement, flood protection, emergency measures, structural adjustments, land use readjustments, public relief, and insurance.

At the same time, the Tennessee Valley Authority was considering an overall approach to managing the water resources within its jurisdiction, with an eye also toward economic development of the region. That agency's thinking and that of the geographers gradually coalesced into a movement toward other approaches to the relationship between people and floods. This unofficial campaign was successful enough that during the 1950s both the TVA and the U.S. Army Corps of Engineers moved forward with programs for "floodplain management" rather than simply flood control, and the TVA even issued guidelines for the new approach.

The question soon arose, What level of flooding should these "management" techniques anticipate? For its part, the TVA was using the so-called "maximum flood of reasonable rational expectancy," a level that was calculated separately for each area studied. This was roughly equivalent to the Corps' "standard project flood." For some purposes, the TVA used the "regional flood," which was of lesser magnitude than the maximum flood, and for nonstructural measures, the Corps used the "intermediate regional flood." Other entities, including the Soil Conservation Service, used the 125-year flood, the 25-year flood, the flood of record, and other levels as seemed feasible and appropriate. (Statistical analysis of the TVA's "regional flood" had shown that it ranged from a 10-year event to a 1,000-year event—not a variation that would be supportable on a national basis.)

It is clear now that the entities working in flood hazard management were finding it necessary to have some sort of standard regulatory level and area in order to carry out their missions, but each used its own criteria to decide what those standards should be.

Then several things happened simultaneously to change the picture. Legislation passed by Congress in 1966 in the aftermath of Hurricane Betsy (P.L. 89-399) directed the U.S. Department of Housing and Urban Development to explore whether a program of insurance against flood losses were feasible. At the same time the Office of Management and Budget asked for an analysis of the whole idea of managing flood hazards in the nation, and a committee formed out of the University of Chicago to tackle that task. In addition, the President signed Executive Order 11296, which directed that in all federal activities, steps would be taken to account for the flood hazard.

The HUD investigation concluded that a national scheme of flood insurance was possible and the National Flood Insurance Program was instigated in 1968. The Chicago group, led by Gilbert F. White and Jack Sheaffer, recommended that a "special hazard floodplain" be established as part of efforts to manage floodprone lands, and that the 100-year flood be taken into account when establishing that regulatory area. The report of this group was *House Document 465, A Unified National Program for Managing Flood Losses*. There was widespread agreement that variation in flood risks would need to be taken into account when delineating an area to be managed. None of these three steps set the 1% flood as an absolute standard. That happened in 1971, when HUD (which administered the NFIP at that time) issued a rule setting the 1% or 100-year flood as the mandatory minimum regulatory standard for the NFIP and accompanying local programs.

As the management of floodplains progressed through those early years, complaints reached Washington, D.C., about the 1% standard. The most frequently heard objection was that it cost too much to regulate to that level—suggestions were to pull back to the 25-year or 50-year flood, which would have put less area under regulation. In 1973 the Senate held hearings at which the Corps of Engineers and the Federal Insurance Administration both testified, along with James Wright of the Tennessee Valley Authority, Jon A. Kusler, and Gilbert White, all in support of the 100-year standard as a minimum level. The Senate Committee reported out that the 1% annual chance flood was acceptable as a continuing standard for the nationally based programs, stating that the standard "is reasonable, and consistent with nationwide standards for flood protection" (U.S. Senate, 1973). The U.S. Water Resources Council issued its *Floodplain Management Guidelines* in 1978, incorporating the 1% standard and adding another wrinkle, the notion that "critical facilities" ought to be held to a higher standard of protection, that is, the 500-year flood (U.S. Water Resources Council, 1978). President Carter issued Executive Order 11988, which superseded the earlier EO and set the 1% annual chance flood as the mandatory standard for consideration in all federal and federally supported actions in floodprone areas.

Another round of criticisms ensued, including the Office of Technology Assessment's call for "re-examination" of the 1% annual chance standard, with an eye toward moving toward alternatives; and similar plea from the President's Commission on Housing, whose concerns focused on affordable housing and the fairness of the standard and urged consideration of a risk-based approach (President's Commission on Housing, 1982).

Into this mix came a 1982 National Research Council study on levee standards, requested by the Federal Emergency Management Agency, which concluded that the 1% annual chance standard is too low for flood control structures that protect densely populated areas, because of the catastrophic consequences were they to fail or be overtopped. Certifying 100-year levees as protection for purposes of the NFIP, the NRC noted, violates the spirit of the NFIP by encouraging development in floodprone areas.

Again OMB asked FEMA to examine the 1% annual chance standard. FEMA's report was accepted by OMB within days of its submission, and OMB noted that the 1% annual chance standard seemed to be working well, was supported by the various agencies involved in flood hazard management at both state and federal levels, and that there was no compelling reason to seek a change in it.

Since the mid 1980s, reservations about the 1% standard have persisted, but have changed in focus. Fifteen to 20 years of experience with implementation and application of the 1% standard on the ground led to more focused concerns, most notably that of the uncertainty associated with applying a single, black-and-white standard.

- The sweeping Assessment of Floodplain Management project in 1992 noted the drawbacks posed by the uncertainties of the 1% standard, and that in some cases its application may actually hinder effective floodplain management (Federal Interagency Task Force on Floodplain Management, 1992).
- The National Review Committee associated with the Assessment expressed deep concern about one serious impact of the 1% standard, that is, the tendency for new development to cluster just outside the edge of regulatory zone, thus increasing potential damage when the base flood is exceeded, or when cumulative impacts of nearby development cause the 1% annual chance flood itself (or a smaller flood) to overflow the delineated boundary (National Review Committee, 1992).
- The problem of over-reliance on levees did not go away; after the 1993 Midwest floods the impact of levees and the tendency of people to believe all levees are completely reliable flood control works was examined again. A 1999 NRC study of the American River in California revealed the conflict between the standards to which levees are built, land regulated, and construction carried out and those levels that are necessary to protect adequately any development behind the levees (National Research Council, 1999).
- In the mid 1990s the Corps of Engineers began to use "risk and uncertainty" methods for evaluating levee performance and for examining other projects. Partly because risk and uncertainty analysis is designed for performing economic evaluations, its outputs do not mesh well with a standards-based program such as the NFIP. Basically, it assigns a statistical probability of failure to each structure for each level of flood event. Little work has been undertaken, however, to evaluate what would be an "acceptable" probability of failure if risk analysis methods were to be applied to the floodplain management programs and policies that are based on the 1% standard. Further, the consequences of the failure of the project to perform as expected (for whatever reason, be it overtopping, erosion,

settling, wave action, or other foreseeable or unforeseeable factors) are not accounted for in the risk and uncertainty method used by the Corps.

Another NRC study examined the feasibility and effectiveness of the Corps technique, concluding in 2000 that, while the committee was generally supportive of the approach, the Corps' current method has shortcomings in assessing uncertainties and recommending that the agency improve its analysis of hydrological, hydraulic, geotechnical, and economic uncertainties. (National Research Council, 2000).

Many other nations have followed the U.S. lead and adopted the 1% chance flood as their basis of regulation, but there is variation as well. For example, on its North Sea coast, the Netherlands builds and maintains a system of dikes to a 10,000-year flood standard. On the Rhine River, its standard is the 1,250-year flood, based on the severity of the damage that would be expected, and on the River Meuse the standard is lower still. Canada uses the 1% flood level as a guide but not as a regulatory standard. Australia's law provides for local choice but in practice the localities select the 1% annual chance standard. Norway has a hierarchy of standards, from 1,000-year for critical areas and facilities to the 50-year for outbuildings. France likewise has a range of zones depending on risk. (For more on standards in other nations, see the background papers in the supplemental materials by Makarem and Parisi; Bourget and Bailey; and Smith.)

Part 2

How the 1% Annual Chance Standard has Served us Well

As a vehicle for furthering wise floodplain management, how has the 1% standard fared? National policy states that floodplain management has two goals: (1) reduce the loss of life, damage, and disruption caused by floods; and (2) preserve and restore the natural resources of floodplains. These goals are reiterated in the regulations of numerous federal agencies, expressed in Executive Order 11988, and embraced throughout state and local programs. The *Unified National Program for Floodplain Management*, transmitted to the President in 1994 by the Federal Interagency Floodplain Management Task Force (representatives of the Corps of Engineers, Environmental Protection Agency, Federal Emergency Management Agency, Soil Conservation Service, Tennessee Valley Authority, U.S. Geological Survey, and the Association of State Floodplain Managers) emphasized that these two goals are to be considered co-equal; that is, efforts should not be directed predominantly toward reducing flood costs at the expense of the floodplain's natural resources, or vice versa. These, then are the overall benchmarks against which policies, including the 1% standard, ought to be measured.

Unfortunately, there is precious little hard evidence of the on-the-ground impacts of floodplain management in the United States, much less of the implementation of the 1% chance flood standard specifically. The forthcoming evaluation of the NFIP may shed some light on the important questions of how much progress is being made in reducing flood hazards and protecting resources nationwide. But at this point we cannot quantify how much good the 1% standard is really doing, or predict whether another level or standard would work better.

However, the floodplain management experts at the 2004 Assembly of the Forum agreed that several results or outcomes of national floodplain management as implemented through the 1% standard can be listed with confidence.

Positive Outcomes and Possibilities

- In 20,000 communities, flood hazards are being managed.
- There are 4.5 million flood insurance policies in force (covering about 40–55% of the structures in mapped floodprone areas nationwide).

- Within the mapped 1% annual chance flood area, homes and other buildings constructed since regulations began are safer and in post-disaster surveys have been found to sustain less damage.
- About 1,000 communities, representing about 2/3 of the flood policy base nationwide, participate in the Community Rating System. Many of these communities are doing floodplain management jobs that exceed the minimum requirements associated with the 1% annual chance standard. (See the paper by Foster in the supplemental materials.)
- The 1% annual chance standard is well institutionalized, supported by a body of case law, and integrated into federal, state, and local floodplain management initiatives. While there is support to reduce annual flood damage, there is no overwhelming cry for reform of the 1% annual chance flood standard itself.
- Technological advances made in communications, cartography, computing, modeling, and other fields over the last few decades have enhanced and simplified many aspects of floodplain management, particularly mapping and information dissemination.
- Methods of assigning economic values to the natural resources and functions of floodplains are far better than the techniques that were available even a decade ago. Scientific understanding of water-based ecosystems, and what it takes to protect and restore them, has advanced considerably.
- Costs for flood protection, flood damage, and flood disasters are being spread more widely among states, localities, individuals, and the federal government.
- The single, prescriptive standard has satisfied our social needs for uniformity, administrative ease, and a baseline for equity (even if the implementation falls short of equitable treatment for everyone).

Discussion

The discussion below provides more background on these successes, organized under (1) the status of the implementation of the 1% annual chance standard; (2) impacts of the science, technology, and tools used to derive and apply the 1% standard; and (3) the 1% standard's effect on societal issues.

Status of Implementation of the Standard

Implementation must be viable at the local level. The decades of experience with applying the 1% annual chance standard and its associated policies throughout many thousands of communities have shown the complexity of such an undertaking. That experience has revealed the wide range of situations that exist throughout the nation and the need for more flexibility than now exists. We also now know that state and local officials and staff can exercise considerable ingenuity and initiative in tackling their flood problems. The technical and managerial capability at those levels is formidable and far stronger than it was at the onset of nationwide floodplain management.

State and local governments must integrate the 1% annual chance standard with all the other management challenges they face, and this can require flexibility and creativity. The NFIP regulations allow communities to exceed the 1% standard and many communities frankly consider it a bare minimum and manage their floodplain areas with enhanced techniques such as no-rise floodways, future-conditions hydrology, comprehensive maps, and accounting for special hazards such as ice jams or subsidence. State and local governments have developed higher standards in some cases, and in the case of future-conditions hydrology, have gained permission from the Federal Emergency Management Agency (FEMA) to have that data depicted on the official Flood Insurance Rate Map (FIRM) for the community. Thus they compensate, in part, for the inflexibility of the fixed, single standard and its inability to account for changing land use or a range of risks.

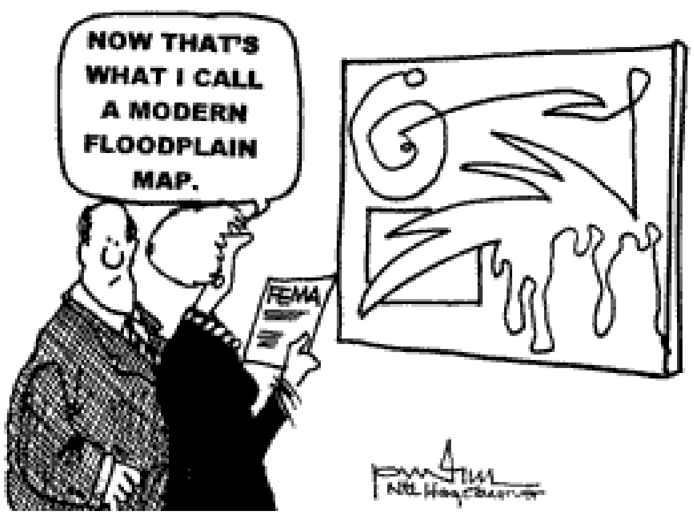
State and federal programs for dam safety, water quality, stormwater, species preservation, greenways, bridge maintenance and construction, irrigation, toxic waste disposal, and many others must be coordinated at the local and state levels with the assortment of policies and regulations that accompany floodplain management—development standards, building codes, floodplain permitting, and the like. Each of these programs has its own standards, expressed in different ways, that must be artfully combined if communities are to effectively manage their operations and responsibilities. In general, states and localities have found ways to make the program pieces fit together. However, this requires ongoing diligence and coordination among levels of government and among the state and local departments and agencies.

- The 1% chance flood standard has been widely implemented and accepted nationally. It has been incorporated in some fashion into federal programs for housing, highways, economic development measures, insurance, and many other activities.
- There is a large body of statutory and common law that supports the 1% annual chance standard. Particularly in the case of the common law, it takes years for an issue (like the supportability of the 1% standard) to make its way through lawsuits at the local and state levels and to finally reach the Supreme Court where a definitive decision can be made. The 1% standard has stood this test and is well established (see the supplemental paper by Kusler).
- We have an extensive infrastructure of policy, regulations, law, programs at all levels, standards for funding, and other measures that are institutionalized on the basis of the 1% chance flood standard. The Disaster Mitigation Act of 2000 for the first time has institutionalized the 1% annual chance standard as a basis for planning—for mitigation of flood hazards.

Impacts of Science, Technology, Tools, and Engineering

The mapping component of floodplain management has been the biggest beneficiary of advances in technology. Remote sensing technology (LIDAR in particular) has made the process of collecting topographic data faster and less expensive. Geospatial technology allows engineers to have the computer intersect these digital topographic data sets with the predicted flood surface to automatically calculate which sections of ground will be flooded when the river crests. Not only is the floodplain boundary more accurate and more readily depicted, but also it is much more easily replicated so that people can be more assured of being treated fairly.

An array of new commercial software and technology has made it easy to generate maps, tailor them to particular uses and audiences, and make them readily available. Geographic information systems enable government agencies and others to readily combine a "flood information layer" with other relevant spatial information such as roads, infrastructure, building footprints, vegetation, wetlands and other natural features, or land ownership. Digital technology has made newer flood maps more attractive, flexible in their use, relatively quickly produced, readily available, and extremely faithful to the figures that underlie them.



—***Natural Hazards Observer***, *November 2001*

It should be noted that the expense of many forms of the newer technology and tools—including purchase, training of staff, maintenance, and upgrades—may inhibit their widespread adoption, particularly among small local governments.

- Computer power has made it possible to handle vastly more complex models and do more complicated calculations in a reasonable time frame.
- Technological advancements have made it easier to disseminate flood hazard information and/or maps widely, including to decisionmakers, the public, and technical staff. Information passes via the internet, television, email, cell phones, toll-free phone numbers, printed graphics, videos, and other means. The same is true of raw water data; both the National Weather Service and U.S. Geological Survey have their precipitation, gage, and stage data online and in many cases in

real time. This also helps improve modeling, because analysts can readily obtain what they need to test refinements immediately.

- Improved access to geospatial data has improved the accuracy and speed of the engineering models used to predict the 1% chance flood discharges.
- Methods of assigning economic values to natural resources and functions are far better than the techniques that were available even a decade ago. Scientific understanding of water-based ecosystems, and what it takes to protect and restore them, has advanced considerably. There are numerous widely used engineering techniques for maintaining the natural integrity of channels, promoting re-vegetation, and protecting aquatic habitat, for example.
- The statistical methods, models, and technology exist to analyze uncertainty in flood discharge calculations and to incorporate it into some at least some standards that underlie floodplain management.

Societal Considerations

The Purpose of a Standard

The reasons for setting any standard at all tend to be socially based. These reasons underlay the decision in 1968 to set a nationwide standard (though not the specific 1% annual chance standard that was reached) and they are just as compelling today.

- For reasons of equity and administration (see below) a nationwide program has to have a baseline. The National Flood Insurance Program could not have gotten started without a fairly prescriptive standard: a statement that “this is the area deemed most floodprone and hence the place where protective measures are going be taken and insurance provided.”
- We want people to be treated fairly—that is, equally—and we appreciate having a set of established criteria that applies to everyone. This can be seen throughout the scheme we have set up for floodplain management: we strive for consistency in mapping, enforcement; and insurance. Even if the standard is not uniformly applied, we try to do so, and there is a wide perception of attempted fairness.
- A standard can act as a benchmark by which to measure performance, progress, or success. Comparing the extent of a 1% chance flood with its prior delineation on a flood map, for example, gives a fair idea at a glance whether things are improving or whether there is something wrong.
- A standard helps us set goals, such as “reduce the number of properties within the 1% chance floodplain by 50% within 20 years.”
- A uniform standard eases implementation; sharing of techniques is possible when people are working against the same benchmark. Otherwise, much more in the way of procedures, rules and regulations, analysis, etc. would have to be invented independently.

- A standard eases communication by simplifying a complex concept. Although people may not fully understand how the 1% chance floodplain is calculated, they realize that it means the same area no matter who is talking.
- In the case of the 1% chance flood, having the standard gives non-technical decisionmakers a guide that relieves them from understanding complex engineering or scientific formulations.
- A single institutionalized standard can be easier to defend in a court of law, thus allowing the creation of a supportive legal framework.

The 1% annual chance standard has more or less satisfied most of these social concerns. It has resulted in considerable uniformity in application and a sense of a fair amount of equity, even though there are variations in how is it applied across the country, exceptions, and grandfathering. Strictly speaking, everyone in the flood risk zone probably is not facing the same degree of flood risk, and some of those outside of the zone probably ought to be in it. But these are flaws in implementation and it is doubtful that a change to another standard would remedy all of them.

Shifted Costs

One way society deals with risks and costs is to transfer them to people or entities for whom they are appropriate burdens. This has been carried out in part with regard to the National Flood Insurance Program. Part of the motivation in setting the 1% annual chance standard in the late 1960s was to establish a zone within which some of the costs of flooding would be transferred away from the federal government. Under the scheme now in place of providing flood insurance in exchange for land use regulation, communities bear the costs of administering actions to keep development out of the flood zone (or protected, if it is inside the zone) and individuals and the private sector share the costs of damage, through insurance.

Part 3

Where the 1% Annual Chance Standard has Fallen Short

As noted in Part 2, floodplain management in the United States has two main goals: (1) reducing the loss of life, damage, and disruption caused by floods; and (2) protecting and restoring the natural resources and functions of floodplains. Since losses continue to rise and there is no evidence that floodplain ecosystems are in better shape than they were decades ago, much of the discussion among the Forum participants understandably focused on problems that have arisen (or were never solved) through the adoption and use of the 1% annual chance flood standard.

Some of the deficiencies in our flood hazard management scheme today are traceable directly to the 1% standard; some are only peripherally related to the standard itself; and many are of uncertain (or complex) origin. This part presents the Forum's observations about the problems with the use of the 1% annual chance standard to date in the United States, along with some of the ideas for addressing those problems.

Negative Outcomes and Portents

- Flood losses nationwide continue to rise, perhaps because the 1% annual chance standard is not high enough, perhaps because it is not effectively implemented, or both. Since 1978, the National Flood Insurance Program has paid over $2.8 billion in claims for flood damage on properties rated as being outside the 1% floodplain—over 20% of all flood insurance claims paid to date.
- Because of the standard, in many parts of the country development has tended to cluster just outside of the 1% chance floodplain boundary, an area certainly not free from flood risk and possibly subject to the 1% chance flood (or more) now that urbanization has increased flooding—and changed its character—in many watersheds. In Boulder, Colorado, for example, hundreds of properties have been developed outside the 1% chance floodplain but within the 0.2% floodplain.
- Natural floodplain resources and functions are ignored in the 1% determination and delineation, and therefore their protection is a hit-or-miss proposition in the rest of the program. A scientific connection has not been established between the 1% chance floodplain and the biological, physical, or geomorphological floodplain.

- There is a "gray area" of uncertainty surrounding the calculation and the mapped floodprone zone.
    - The 1% annual chance standard is underlain by engineering calculations that rely on measures of flood discharges. The stream gage and precipitation data on which the discharges are based are not highly accurate, for a number of reasons. Published rainfall and precipitation data are out-of-date, and stream gage networks are diminishing.
    - Errors were introduced during the manual cartographic processes used when most maps were produced.
    - Changing and future conditions within a given watershed (especially due to urbanization) are not considered when the 1% floodplain is delineated.
    - Oversimplified assumptions are made in the course of calculating a flood discharge (such as assuming a fixed-bed channel).
- The 1% annual chance standard has not lent itself to ready integration with water-related programs based on other types of standards, such as those for water quality or resource management.
- As a means of communicating flood risk, the 1% chance floodplain has been problematic. Both the terminology and concept are confusing, and the inaccuracies have undermined the credibility of the maps and the program operations. The implications of the gray area of uncertainty are not clearly conveyed to professionals, decisionmakers, and the public.
- The "in or out" nature of the prescriptive standard triggers a normal human reaction of "it can't happen to me" even in the face of scientific evidence. It also has fueled attempts to "remove" properties from a floodplain via fill and/or map changes. This has led to the transfer of flooding impacts to other locations and the demise of the natural functions of the floodplain.
- Our programs are based on the flawed assumption that we have calculated and depicted on the maps the real 1% floodplain. This may present problems of legal liability in the future.
- The 1% annual chance standard is inadequate when applied to levees.

Discussion

More detailed descriptions of the difficulties being faced with the 1% annual chance flood standard are presented below, organized under three main topics: (1) problems with implementation of the 1% standard; (2) shortcomings in the science, technology, and tools used to derive and apply the 1% standard; and (3) the societal implications of the 1% standard.

Problems in Implementation

There have been countless minor difficulties with implementation of the 1% standard, as there are with any program. The standard has been used for a century as a basis for structural measures and through 35 years of the NFIP. During that time, floodplain managers have gained experience in its implementation, including developing regulations, policy and guidelines for it; applying it to endlessly varying circumstances nationwide; and gaging public and official reaction to its presence in everyday life. Based on that perspective, four major problem areas have been identified (natural resources and functions, levees, risk communication, and future watershed conditions) that are directly related to the standard itself and significant enough that they require either remedial action within the context of programs based on the 1% chance standard or adopting another standard that better acknowledges their importance. In addition to the four most significant problems there are several additional minor ones, described at the end of this section.

All standards have real impacts on real people and places.

Natural Resources and Functions

The 1% annual chance standard is an engineered concept that has no basis in the natural sciences. The high-risk floodway within the 1% floodplain was derived as an area that needed to be reserved for conveyance of floodwaters. No background work has been done to determine what portion of a waterway's normal floodplain is critical for protecting the floodplain's natural functions and resources.

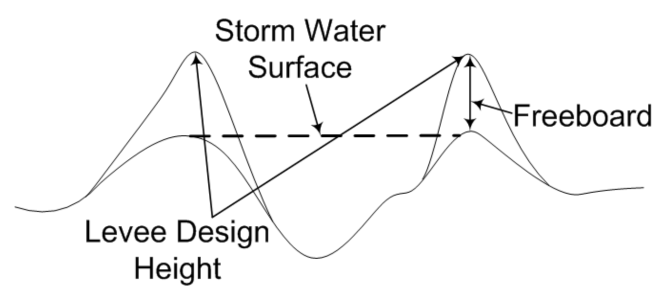
It is widely accepted that preserving or restoring the natural quality of floodplains is worthwhile not only because it minimizes the amount of development subject to damage but also because of the filtering vegetation, water quality benefits, habitat, and other natural resources and functions that are thereby protected. This protection is assumed to be accomplished, usually and often incidentally, by designating the 1% floodplain (or part of it) as open space. Yet the work we have done to define and implement the 1% annual chance standard has provided no scientific information about what is required to protect those functions and resources. How much area is needed on either side of the waterway to sustain the native wildlife? What range of vegetation is needed to maintain bank stability, shelter aquatic habitat, or promote infiltration? What channel characteristics are critical to maintenance of the stream's geomorphology?

Fortunately, many acres of riparian habitat and many stream functions are protected by the development restrictions in place with the 1% annual chance standard. But the same careful investigation of precisely what is necessary to adequately preserve those functions and resources should be done as was done to arrive at a 1% chance floodplain and conveyance floodway for protecting people and property. Perhaps a new "stream nourishment floodway" should be defined along with the conveyance floodway. (For more on these ideas, see the papers by Conrad, Coulton, Meagher, and Berginnis in the supplemental materials.)

In addition, there is still insufficient quantitative information about the natural resources and functions of floodplains applied to decisionmaking about those areas. Methods of assigning economic values to natural resource and functions are still rough, but they are far better than what was available even a decade ago and should be applied to floodplain management.

Levees

The 1% annual chance standard has proven to be poorly applicable to levees. The 1% chance flood level is too low for a levee that protects densely developed areas. But the all-or-nothing dichotomy of the National Flood Insurance Program (NFIP) detracts from the effectiveness of having the levee. If the levee is certified as protecting the community from the 1% chance flood, it takes the development behind the levee out of the flood zone and makes flood insurance optional and flood protection building standards irrelevant. But if the levee fails or is overtopped, all that development is not only unprotected but also is uninsured. The 1% standard does not express the residual risk of developing behind a levee (or below a dam), nor does it convey the risk of catastrophic failure of the structure. (For further discussion of levees, see the supplemental material papers by Pineda, and by Hecker and Conner.)



Some considerations in levee design

—*Corps of Engineers*

Risk Communication

The "all-or-nothing" quality conveyed by the delineation of a 1% chance floodplain is a continuing and insidious problem. The public, local officials, and insurance agents take the map, for example, to mean that there is no flood risk whatsoever just outside of the 1% zone. Better-defined risk zones that will come with map modernization may help this situation somewhat, but surely will not solve it.

The terms "1% annual chance flood" and "100-year flood" both have been a source of continual misunderstanding. To the extent that we rely on risk communication to convey the danger implied by the "1% chance" or "100-year" flood, we have problems. Lately, the ready availability of flood hazard information through the public media (the internet or the television or both) has in some ways acted to undermine the 1% annual chance standard. For example, people can access via the internet National Weather Service information that shows streamflow data and flood stages and an accompanying estimate of the risk (when appropriate). The risk is expressed not as a percentage frequency (like the 1% flood) but rather in terms that the designer of the software thought reasonable (like minor, moderate, or major flooding).

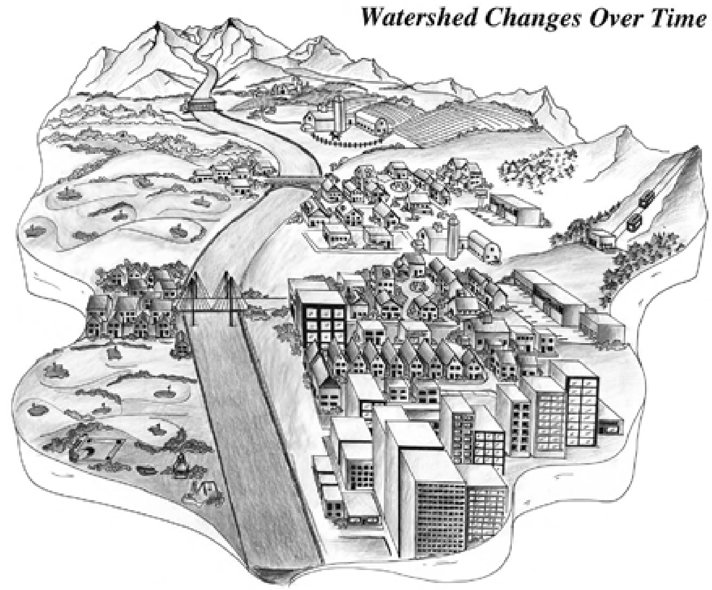
The range of risk is not well understood and thus not well incorporated into our regulations and policies. The oversimplicity of being "in or out" of the floodplain has been a hindrance in some ways. Although uncertainty can be better quantified now, it is not being effectively incorporated into our standards. (More details on risk and probability analysis can be found in the paper by Baecher in the supplemental materials.)

To successfully disseminate information, we need to acknowledge that multiple audiences need multiple messages delivered in multiple ways. Experience with floods and with earthquakes shows that people can be induced to change their behavior at least in specific, immediate ways, but it takes careful planning and understanding of the precise content of the message and the delivery of it (and the funding to do so). It must also be recognized that simply disseminating information probably will not be enough to effect changes in human behavior, as noted below in the section on Societal Concerns. (Some of the considerations in communicating flood risks are explained in the papers by Murphy, Ogle, Goodwin, and Buss in the supplemental material.)

Future Conditions in Watersheds

Although there is no regulatory restriction on states or localities who wish to exceed the 1% standard, there is little on-the-ground encouragement or incentive to do so. Many, many communities are still taken by surprise when development pressure begins and they have no idea what steps they could take at the onset to ensure that new and existing neighborhoods and commercial areas not only are protected from flooding but also form attractive additions to the community. Its failure to take into account changing and future conditions on the ground is an important instance in which the1% standard falls short.

Watershed Changes Over Time



It is very possible to get beyond this restriction by acting independently. One shining example is the City of Charlotte and Mecklenberg County (North Carolina), which researched the effects that development and urbanization of the watershed would have on flood heights in the region. (These impacts occur because the increase in impervious surfaces, such as pavement and rooftops, results in more water from a storm running off the land's surface into the drainage system than was the case before development, and usually at a faster pace). They calculated that flood heights when the area was fully built out—some time in the future—would be an average of 4.3 feet higher than shown on the official flood maps, which were issued in 1975. Further, they were also able to calculate the offsetting benefits (in terms of lowered flood heights and in dollars saved) of adopting measures such as buffers and restrictions on filling in the flood fringe. The city and county based their new floodplain management regulations on the results of these analyses.

Other Problems in Implementation

One nationwide area in which the 1% annual chance standard has not been well integrated is that of water quality as practiced and enforced at the watershed level, especially through U.S. Environmental Protection Agency programs promulgated under the authority of the Clean Water Act. To a large extent, watershed-based planning, modeling, and regulation nationwide are founded in water quality issues and standards, not water quantity standards. The 1% chance flood is an almost-unheard-of parameter in these circles, in part because most attention is focused on low flow levels, when water quality is most vulnerable. This is a critical discontinuity because the management of water quality and quantity need to go hand-in-hand. Separate watershed-wide programs for water quality and floodplain management are counterproductive.

Because it is prescriptive, the 1% annual chance standard has inhibited broader analyses that might have occurred under some other system. For example, because there are only two significant conditions under the scheme for implementing the 1% annual chance standard ("in" the floodplain or "out" of the floodplain) there is no reason for a developer or a community to explore fully the ramifications of developing a parcel, leaving it open, designing with the flood risk in mind, or other options. The usual response is to find a way to be designated "out" of the floodplain and, ironically, procedures do exist for following this avenue but not for examining more sensible alternatives. For example, although economic analysis of the costs and benefits of different approaches is possible, under the prescriptive standard in place today there is no incentive to use such an analysis.

One very important potential problem is that programs, as implemented, are based on the assumption that the maps depict the real 1% floodplain. Because of the uncertainty problems discussed below, this is certainly not true at every location and may be a more pervasive problem than we think. This could cause issues of legal liability to arise in the future.

The errors and uncertainties in the calculation of the 1% flood and in depicting it on the flood maps have undermined the credibility of the maps and to some extent the whole idea of regulating floodprone areas. This skepticism shows up at the local level and hinders implementation and enforcement of regulations in some parts of the country.

Science, Technology, Tools, and Engineering

The advances in technology since the 1% annual chance standard was established have been nothing short of astonishing—including computers, computing power, geographic information systems (GISs), remote sensing, global positioning systems, the internet, and mass digitization of graphics. Yet having the precise capability to use the data in ways that fit within a framework that was devised in a simpler time, and developing and applying that capability in appropriate ways, are not automatic with the advent of new technology. New techniques for modeling, mapping, data gathering, and analyzing risk do not necessarily result in a more accurate estimate of the 1% chance flood, or improve our effectiveness in managing our floodplains. There are three main deficiencies growing out of the way that science and engineering are used in floodplain management: (1) inaccurate delineation of the 1% flood; (2) failure to account for (or compensate for) the inaccuracy and other uncertainties; and (3) ignoring natural functions and resources of floodplains in the delineation of a risk management zone.

> *Flood maps look like superhighway products, but the hydrology they are based on is still a dirt road.*

Inaccuracy in Delineating the 1% Flood

As we have seen, the decision was made in the late 1960s to use the1% chance flood as the level for determining where regulatory and insurance-based flood management measures would be applied. To show what that area is, we need maps of the places that would be inundated by the 1% chance flood. That requires calculating how much water there will be in a certain place (usually along a waterway) at a certain time, during a certain rainfall or runoff event, combined with where the water will flow on the terrain at that place. Reaching this level of knowledge for those purposes is a three-step process: (1) calculating a discharge; (2) translating that into a height for the water surface; and (3) combining the water surface elevations with topographic information to produce a map of the expected flood. (Further discussion of various aspects of this process, and its implications, can be accessed in the papers by Hirsch et al., Thomas, and Djokic in the supplemental material.)

Calculating a Discharge

Each of the three main ways to predict the amount of water that will be discharged at a given point at a given time is subject to inaccuracy, primarily because of problems with the underlying data.

(1) Flow frequency analysis relies upon stream gage data from waterways and watersheds that have not been altered by flood control or other structures, urbanization, channelization, or other means (or if they have been, the alterations were already in place when gage recording began). The gages also tell what the flows on the stream were during past floods. In a rapidly developing watershed, the characteristics of the watershed are changing so that future floods on the stream may be more severe.

This approach is seriously hampered by the fact that there are not as many gages as are needed for the method to work adequately. Further, the rain gage and stream gage data that do exist are gradually being lost due to lack of funding for their maintenance. A secondary difficulty is that, as more waterways become regulated by structures, more of the long-term gage records become unusable, because current readings are not comparable to older ones. New gage data are needed as watersheds develop.

(2) Regional regression equations are empirical equations that combine the characteristics (slopes, land cover, soil types, etc.) of a watershed with stream gage records to produce a value for the flow associated with the 1% chance flood at that gage.

Unfortunately, the regional regression equations themselves were developed some time ago. The curves they describe are based upon flood data provided by the USGS that is now 20 to 30 years old. In some parts of the country, notably California, the biggest floods on record have occurred since then. In addition, the characteristics of the watersheds have changed. With development within the watershed, the amount of impervious surface increases.

Using regression equations also may result in significant error in the calculation of the discharge. This is because there are few long-term stream gage records in the country on which to build accurate equations; because there is significant variability in the characteristics of the different watersheds to which the equations are applied; and because the existing data sets tend to be dominated by non-urban streams and do not translate well to urbanizing areas or changed watershed conditions. Errors of 30 to 100 % are not uncommon. (For an application of regression equations to a discharge calculation, see the paper by Bond in the supplemental material.)

(3) A design storm runoff model uses a selected rainfall figure (real or predicted) and combines it with a model of how the particular watershed will respond when that amount of rain falls. A discharge for a given probability then is derived from the results of the modeling. The rainfall data used in this method are usually taken from published National Weather Service sources (NOAA Atlas 2 in the West, which is being replaced by the forthcoming NOAA 14; and TP 40 and TP 49 in the eastern United States). The age of these data makes them questionable—NOAA Atlas 2 was based on 1967 figures.

Calculating a Water Surface Elevation

The flood discharge information, stream cross sections, and stream characteristics are combined, using physics equations, to simulate (model) the flood heights along the stream during a 1% chance flood. There is an array of sophisticated hydraulic models available to relatively quickly generate the flood elevations. Automated tools have made the process more accurate and much less time consuming

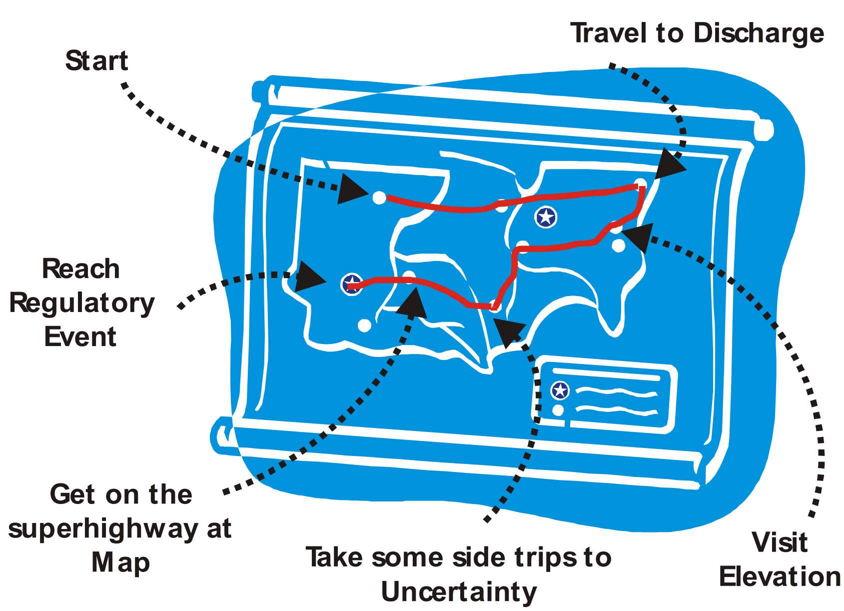
Mapping the Expected Flood

Once the elevations of the flood crests have been determined, they are transferred to a map. Misrepresentations of the portion of the landscape that will be covered by a 1% chance flood are a function of the accuracy of the discharge information, the water surface calculation, the topographic mapping, and the process used to transfer the elevations to a map. Digital processes for mapping are much more accurate than manual ones, but are not perfect and cannot overcome inaccuracies in the earlier steps of the procedure.

Uncertainty and the 1% Delineation

It is clear that assumptions are introduced at each step in the process of estimating—and displaying—how much of the landscape will be flooded during a 1 % chance flood. This generates uncertainty about the 1% chance flood boundary as it appears on a map. A "gray area" surrounds both the calculation and the mapped floodprone zone, resulting from one or a combination of these factors:

- The shortness of the rainfall/runoff records introduces an element of uncertainty about the validity of any calculations that are based upon them.
- The nation's stream gage network is inadequate and is shrinking.
- Hydrologic models tend to require more qualitative processes in the selection of parameters, leading to a sense that hydrology is both an art and a science.
- Hydraulic models tend to be more quantitative in terms of parameter input and, although they still require judgments, those judgments tend to be more physically based (e.g., placement of cross sections).
- Any deficiencies in our information about the terrain over which the floodwaters may flow (or inaccuracies in the way that information is incorporated into the model) will produce an unreliable flood surface elevation.



Predicting and depicting the area expected to be inundated during a future flood is a complex task.

—David Ford Consulting Engineers, Inc.

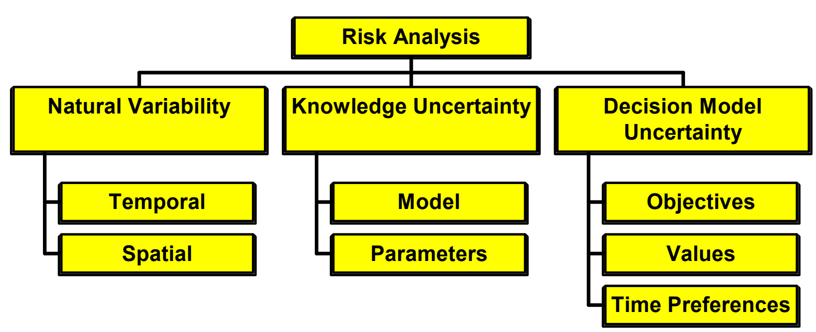
- The accuracy of base maps varies.
- Normal variability in climate is not accounted for in the models used to translate the discharge into the surface elevation.
- Global warming may be affecting the validity of even fairly long-term precipitation and flow records.
- Watersheds are changing continually, particularly through urbanization, and this has not been taken into account during the modeling. In engineering terms, floods have a distinct probability distribution but in reality the distribution determination is a moving target (the non-stationarity problem).

The result of these assorted uncertainties and resultant inaccuracy is that the flood maps, no matter how appealing in appearance and usefulness, mislead us about the quality of the predictive information they portray. This can (and does) result in decisionmakers, landowners, and others being distrustful of the maps' validity. New standards being established by FEMA will ensure that new mapping will do a better job of matching topography, but the data and methods used to estimate flood flows that underlie those maps are not keeping pace.

Ways to Account for Uncertainty

The simple answer to this situation is to find a way to build in some margin of error or safety as part of the production of the discharge calculation, hydrologic model, flood surface elevation, or map. This is often referred to as "accounting for uncertainty." Had steps been taken to do this at the outset, several decades ago, many of today's problems could perhaps have been avoided. Indeed, in the late 1960s there was talk about the desirability of measuring different levels of risk in order to convey a more accurate "range" rather than a single zone, but the capability of doing it on a national scale simply was not there.

One rough way to compensate for uncertainty today is to apply "freeboard" to regulatory flood elevations. Adding (on paper) a foot or more to the calculated flood surface elevation and then basing the building standard or elevation requirement on that is one way to build in a safety margin, and some states and localities have done so. Enhanced statistical analyses applied to discharge models can be used to justify the adoption of freeboard standards and thus encourage more widespread use of them, and even give an idea of how much freeboard is advisable.



Categories of uncertainty in flood damage reduction studies

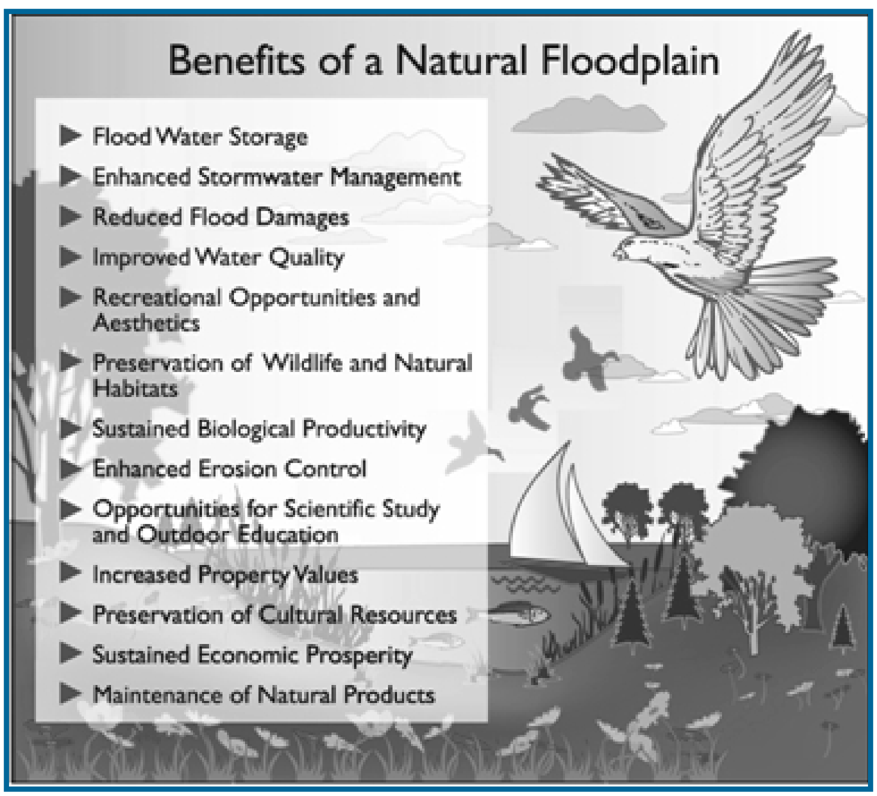
—National Research Council, 2000

Another way to make up for uncertainty is to incorporate it into floodplain management methods and models. Statistical analyses to do this have been available for 40 years or so, and now the technology and computing power are available to more readily model uncertainty. We have the capability of incorporating how the shortness of the statistical record (rainfall or streamflow) or lack of data about the terrain affects the discharge we compute, for example. This can—and should—enable the adoption of techniques to help compensate for inaccuracies in the discharge calculation.

One other technique that helps account for uncertainty but is little used in floodplain management is integrating the reliability of the protection measure (whatever it is) and the consequences of its failure into estimates of risk. In many engineered systems, the reliability of the system (how prone it is to failure) is incorporated into the design. With existing computer power and modeling capabilities, it is possible to use this sort of risk analysis to narrow some uncertainties (such as the probability of the flood, the potential for failure of the protective measure, inadequacy of underlying data, etc.). This technique is used by the Corps of Engineers for some of its projects. It is not clear, however, that it can be applied on more than a project-by-project basis. (See the papers by Davis, Haimes, and Baecher in the supplemental materials.)

Natural Functions and Resources of Floodplains

Water surface elevations during the 1% flood are produced to help determine the danger posed to people and buildings and to help determine how to lessen that risk. They do not help in understanding or protecting the natural functions of waterways. There is, in fact, no analogous procedure in use to guide floodplain managers in how various parts of the stream system—channel, riparian area, vegetation, soil—need to be treated in order to keep the system functioning and nourishing its natural resources.



It may not have been possible 35 years ago to determine precisely how to protect floodplain resources, but science and technology have progressed to such an extent that it can be done with fair certainty today. In fact, along with that progression has come scientific confirmation that protecting those functions and resources is absolutely essential. Just as the characteristics of a “conveyance floodway” were determined through engineering methods, so we can and should use science and engineering to determine what part of the stream system is critical to its self-maintenance. What flow frequency is the “channel-forming flow?” What is the extent of the “stream nourishment floodway?”

- Hydraulic modeling has advanced so much in the last 20 years or so that simulation is now possible of storage scenarios, two-dimensional flow velocities, and other factors that contribute to understanding how waterways renew themselves.
- The ecological sciences likewise are capable of explaining how the associated ecosystem (soils, vegetation, wildlife, aquatic habitat) is linked to the hydrology and hydraulics of the stream, but this is rarely done in floodplain management.
- The new economics of natural capital are beginning to assign economic values to some of the natural resources and functions associated with floodplains, but these are not being incorporated into floodplain management and may in fact have little relationship to the 1% floodplain.
- Much more is known now about fish and their optimal habitat—and how changes in flow, velocity, temperature, channel geomorphology and other factors affect them. This information ought to be incorporated into plans for floodplain management.
- Recent research has suggested that the 1.5- or 1-year (99% annual chance) “flood” may be the level of flow most critical to channel formation. How this relates to 1% flood-related management measures has not yet been established.

Societal Concerns

Floods are this society’s most frequent and most expensive disasters. Yet at any single site a flood is a “low-probability, high-consequence” risk. That is, it’s not very likely to happen but if it does the results will be drastic. Social science research over the decades has taught that people’s ability to understand such risks and to make decisions about them is problematic. Human behavior continues to confound many floodplain management approaches (including the 1% annual chance standard), in at least four main ways: (1)subjective views of risk; (2) the desire to feel safe; (3) misunderstanding of scientific terms and concepts; and (4) aversion to bearing the costs of floods.

> *Floodplain managers live in the world of the 1% standard . . .*
> *but everyone else is living in the 99%-chance-it-won’t-happen world.*

Unrealistic Views of Flood Risk

People do not always behave rationally, either individually or in groups. Knee-jerk reactions are an all-too-common response to the risk of floods and to floods themselves (as well as to other dangers). Most major government actions to minimize the harm done by floods have come after a disaster has occurred, rather than in anticipation of preventing one. At the individual level, for example, hurricane clips (or straps) are both inexpensive and easy to install, but for decades very few homeowners bothered with them.

Furthermore, flood risk is not objective, but lies largely in human perception. Objective risk as defined by science (the quantitative likelihood of an event's occurring combined with the consequences if it does) is still subject to the scientists' perceptions, assumptions, and points of view. Even if there were completely objective levels of risk, individuals consistently underrate the danger to themselves. People look at risks through a filter of feeling fundamentally exempt from them. They are living in the 99% world—the world inside their perception, where the risk is not real.

The Ideology of Safety

Western society is famous for fostering the notion among its members that they can—and ought to be—completely safe from risks of all sorts. Government is ripe with programs based in science and designed to make people feel safe, from seat belts to food inspection to dams. Many of those programs do improve "safety," but the down side is their perpetuation of people's feelings—sometimes unjustified—of being safe and their feelings of being entitled to be safe.

The 1% flood standard has both fallen victim to and perpetuated this ideology of safety. By drawing a line around the flood hazard, the standard has made flood risk a question of being "in" or "out" of danger when the reality is much more complicated. Furthermore, upon hearing that it is possible to be "out" of danger by being on one side of the line, people immediately assume their own absolute safety and even abrogate responsibility for taking individual action to lessen any residual risk. Even people who are shown that they are in the scientifically calculated 1% chance zone persist in believing that "it won't happen," as noted above.

Confusing Terminology

Not only are most attempts to objectively express risk resisted by most people, but the 1% standard, unfortunately, has been particularly difficult to explain and to understand. The term alone—a mathematical expression—is an abstraction and the alternative "100-year" flood has its own well-known misleading qualities. Add to this the fact that we have not been able to communicate to the public or to many decisionmakers the uncertainty that really surrounds this seemingly carved-in-stone edge of risk. It has been as though the 1% flood was the only one possible and that there was no need to consider taking actions to add margins of safety. Yet it is a scientific reality that the calculation of the standard is based on data, models, variables, and other factors that have their own weaknesses; that climate does vary; that unforeseen contingencies occur; and that the standard as expressed on a map (or any other way) is not keeping up with changes on the ground.

The Myth of Risk Reduction

As a society, it is extremely difficult, if not impossible, to reduce overall risk. Any apparent minimization of risk is frequently only a transfer of the risk to another person or group or into another form. Modifying a waterway to keep it from overflowing its banks results only in pushing the water more quickly to downstream people. Insuring floodprone property does not reduce the risk; it merely makes it possible to be compensated financially for suffering from it. These concepts are only now beginning to be fully realized in floodplain management, through approaches such as basin-wide planning and no adverse impact floodplain management. Society must decide which shifts are desirable and few such deliberations have taken place in the case of the 1% standard, although inadvertent shifts of risk have doubtless occurred.

Although shifting flood disaster costs from the federal government to other arenas was contemplated when the National Flood Insurance Program was devised, the wherewithal was not there at the time to conduct a full economic analysis of whether the 1% standard would shift enough of the costs, or too many of them, or be about right. It was always intended that the standard be revisited, but as the years went by this was not done.

Another unanswered social question is whether reducing the flood risk (and costs) should be a high national priority. About $6 billion in flood losses annually amounts to $22 per person. How much can that reasonably be reduced, and how much is such a reduction worth to society?

The existing and familiar management structure for trying to reduce flood losses has had results with which everyone is less than satisfied. Continuing to operate within it may be a mistake. A revolutionary shift may be needed in our thinking—perhaps a new paradigm that helps us look at floods from the perspective of the 99% world.

Part 4

Conclusions and the Future

Based on the discussions at the 2004 Assembly of the Forum, it is possible to offer professional judgments about the sufficiency of the 1% chance flood standard, centered around the questions for analysis of hazards-related science and policy posed by Gilbert White and his colleagues in a recent publication (see box).

> 1. *Is knowledge lacking? Is floodplain management flawed by significant areas of ignorance?*
> 2. *Is knowledge sufficient but not used?*
> 3. *Is appropriate knowledge used, but in an ineffective manner or one that is counterproductive?*
> 4. *To what extent is it that knowledge is available; is used effectively, but that it simply takes time for effects to be felt?*
> 5. *Is appropriate knowledge available, properly used, and achieving positive results, but those results have simply been overwhelmed by the scale and speed of the processes that increase vulnerability to floods?*
>
> *White et al., 2001*

1. **The 1% chance standard has proven to be a valid piece of scientific and engineering "knowledge" (in White's terms) for working towards one goal—managing floodplains in ways that will reduce loss of life and property damage—but has proven inadequate for furthering the other goal—protection of floodplain resources.** The standard is not based on scientific knowledge about the natural functions and resources of floodplains. The result has been that we have insufficient knowledge in that area to further our work (through the 1% chance standard and its associated practices) toward the goal of protecting floodplain resources.

   Other types of knowledge, in the form of practices that support the 1% standard, have proven inadequate in a couple of ways. There is a sense that we do not know enough either about properly communicating risk or about other ways to induce individual and collective action.

2. **Is our knowledge (as reflected in the 1% standard) sufficient but not used?** This is a big unanswered question. Although there was agreement at the Forum that the 1% standard is a valid, though not necessarily perfect, choice as a level of flood protection (though not resource protection), it is not at all clear that what is being

mapped, regulated, and managed throughout the nation is a true 1% floodplain. Because of a range of errors possible and uncertainties inherent in the long process of moving from a precipitation or runoff figure to a map and then to on-the-ground management, there is a good possibility that the 1% standard is in fact not being implemented but that, instead, a lower standard is being used inadvertently.

3. It is entirely possible that our failure to minimize flood losses is a result of the 1% standard's being used ineffectively. There have been some failures in implementation. Drawing a line on a map has turned out not to have been a good technique for communicating or managing the flood risk; the "in or out" dichotomy inhibits broader thinking and management approaches. Attempts have been made to apply the standard to things it doesn't fit well, such as levees and special flood hazard areas like alluvial fans or coastal zones. Although there are existing means for accounting for uncertainty , they have not been applied effectively to floodplain management. The simple and critical matter of collecting data on which to base discharge calculations has been ignored by policymakers. The crucial feedback loops for determining what effects the implementation of the standard has had are undeveloped and underutilized.

4. Is it possible that the 1% standard is adequate, and being fairly effectively applied, but that not enough time has passed to see results? Based on the Forum discussion, this appears to be a possibility, but not a very strong one. We have seen considerable progress in the decades of use of a standards-based approach, as illustrated by the thousands of local flood management programs and the large number of insured and more safely built structures. However, the anticipated phase-out of the pre-FIRM buildings is taking longer than anticipated, and it is questionable if the1% floodplain will ever be cleared of nonconforming buildings, because the 1% area is growing due to other changes (see below). It does not seem prudent to wait for results to manifest themselves.

5. Is it possible that the 1% standard is adequate and effectively applied so that there would be a reduction in flood losses if it were not for various changes that overtake the nation's efforts? There was support at the Forum for this observation. The 1% standard and its associated practices are stationary. The flood study and mapping process that underlies much of our implementation of the 1% standard has been slow in comparison to urbanization and population growth in hazardous areas, such as the coast. Steady economic growth tends to allow the nation to absorb rising flood costs. Rapid urbanization and global warming threaten to render some management efforts obsolete.

Thus, in conjunction with the recognizable progress that has been made with managing floodplains according to the 1% chance standard and its framework, there is also a combination of possible reasons why its use has not resulted in more substantial reduction in losses or in more substantial gains in protection or restoration of floodplain functions and resources. An additional consideration is that there is minimal quantified information about how successful floodplain management efforts have been overall. Nor do we know what flood losses would be, or what the status of floodplain resources and functions would be, had we been implementing the existing standard perfectly or if we had adopted another standard years ago.

With these vagaries and identified inadequacies in mind, Forum participants pondered two questions. First, what alternatives are there to "business as usual?" They attempted to identify other broad management approaches that could be more effective than the 1% standard. Second, they provided numerous recommendations for immediately feasible action and research that would help remedy deficiencies in floodplain management—within the context of the 1% standard as well as within some other as-yet unspecified management scheme.

Some Promising Avenues

Evolution or revolution?

In considering possible modifications to the 1% annual chance standard and the practices and programs that support it, or a shift to another type of standard, several points should be kept in mind. First, there are listed below a number of principles that Forum participants mentioned repeatedly: these are guiding concepts that need to inform decisionmaking and implementation. The second list is a series of present-day "realities" that ought to be taken into account when changes are considered.

Principles for Progress

- Whatever its drawbacks, a single standard tends to satisfy our social needs for uniformity, administrative ease, and a baseline for equitable treatment.
- Avoiding all flood risk is impossible and providing everybody with a very high degree of protection would be too costly to society. Costs and risks must be shared, shifted, and borne, as appropriate.
- For any future program, improvements, or changes, we have to be thinking about the communities more than about the engineering. What do local governments and citizens want in terms of managing their flood hazard and floodprone lands? What do they need? What incentives and assistance will help them overcome weaknesses in the standard (whatever it is) and plan for a changing future?
- Floodplain management may need to be more about managing human behavior than about managing the floodplains. Finding out what motivations and incentives will promote understanding and induce action (given cultural perceptions, economic goals, and private interests) may yield better results.
- Broad societal questions may need to be revisited after a century of implementing this standard for a range of floodplain management activities. Do we still believe it is fair or useful to restrict the use of land that could be of societal or economic benefit? Do the dual goals of protecting property and protecting resources still reflect societal values? Are annual national flood losses unreasonable, when

measured against broader indicators such as gross national product? Are the costs and risks of flooding being shifted in the right directions?

Realities

- By its very nature, a single standard has the potential for being implemented inequitably, simply because of the innumerable variations in the circumstances to which it must be applied.
- The cost of changing to another type of standard would be huge—in dollars, time, confusion, public perception, and other areas. The cost of using the same type of standard but changing the level also would be significant, but not as great.
- The technical and managerial capability exists throughout the nation to make and implement appropriate changes and improvements. With their many decades of experience in managing floodplains to the 1% standard, state and local officials and staff have considerable mastery of the issues and problems that can arise both in adapting to the flood hazard and in coordinating their efforts with program standards set at the national level.
- The prescriptive 1% chance standard oversimplifies complicated concepts. Much happens within the floodplain that cannot be captured in a simple "in or out" determination. Although such simplicity has its appeal, a broader, more flexible approach would allow for the reflection of more detail and more accuracy.
- The ready availability of advanced technology for computing, communication, modeling, and other functions could ease the transition to another standard.
- Flood insurance and floodplain management are linked today and no doubt each of the programs has been shaped in part by the needs of the other. This link may be a constraining factor or an advantage.
- Changing to another standard or making incremental changes in the existing standard or its implementation will have ripple effects throughout government and private programs that are based on the 1% annual chance standard. There will be social and economic impacts as well as induced shifts in programs for the environment, forecasting, warnings, water quality, highways, building standards, levees, dam safety, insurance, the housing industry, and many more. Any change will encounter some obstacles—bureaucratic, legal, political, technological, educational. (For more on these considerations, see the papers by Kolowith et al., Banachowski, Capka et al., Stewart, Hawley, Riggs, Galik, Julian, Jackson, and Moye in the supplemental materials.)
- A significant change in the 1% annual chance standard will be costly to states and localities because of the many shifts in related programs, regulations, policies, and coordinating mechanisms that would be required. Retrenching would be a long process, if only because of the extra staff time that would be needed but almost impossible to obtain given most state budgets.

Options

All the suggestions for new ways to approach floodplain management that were raised at the 2004 Assembly of the Forum centered on the six basic approaches described below. They were offered as remedies for what participants thought were the most fundamental drawbacks in the existing scheme. No option discussed was rejected outright, but some were discussed more thoroughly than others. The Assembly did not attempt to reach consensus on which approach would be best, although there was a tendency in favor of sticking with the existing scheme and fixing it, instead of departing on an entirely new adventure. The options are listed roughly from the smallest increment of change to the most dramatic. Note also that they are not mutually exclusive: some combination may well be workable and effective. (Further explication of some of these options can be found in the papers by Lawlor, DeGroot, Jones, Lulloff, Thomas, Maune, and James in the supplemental material.)

Bring the 1% Standard Approach up to the 1% Standard

There is a well-founded suspicion that the standard being implemented in the United States today is actually lower than the 1% chance flood. Some professionals judge that, because of Letters of Map Amendment, changes in land use since mapping and studies were done, inaccuracies in data and calculations, uncertainty, and other factors, many parts of the country are actually being managed to only a 30-year or perhaps 50-year standard. (See the papers by Jones and by Lulloff in the supplemental material.)

Under this alternative approach, investigations would be done to determine what standard we are actually implementing. Then a decision would be made either to (1) change the standard in the rules, regulations, maps, and other materials to coincide with what is happening on the ground, or (2) make appropriate corrections in calculations and implementation to make sure the 1% annual chance standard is being met.

Enhance the 1% Standard Approach

There was general agreement among the Forum participants that improvements could be made in the policies, regulations, and implementation of the 1% annual chance standard to make it more accurate and effective at achieving its goals. The most badly needed improvements are listed below. The technical and scientific capability exists to investigate and carry out all of them. Little or no research would be needed to move forward on these fronts. Additional work may be necessary and decisions made about how they would be implemented—through new legislation, changes in regulations, incentives, technical assistance, or some combination of those.

- Figure out how to integrate the protection of floodplain functions and resources into the 1% chance flood programs, policies, and regulations.
- Eliminate the 1-foot rise allowed in the floodway (easier to implement) or perhaps extend the no-development standard to the entire floodplain and thereby make the floodway concept irrelevant (harder to implement).
- Encourage or require use of future-conditions hydrology at the local level to account for the uncertainty of changing conditions on the ground.

- Encourage or require adding freeboard to base flood elevations to allow for uncertainty about the depth/discharge data and calculations and maps based on them.
- Re-assess and adjust the mapping and regulatory standards for coastal areas, especially with regard to debris loading and wave action.
- Establish a workable levee standard.
- Separate the flood hazard mapping program into two products: one set of maps for flood insurance and another for floodplain management.
- Improve nationwide hydrological data, particularly by buttressing the stream gage network.

Adopt a Two-Tiered Standard

It is probably not feasible to attempt to impose a higher standard (say, the 0.2% or 500-year flood) throughout all the programs today, although in retrospect we may have fared better if that higher level of protection had been imposed from the beginning. The costs of change, plus all the millions of structures already in place that would probably end up being "grandfathered in" make this an unwieldy, though not impossible, scenario.

A two-tiered approach, however, would keep the 1% annual chance standard for the bulk of activities to which it is currently applied, without change. Another, higher standard (presumably the 0.2% chance flood) would be added, however, for important specific uses and facilities (a broader category than the "critical facilities" or "critical infrastructure" as those terms are used today). This would help take into account both the increased vulnerability of special populations (schoolchildren, the elderly, prisoners, the disabled) and also the importance of certain activities or uses to the community or its economy. Many states and localities already impose higher standards on certain areas of highest risk or special risk (such as subsidence, alluvial fans, or ice jams) or on certain facilities such as wastewater treatment plants, power facilities, emergency operations, museums, nursing homes, prisons, hospitals, toxic waste disposal sites, and others. Incentives to communities could result in the expansion of such beyond-the-minimum efforts. The Community Rating System's reduction in flood insurance premiums is one such incentive. Others could include a reduced cost-share in mitigation or other projects, or credit toward the local share of the costs of the next disaster.

Adding this to the existing national requirements to yield a two-tiered system would add a measure of extra protection in those places and situations in which it is most needed. Note that this approach still necessitates discharge data, hydrologic models, and maps. The quantity and validity of the discharge data would still be the weakest link in the chain whether we are using a 1% annual chance standard, a 0.2% standard, or some other number.

Use A Vertical Standard

Under this approach, flood insurance would become mandatory for every building in the country, perhaps as part of a standard homeowners' insurance policy. The elevation of each building (or lot) would be specified and compared to the flood elevation at that site.

Insurance rates would be based on the flood level, the size of the building, and the amount of coverage needed. Flood protection measures (similar to those used in the NFIP today) would be imposed for buildings within a certain vertical distance of the flood elevation. The fundamental question then would not be "Are you in or out of the floodplain?" but "How high is your building in relation to the expected flood?" Those who were far above the flood level would pay only a minimum amount and would have no restrictions on construction. This takes advantage of technological advances that allow us to quickly and accurately find the elevation of individual structures.

This would not mean that floodplains would be opened up to all types of development. Some prohibitions and other regulatory approaches would need to be worked out. This approach would still require hydrologic models and discharge data, though maps would be optional (see below). Note that moving toward this approach would require re-thinking of the current map modernization effort.

A variation of this option would be to use the vertical standard only for flood insurance and continue to use flood hazard maps (refined as needed) for planning, regulatory, and management purposes.

Apply a Benefit/Cost Model

This would in effect be a move toward risk-based analysis. Each proposed activity in a floodprone area would be analyzed for the probability of flooding at that site, the consequences of flooding to that activity, and the uncertainties associated with those estimates. After some experience it may be possible to group similarly situated structures with similar vulnerabilities, so the risk analysis would not have to be constantly repeated. This would be a complex undertaking and the lessons learned through the NFIP's attempt to use numbered A Zones should be heeded. Although risk-based analysis is used by the Corps for some of its projects, applying that technique to thousands of individual structures has not been attempted.

Use of benefit/cost analysis is one step towards this, because the process allows consideration of a wide range of factors bearing on the activity, as opposed to the prescriptive standard of a flood frequency level beyond which all activity is prohibited.

Note that we would still need discharge data, hydrologic models, and maps. The quantity and validity of the discharge data would still be a drawback.

Take an Incentive-based Approach

Under this approach, standards would be abandoned and instead market incentives would be used to move toward multiple use of our floodplains, instead of the single use (development) we put them to now. This would involve re-delineating the floodplain from the current 1% annual chance area to something larger. Without regulation or federally backed flood insurance, any development of the area would have to bear the costs of flooding by itself. This would be an inducement to put the floodplain to the multiple uses to which it is best suited and most needed, such as agriculture, sequestering carbon, filtering pollutants, providing wildlife habitat, and conveying and storing normal and extreme flows.

There are examples of success with this approach on a small scale and for certain types of floodplains, soils, and uses. This dramatic departure from business as usual would face serious political obstacles and require considerable re-trenching of policy and attitudes. A transition period, probably a very long one, would be essential. This option does not address existing floodprone buildings and other development.

Summary

The six options described above are a synthesis of best thinking of the nation's leading floodplain management experts when asked whether there are reasonable alternatives to using the 1% annual chance flood standard. It was not the Forum's purpose to take a position or make a recommendation about the advisability of any one option. However, there was considerable support among the group for moving directly ahead now with improvements to the framework of policies and practices that has been built around the existing 1% standard (the second option, above). This should be done in any case, and could be accomplished even while contemplation of more dramatic change was taking place.

When asked to specify what could be done to remedy specific inadequacies in the 1% annual flood standard and its practices, Forum participants suggested numerous actions that are compiled in the action agenda accompanying this report. Many of these steps follow up on the "enhancement" option; others break ground on some of the other options presented, but none would be wasted effort. They include improvements in data collection, policy changes, scientific research, and other activities.

An Agenda for Action

This compilation of issues that need further attention grew out of the discussions at the 2004 Assembly of the Gilbert F. White National Flood Policy Forum, "Is the 1% Annual Chance Flood Standard Sufficient?" It is not just a "wish list" but an assessment of work that can be tackled with existing techniques and data and that is essential to progress, even for relatively minor adjustments to use of the 1% annual chance standard. If a major departure from the 1% annual chance standard were made, additional research in appropriate directions would be needed as well. Within each category, the needs are arranged with the highest priorities first. Note that a few of these topics are being addressed in part through the evaluation of the NFIP currently in progress by the American Institutes for Research (see the paper by Tobin in the supplemental material).

Data and Application Needs

Many of the deficiencies in the 1% approach (or other approach) could be remedied by gathering more information, or reviving or expanding the data-gathering networks that are languishing today. In order of priority, the most pressing data needs are given below.

- Obtain more and better stream gage data, both in terms of geographic areas covered and time periods. Stream gage needs should be assessed based in part on population growth.
- Update precipitation, streamflow, and snowpack data and estimates (both amount and frequency) for parts of the country where they are outdated.
- Conduct studies to reduce the standard error of flood discharges from regression equations and rainfall-runoff models.
- Gather data to appropriately map and manage special flood-related hazard areas, such as alluvial fans, closed basin lakes, subsidence-prone regions, debris flows, erosion areas, uncertain flow paths, and others.
- Find ways to inventory natural and beneficial floodplain functions within the 1% (or any) floodplain.
- Obtain and catalog bathymetric data in all coastal areas (including the Great Lakes), so the above-water contours can be integrated with the bathymetric data to correctly model wave set up and run up and associated flood heights. Also needed are historic wind speeds and wave heights for coastal areas, along with soils data to help identify areas where dunes are likely to fail during storms or where shore protection structures will be jeopardized.

Policy and Implementation Needs

Effective floodplain management today requires a more complex approach than was in place—or even envisioned—decades ago. Many links to numerous other programs need to be established and nurtured, informally if no formal policy or mandate is forthcoming. Many of the following suggestions reflect the need to connect floodplain management with stormwater management, water quality initiatives, environmental protection, sustainable development, economic development, and other issues and programs. Others are needed to redress omissions in prior approaches, respond to expanding experience, or correct earlier decisions that now can be recognized as less than optimal. Policies, laws, and programs need to be established or modified to define more direct and effective paths to achieving the dual goals of flood loss reduction and floodplain resource protection. The highest priorities are listed first.

- Establish a standard method for determining future conditions within a watershed.
    - Should ultimate build-out be used as the standard for such a determination?
    - Should another standard, such as 10, 20, or 30 years into the future, be used?
    - Agree on a method for quantifying the benefits that accrue from flood protection based on future conditions.
- Use management techniques and develop maps based on future-conditions hydrology at the local level. At the state and federal levels, encourage or require localities to use future conditions hydrology for planning, mapping, and management.
- Examine the role of levees in floodplain management, and particularly with regard to the 1% standard.
    - Evaluate existing levee standards for their adequacy and what they cover (hydraulics, geotechnical factors, hydrology, topography, subsidence, multiple hazards).
    - Develop a uniform procedure among all agencies for the certification and re-certification of levees.
- Establish an appropriate policy for coastal A Zone designations and standards, especially in light of the 2004 hurricanes.
- Find ways within the context of existing flood damage reduction programs to better protect natural and beneficial functions of floodplains.
- Establish a standard method (and/or guidance for consistent application of an existing method) for an engineer’s calculation and certification of “no rise” in a floodway.
- Ensure that the regional regression equations are updated as needed.

- Establish a national-level body for coordination of the many flood damage reduction programs in the United States. Re-activating the Federal Interagency Task Force for Floodplain Management is one workable option, if appropriate high-level administration support were forthcoming. Among the issues that such a body should address soon are
    - Updating the *Unified National Program for Floodplain Management*.
    - Improving coordination and establishing partnerships between the floodplain management world and entities, approaches, and concepts that did not exist years ago—particularly those that are not based on the 1% standard, such as coastal zone management, stormwater management, water quality, multi-objective management, no adverse impact floodplain management, watershed management, source water protection, habitat for threatened/endangered species, and others.
    - Better defining the roles of federal, state, and local governments; professional associations; non-governmental organizations, and the private sector to foster effective flood loss reduction and resource protection in the nation.
- Set a policy that requires use of higher confidence limits in application of hydrologic runoff models.
- Include all stakeholders in review and development of new approaches to using the 1% standard
- Ensure that rainfall and runoff models are appropriately tailored to basins with different characteristics such as storage, slope, ground cover, etc. This need is especially crucial for small basins.
- Develop and foster incentives for state and local action to improve implementation of the 1% chance standard. States can examine their ability to establish incentives for localities.

Research Needs

One essential contributor to future improvement in floodplain management will be advancement of knowledge about the systems and processes that relate to flood hazards, processes, and resources. The deficiencies in basic knowledge are spread across several disciplines. In each of the categories addressed below, the most critical research needs are listed first.

Environmental Science Research Needs

- Determine what effect the 1% standard and associated practices has had on our ability to enhance and protect the natural functions and resources of floodplains.

- Determine how to delineate a “resource-based” floodplain or floodway (that portion of the floodplain needed to support natural functions and resources). Consider soil types, meander belts, wetland characteristics, changes in slope, vegetation, bank stability, aquatic habitat, infiltration, and any other geomorphological or ecological characteristics as needed.
- Analyze the links and/or discontinuities between the 1% chance floodplain, the conveyance floodway, and the resource-based (natural) floodway.

Engineering Research Needs

- Conduct hydrologic research in the following areas:
    - Conduct research to improve algorithms and methods for rainfall/runoff modeling for traditional applications as well as for special situations like alluvial fans, subsidence areas, and closed basin lakes. Use data on topography, wetlands, road networks, seasonal permeability of soils, etc.
    - Conduct independent research to determine the applicability of the Bulletin 17B guidelines for flood flow frequencies (Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982). Are the statistics and policies still valid?
    - Investigate how to estimate flood frequency using nonstandard and non-homogeneous data for urbanizing watersheds and places where flood control works are present.
- Conduct independent research on estimating uncertainties surrounding variables such as hydrology, hydraulics, geotechnical factors, and other engineering parameters as well as climate and societal parameters. Also investigate the practicality of applying estimates of these uncertainties to local floodplain management decisions.
- Evaluate coastal standards to determine what the impacts would be of requiring freeboard above the 1% level and also how much freeboard would be needed to make a difference.

Public Policy Research Needs

- Determine how residual risk could be incorporated into floodplain management programs and policies.
- Is it time to de-couple flood insurance and floodplain management? What would the impacts be of separating flood insurance from regulatory floodplain management? To what extent has insurance driven adherence to the 1% annual chance standard to date?
- Are the real and perceived deficiencies in the flood maps causing a quantifiable detraction in the operation of the 1% flood standard, or are they just annoyances to implementation?

- Investigate the experience in other countries of adoption of the 1% or other standard. What factors entered into their decision? What levels were selected and rejected and why? What have been the impacts of their use of the standard?

Economic Research Needs

- What have been the economic costs and benefits of application of the 1% annual chance standard? Consider public and private property damage, property protected, loss of life, cost of repair and reconstruction, insurance coverage, lost opportunity, environmental costs and benefits, disaster relief, and other factors.
- Evaluate the opportunity costs to the federal budget of continually escalating annual flood damage and its associated costs.
- Quantify the costs of failure to consider future conditions in flood mapping and management.
- Determine what the economic threshold is for putting a use or facility in a "high-consequence" category, which would be subject to a higher level of flood protection through management, regulations, or other means. In this category should be uses and facilities whose extra protection is vital, either because of the special vulnerability of their residents or (in the case of a facility) the impact the destruction or damage of that facility (due to flooding) would have on the community. Take into account economic, environmental, health, and social costs. Develop a standard procedure for assessing this threshold that would be applicable in many situations.
- Determine whether additional market and tax incentives would encourage better floodplain management. What would induce action by individuals or businesses?
- Assess the value of the natural resources and functions at several floodplain sites.

Social Science Research Needs

- Investigate techniques for better communication of the probability of flooding, flood risk, expected damage, impacts of changing conditions in watersheds, and other concepts to
    - Differentiate between risk and safety;
    - Reach multiple audiences with different ways of learning. Alternative audiences include planners, engineers, the mass media, elected officials, consumer groups, environmentalists, property owners, and business owners;
    - Distinguish between community-wide risk and risk to individual property owners;
    - Convey the "moving target" nature of the flood risk (due to urbanization, climate variability, and global warming).

- Develop decision support systems that would help local decisionmakers in their deliberations about development, growth, infrastructure, resource preservation, and other issues. With such systems, the potential impacts from different levels of floods under different community scenarios can be assessed and even quantified, thus providing a more complete basis for decisionmaking.
- Find ways to capitalize on "teachable moments" to improve people's understanding of flood risk and uncertainty.
- Investigate people's expectations of the 1% flood standard and its associated practices and programs, and what it all means to their personal well-being.

Pilot Projects and Case Studies Needed

Innovations, improvements to existing practice, and the application of new technology and techniques to floodplain management all have a greater impact when they are illustrated through on-the-ground examples. The projects listed here are those that the Forum participants believed would best help show other practitioners, decisionmakers, and/or the public how to better use existing information, techniques, data, and technology or apply it in ways that are feasible but have not yet been widely used or accepted. Demonstration and documentation of these techniques, Forum participants believe, will serve both to refine techniques and approaches and to foster their broader use.

- Quantify both the accuracy and effectiveness of the 1% annual chance standard in specific riverine and coastal situations, such as in the hurricanes of 2004.
- Conduct case studies to identify and evaluate factors leading to inaccuracy in mapping and management. Compare inundated areas (actual or modeled) with predicted flood levels.
- Conduct pilot studies using risk and uncertainty methods to evaluate their applicability to floodplain management.
- Demonstrate the use of three-dimensional visualization models to show the flood hazard now and over time and in specific circumstances, for outreach and education. Such models need to incorporate other relevant hazards, such as erosion and wave impacts in coastal areas. Find ways to depict future development, the uncertainty of the floodprone area's boundary, the flood surface elevations, and other concepts.
- Develop "model" approaches or best management practices to design complementary mapping and management techniques for different types of watersheds. For example, a model approach for a developing watershed could be that the flood mapping be based on future-conditions hydrology, unless there were requirements to prevent increased runoff. Or, in a watershed whose floodways are not static (such as those with alluvial fans or moveable bed streams), the flood maps should reflect the likelihood of future changes, and the management techniques the community uses should compensate for this uncertainty.

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Appendix A

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Appendix B

Agenda from 2004 Assembly

Tuesday September 21

2:00 PM **Welcome**—Bill Hooke, Natural Disasters Roundtable
Larry Olinger, ASFPM Foundation

Self introductions, explanation of process—Larry Larson, ASFPM

3:00 5:00 **Setting the Stage**—Larry Larson, moderator

Presentations on each of four major themes, with time for discussion

- History of use of 1% standard—Gerry Galloway, Titan Corp
- How does technology affect use of the 1% standard?--David Ford,-David Ford Consulting Engineers Inc.
- Implementation of the 1% chance standard—Chad Berginnis, Ohio Dept. of Natural Resources
- Societal implications of the 1% chance standard or changes in it—Dennis Mileti, Natural Hazards Center

5:00-7:00 **Reception**

With the help of beverages and hors d'oeuvre, participants can mingle among stations matching the four main topics (above) to interact and provide additional thoughts.

Wednesday September 22

8:30-9:00 **Opening remarks, summary of previous evening's discussions—**
Gerry Galloway and Doug Plasencia, AMEC Earth and Environmental

9:00- 10:40 **Lessons learned from the past—**
Mike Armstrong, ICF Consulting, Gerry Galloway, Doug Plasencia, facilitators

The assembly will split into three groups to consider the following questions:

- What is the purpose of setting a standard?
- How well has 1% standard met that purpose , and can it continue to do so (considering technology, policy, legal considerations, and implementation issues)?

11:00-12:00 **Feedback session 1**—Report from a selected representative of each group, with discussion from the assembly

12:00-1:00 **Lunch**

1:00-2:00 **Future options to achieve flood loss reduction—**

Mike Armstrong, Gerry Galloway, Doug Plasencia, facilitators

Three groups will consider the following questions:

- What are the options for change (considering technology, policy, legal considerations, and implementation issues)?
- What are the obstacles to change (considering the same factors)?
- What roles can/should be played by local, state, and federal governments, non-governmental organizations, and the private sector?

2:00-3:15 **Identifying Next Steps—**

Gerry Galloway, facilitator

This plenary discussion will explore these questions:

- What are the best options for a standard?
- What don't we know to make them work?
- Where are the gaps in research, data, and implementation?

3:15-3:30 **Wrap up—**Larry Olinger and Larry Larson

Identify next steps for the ASFPM Foundation, the ASFPM, and others.

Topic for next year's Assembly?

Appendix C

List of Supplemental Materials

The Background Papers and the Historical Documents have been published separately on a compact disk and posted on the ASFPM website at **http://www.floods.org**. The contents of both these collections are listed below.

Background Papers

These technical papers were submitted as background reading for the 2004 Assembly of the Gilbert F. White National Flood Policy Forum.

Part 1. History and Use of the 1% Chance Flood Standard

HISTORY OF THE 1 PERCENT CHANCE FLOOD STANDARD
Michael F. Robinson

THE EVOLUTION OF THE 100-YEAR FLOOD STANDARD
John R. Sheaffer

WHY THE 100 YEAR FLOOD STANDARD
Richard Krimm

THE "BASE FLOOD STANDARD" — HISTORICAL PROSPECTIVE
Francis V. Reilly

NOTES ON PROBABILITY ANALYSIS AND FLOOD FREQUENCY STANDARDS
Martin Reuss

THE DURABILITY OF THE ONE PERCENT/100 YEAR FLOOD STANDARD DESPITE ITS MANY FAULTS
Rutherford H. Platt

FLOOD STANDARDS IN OTHER COUNTRIES
Firas Makarem and Vincent Parisi

BINATIONAL PERSPECTIVES ON FLOOD RISK
Lisa Bourget and Ted Bailey

SHORTCOMINGS IN THE 1% CHANCE FLOOD STANDARD
Dingle Smith

LIVING WITH THE 1% FLOOD STANDARD — HELP OR HINDRANCE?
William R. Dawson

OBJECTIVE GUIDANCE OF FLOODPLAIN USE
L. Douglas James

EVALUATION OF THE NATIONAL FLOOD INSURANCE PROGRAM
Rich Tobin

Part 2. Tools and Technology as applied to the 1% Chance Flood Standard

DIGITAL ELEVATION TECHNOLOGIES —
NEW PARADIGMS FOR FLOOD RISK ASSESSMENTS
David F. Maune

ROLE OF MAPPING IN SETTING FLOOD STANDARDS
Dean Djokic

WILL THE DATA SUPPORT MODELING FOR A NEW STANDARD?
Wilbert O. Thomas, Jr.

RISK OF EXTREME EVENTS, RELIABILITY,
AND THE FALLACY OF THE EXPECTED VALUE
Yacov Y. Haimes

CONTEMPORARY RISK ANALYSIS AS THE FOUNDATION OF
A NEW NATIONAL FLOOD STANDARD
Darryl W. Davis

ASSIGNING THE 1% FLOOD: LESSONS FROM RISK ANALYSIS
Gregory B. Baecher

Part 3. Implementation of the 1% Chance Flood Standard

LESSONS LEARNED FROM THE CRS RELATED TO THE 1% CHANCE FLOOD
Jerry Foster

POTENTIAL EFFECTS OF CHANGING THE 1% CHANCE FLOOD STANDARD ON STATE DAM SAFETY PROGRAMS
Keith Banachowski

USE OF THE 90TH PERCENTILE FLOOD ESTIMATE
Leslie A. Bond

ARE WE REALLY MAPPING/MANAGING THE 1% CHANCE FLOODPLAIN?
Alan Lulloff

BRIDGING THE GAP BETWEEN FLOODPLAIN MANAGEMENT AND FLOOD FORECASTING—THE FEMA 1%-CHANCE FLOOD AND THE NATIONAL WEATHER SERVICE FLOOD CATEGORIES
Mark Kolowith, Doug Marcy, Glenn Austin, Margaret Davidson

A PERSPECTIVE ON FLOODPLAIN MANAGEMENT PRACTICES
FROM THE HYDROLOGIC WARNING COMMUNITY
Kevin Stewart

THE RESIDUAL FLOOD RISK BEHIND CALIFORNIA'S LEVEES
Ricardo S. Pineda

THE NATION'S LEVEES AND THE FEMA MAP MODERNIZATION PROGRAM:
THE COMING CHALLENGE FOR NATIONAL RISK MANAGEMENT
Edward J. Hecker and Ronald Conner

PLANNING AND THE 100-YEAR FLOOD STANDARD
Peter Hawley

BUILDING STANDARDS AND THE 1% ANNUAL CHANCE FLOOD STANDARD
Chris Jones

ARE NATURAL AND BENEFICIAL FUNCTIONS OF FLOODPLAINS BEING AFFECTED BY THE 1% CHANCE FLOOD STANDARD?
David Conrad

HOW THE 1% STANDARD RELATES TO PROTECTION OF NATURAL AND BENEFICIAL FUNCTIONS OF FLOODPLAINS
Chad Berginnis

DEFINITION OF A NATURAL—VERSUS REGULATORY—FLOODWAY TO PROTECT BENEFICIAL FLOODPLAIN FUNCTIONS
Kevin G. Coulton

HOW DOES THE 1% STANDARD AFFECT FEDERAL HIGHWAY ADMINISTRATION PROGRAMS? WHAT MIGHT CHANGES IN THE STANDARD MEAN?
Rick Capka, Larry Arneson, Jorge Pagan, and Joe Krolak

NRCS PERSPECTIVES ON THE 100-YEAR FLOOD STANDARD
Bruce Julian

IMPROVING IMPLEMENTATION OF THE 1% FLOOD STANDARD
Bill DeGroot

MODIFICATIONS NEEDED IN IMPLEMENTATION OF THE
1% CHANCE FLOOD STANDARD
Dennis Lawlor

WHAT DOES THE 1% FLOOD STANDARD MEAN?
REVISITING THE 100-YEAR FLOOD
R. M. Hirsch, T. A. Cohn, and W. H. Kirby

THE BENEFITS OF INTEGRATING PRE-DISASTER MITIGATION AND WATERSHED MANAGEMENT
John Meagher

Part 4. Societal Implications of the 1% Chance Flood Standard

ISSUES AND PERSPECTIVES ON FLOODPLAIN MANAGEMENT
Russell W. Riggs

A LEGAL PERSPECTIVE ON THE 100 YEAR FLOOD STANDARD
Jon Kusler

RAISING THE NATIONAL STANDARD FOR FLOOD PLAIN MANAGEMENT—
EDUCATION OF THE PUBLIC AND POLICY MAKERS
Larry S. Buss

INSURANCE ALONE IS NOT ENOUGH —
UNDERSTANDING THE FLOOD HAZARD IS THE KEY
Clive Q. Goodwin

COMMUNICATING WHAT THE 1% CHANCE FLOOD MEANS
Robert Ogle

LENDERS AND THE 100-YEAR BASE FLOOD
Michael Moye

THE ENHANCED BENEFITS ACCRUED FROM INCENTIVE-BASED PLANNING VS.
REGULATORY PLANNING
Cherry Jackson

THE 1% STANDARD – AN APPROPRIATE IDENTIFICATION OF RISK
Christopher S. Galik

PERCEPTIONS OF RISK FOR THE 1% CHANCE FLOOD
James K. Murphy

Historical Documents

A collection of pertinent historical documents and excerpts has been published separately on a compact disk and posted on the ASFPM website at **http://www.floods.org**.

A Unified National Program for Managing Flood Losses. House Document 465, report of the Bureau of the Budget Task Force on Federal Flood Control Policy, 1966.

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Other selected documents