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Natural Hazard Risk Assessment and Public Policy

Anticipating the Unexpected

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With 89 Figures

Springer-Verlag
New York Heidelberg Berlin

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On the front cover: A visible spectrum image, taken at 2200 Greenwich Mean Time (4 PM Eastern Daylight Standard Time) on August 7, 1976 from NOAA's Eastern Geostationary Satellite (GOES-EAST) located at 75° W longitude, 36,000 km above the Equator. Hurricane Belle is located at approximately 27° N and 74° W, northeast of the Bahama Islands. This low sun angle image clearly shows the internal structure of the clouds arcing the hurricane. Photo courtesy of the United States Department of Commerce, National Oceanographic and Atmospheric Administration.

Library of Congress Cataloging in Publication Data
Petak, William J.
Natural hazard risk assessment and public policy.
(Springer series on environmental management)
Bibliography: p.
Includes index.
1. Natural disasters. I. Atkisson, Arthur A. II. Title. III. Series.
GB5014.P47 1982 363.3'49 82-10468

 This book was prepared with support of NSF Grant ERP-75-09998. However, any opinions, findings, conclusions, and/or recommendations herein are those of the authors and do not necessarily reflect the views of NSF.

Typeset by Ms Associates, Champaign, Illinois
Printed and bound by R.R. Donnelley & Sons Company, Harrisonburg, Virginia
Printed in the United States of America

9 8 7 6 5 4 3 2 1

ISBN 0-387-90645-2 Springer-Verlag New York Heidelberg Berlin
ISBN 3-540-90645-2 Springer-Verlag Berlin Heidelberg New York

Series Preface

This series is dedicated to serving the growing community of scholars and practitioners concerned with the principles and applications of environmental management. Each volume is a thorough treatment of a specific topic of importance for proper management practices. A fundamental objective of these books is to help the reader discern and implement man's stewardship of our environment and the world's renewable resources. For we must strive to understand the relationship between man and nature, act to bring harmony to it, and nurture an environment that is both stable and productive.

These objectives have often eluded us because the pursuit of other individual and societal goals has diverted us from a course of living in balance with the environment. At times, therefore, the environmental manager may have to exert restrictive control, which is usually best applied to man, not nature. Attempts to alter or harness nature have often failed or backfired, as exemplified by the results of imprudent use of herbicides, fertilizers, water, and other agents.

Each book in this series will shed light on the fundamental and applied aspects of environmental management. It is hoped that each will help solve a practical and serious environmental problem.

Robert S. DeSanto
East Lyme, Connecticut

Preface

Throughout history, individuals and governments have sought means for limiting the adverse impacts associated with the exposure of people and property to the hazards of the natural environment. In the United States, the hazards of major concern have included riverine flood, coastal storm surge, tsunami, earthquake, expansive soil, landslide, hurricane wind, and severe wind.

In attempts to mitigate the effects of exposures to these hazards, rivers have been dammed, deepened, and diked; coastlines have been equipped with seawalls; storm cellars have been dug in backyards; buildings have been elevated above the level of expected flood heights; and structures have been strengthened to reduce their vulnerability to these forces. Numerous types of building strengthening, area protection, site development, and other technologies are available to reduce the risks associated with exposure to natural hazards, and their mandatory application can be forced through adoption and enforcement of a wide variety of federal, state, and local public policies. Also, the risk of loss may be spread through use of insurance schemes, and the impact of catastrophic hazardous occurrences on exposed populations may be reduced through disaster relief and recovery measures financed by nonimpacted parties.

However, every public and private response that can be made to the risks presented by natural hazard exposures imposes costs on someone, somewhere, at some time. In some cases, the costs of such ventures may exceed the value of the risk reduction produced by the purchased mitigation. In still other cases, the use of the mitigation may engender a false sense of public security and lure additional numbers of people into contact with hazardous areas, thereby increasing the total losses associated with such exposures. What to do about the continuing exposure of people and property to natural hazards is, therefore, both a question of considerable complexity as well as one of increasing importance to public policy makers at federal, state, and local levels. Should building code requirements be strengthened? Should governmentally enforced restrictions be imposed on the use of such hazardous areas as floodplains, earthquake-prone sites, and steep hillsides subject to land slippage? What public problems are posed by the voluntary and involuntary exposure of people and property to natural hazards, and what problems might be produced by public effort to control such exposures?

It is to these and other important questions that this book is addressed. Based primarily on a project funded by the National Science Foundation under Grant ERP-75-09998, the book also contains material derived from a project conducted for the Federal Emergency Management Agency and another funded by the Federal Insurance Administration. In none of these studies, nor in this book, has it been our intention to tell policy makers what solutions should be applied to hazard induced public problems. Rather, we have sought to present data and conclusions that may aid policy makers in performing this task. Specifically, we identify: the various stakeholder groups whose interests are bound up in hazard exposure and hazard mitigation situations; candidate lists of possible public problems; the range of technologic and policy options that may be appropriate to solving each listed candidate problem. Further, we identify and assess the more important costs and benefits associated with each policy option, and we demonstrate how risk analysis can be applied in defining public problems and assisting in the policy-making process.

Our research used risk analysis techniques that resulted in: (1) the generation of annual expected natural hazard loss estimates for 1970 and 2000; (2) the identification of specific strategies and technologies theoretically capable of reducing such losses; (3) the identification of the amortized annual costs associated with selected mitigation strategies; (4) the identification of the candidate public problems and stakeholder groups associated with natural hazard exposures and alternative technology-forcing policy options; (5) the identification and critical evaluation of past and current public policies, institutional arrangements, and administrative practices aimed at mitigation of natural hazards losses; (6) the identification and assessment of the contemporary social, technical, administrative, political, legal, and economic constraints on natural hazards policy making operations; and (7) the development and assessment of policy options appropriate for coping with hazard-related public problems between 1970 and 2000.

Although we accept full responsibility for the conclusions and approaches that appear in this book, we acknowledge the formidable debt we owe the individual members of the several teams of investigators participating in the total effort. Their patient understanding and their help in educating us about previously unknown subjects and techniques made our work possible. Specifically, we wish to acknowledge Jon Chrostowski, Ronald Eguchi, Dr. Peter Gordon, Dr. Gary Hart, Joseph Hirschberg, James Krohn, Larry Lee, Dr. James Slosson, and Dr. John Wiggins. Their contributions are all well documented in the reports listed in the bibliographies.

Dr. Daniel Alesch and Dr. Michael Kraft of the University of Wisconsin-Green Bay deserve special acknowledgment for their contributions to the policy analysis recommendations.

Special thanks are due Shirley Kay, Chris Burch, Marge Judge, Nancy Mulford, Jean Atkisson, and Beth Petak, who were largely responsible for manuscript preparation. Also, special thanks are due Ramona Petak for her able assistance in preparation of the book index. Their tasks proved to be the most laborious. We wish also to acknowledge the very large extent to which the professionally challenging environment of the J. H. Wiggins Company contributed to the completion of the several federally funded studies that are the real parents of this work. Through the support of the company, engineers, economists, management scientists, geoscientists, policy scientists, and computer system specialists were assembled and fused into effective working teams.

Finally, special acknowledgment is due Dr. Charles Thiel, formerly a member of the research staff of the National Science Foundation and the Federal Emergency Management Agency, and Dr. G. Patrick Johnson, National Science Foundation, for their consistent support and patience while we were completing this very difficult project.

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August 16, 1982

Contents

PART I

ANTICIPATING THE UNEXPECTED AS A FOCUS OF PUBLIC POLICY

Public policies are the authoritative *megadecisions* or choices made by, or on behalf of, legally recognized groups of people that guide future subsidiary decisions. As authoritative decision-constraining guides, public policies may deal with the end states to be achieved by future decisions, with the means to be used or avoided in reaching those ends, with other special conditions to be observed in making and implementing such decisions, and with various combinations of the above.

Public policies are embedded in such documents as statutes, ordinances, constitutions, executive orders, regulatory rules and regulations, and opinions of judges.

Typically, public policies are directed at the elimination or reduction of the *public problems* associated with some set of *social impacts*, at the distribution of the benefits of problem-solving activity to one or more stakeholder groups, and at the imposition of problem-solving costs on some such groups. Social impacts consist of the observable primary, secondary, and higher-order consequences associated with some set of causal phenomena, and are raised to the status of public problems when they produce socially unwanted gaps between the states of affairs that are socially desired, or expected, and the states of affairs that are socially perceived to be extant.

Throughout history, such socially unwanted gaps have been created by a rich variety of causes, including the exposure of people and property to hazardous natural events. Volcanic eruptions, riverine and coastal flooding, forest fires, and many other natural events have produced consequences of such magnitude in some communities and societies that they have become public problems.

In terms of those potential problem-causing situations in which the probabilities of event occurrences and their consequences may vary widely from year to year, considerable attention is now being directed to anticipating the unexpected, that is, to the application of risk analysis methods to policymaking. As a formal system for aiding policy makers in reaching rational decisions, the methods of risk analysis may be considered as consisting of those aimed at (1) the identification of risk, (2) the estimation of risk, and (3) the evaluation of risk. Risk estimation is concerned with determining the probabilities that some series of events of various magnitudes will occur in the future, specifying the associated consequences, and identifying the populations exposed to such risks. On the other hand, risk evaluation is concerned with assessing the importance of the identified risk factors to the various stakeholders whose interests are embedded in the candidate problem situations.

In the three chapters included in this section, we examine the attributes of nine natural hazards, the range of primary, secondary, and high-order effects produced, and the role of risk analysis in defining and assessing the associated candidate problems. The characteristics of the American public policy system are examined as are the roles of risk analysis, problem analysis, policy analysis, and technology assessment in the making of major policy decisions. In this section we examine the past and current public policies which have been employed in the United States for the management of natural hazards, and present the concepts which are necessary to understanding the use of the findings presented in later sections of the book.

1
Natural Hazards as Public Policy Problems

Introduction

Throughout history public policy makers have sought to anticipate the unexpected in order to reduce the risk to human life and safety posed by intermittently occuring hazardous natural and man-generated events. The Code of Hammurabi (circa 1950 B.C.) decreed that should a house collapse and kill the occupant, the builder of the house must forfeit his own life. Etched on the cliffs of ancient Babylon, the code was designed to serve the same people who were troubled not only by hazardous structures created by other people, but also by the intermittent flooding of their fertile plains, which lay between the Tigris and Euphrates Rivers. Prompted by the need to record and predict such flooding, the Babylonians developed crude systems of mathematics, laid the intellectual groundwork for the modern field of hydrology, and developed government financed systems for flood control and irrigation.

However much the pre-Hammurabi Babylonians may have viewed building collapse and community flooding as the acts of some malevolent God, as unexpected events to be borne as the natural concomitant of human existence, it is clear that succeeding generations comprehended that the periodicity of floods can be predicted, their causes understood, and that corrective loss bearing measures can be applied by government. They believed buildings collapsed not because of some natural law, but due to carelessness and oversight by their builders. At least these threats to human life and safety could be controlled through the design and enforcement of appropriate public policies.

The lesson is being relearned by contemporary decision makers worldwide. Government sponsored risk management programs now attract increased attention by policy makers at the highest levels of government and the electorate. No matter what the source of risk to human life, safety, and well-being, these electorates now demand that government reduce the uncertainties associated with hazardous events and design and enforce policies to mitigate their effects.

Natural Hazards as Candidate Problems

Natural hazards consist of such phenomena as avalanches; earthquakes; expansive soils; forest, field, marsh, and prairie fires of natural origin; hailstorms; hurricane winds; landslide; lightning; riverine flooding; coastal storm flooding; urban headwater flooding; severe rain, snow, and ice storms; land subsidence; tornadoes; tsunamis; and volcanic eruptions. Each has caused much human suffering and economic loss in earlier periods of history and each continues to do so in the modern world.

There are 516 active volcanoes from which eruptions occur approximately once every 15 days. Monitoring instruments currently record approximately 2000 tremors beneath the crest of the earth's surface each day, and almost twice each day earthquakes of sufficient magnitude to damage buildings and other structures occur. Quakes of sufficient strength to produce widespread damage and death occur 15 to 20 times each year. Above the surface of the earth 1800 orbiting thunderstorms can be observed at any given time, and lightning strikes the planet's outer skin at the rate of 100 times per second.

In late summer, 50 or more hurricanes can be observed forming somewhere in the world, and during approximately the same season of the year from 600 to 1000 tornadoes strike somewhere within the United States at a rate of 4 or more strikes per day. Nearly one half billion members of the planet's total population now reside in riverine and coastal floodplains where they produce one-third of the world's food production; and, on any given day, some fraction of these plains are covered by floodwaters.

Almost no portion of the earth's surface is free from the risks produced by hazardous natural events. Some of these occur infrequently, but with catastrophic results. For example, over the past 10,000 years, Mt. Ranier in the northwestern corner of the United States has produced 12 volcanic ash eruptions, one or more lava flows, several hot avalanches of rock debris, and at least 55 large mudflows. As noted by Foster (1980) one of the largest of these deposited 2.5 billion cubic yards of material over approximately 125 square miles in the now populated lowlands of Puget Sound.

Most of the coastal Minoan cities on the island of Crete were destroyed by an enormous tsunami (giant seismic sea wave) that struck the island between 1450 and 1480 B.C. The tsunami apparently was generated by numerous violent earthquakes accompanying a major volcanic eruption on the island of Santorin.

Twenty-one years before the adoption of the Declaration of Independence, earthquakes shattered Massachusetts, and during the War of 1812, the highest magnitude earthquake in the history of the United States left parts of Missouri and Arkansas permanently sunken. In the immediate post-Civil War years another devastating earthquake struck South Carolina, and in 1871 a forest fire consumed Peshtigo, Wisconsin, and caused 1182 deaths. In 1889, flood waters claimed 2209 lives in Johnstown, Pennsylvania, on a single day, and 11 years later (September 8, 1900) the largest civil disaster in U.S. history occurred when a "great" hurricane pushed the waters of a storm surge over Galveston, Texas, and caused 6000 deaths. Only two years later, but at another point on the globe, a volcanic eruption from Mt. Pelee produced a flowing avalanche that struck the city of St. Pierre and killed 30,000. On April 18, 1906 a "great" earthquake rocked San Francisco and together with the resulting fires caused 500–700 deaths and more than $374 million in property damage. In September 1928, a Florida hurricane caused 1833 deaths over a two-day period, while the previous March a California dam collapse sent a wall of water over an unwary populace and swept 450 to their deaths. Many of these natural disasters prior to 1930 rank among the most severe civil calamities in U.S. history, having claimed more lives per event than the sinking of the Titanic in 1912 (1517 dead); the Texas City ship explosion of 1947 (561 dead); the Coconut Grove Night Club fire of 1942 (492 dead); the Monongah, West Virginia, coal mine explosion of 1970 (361 dead), and the worst air traffic accident in history in March 1977 (581 dead).

In more recent years, the Palm Sunday tornadoes of 1965 claimed 271 lives in five states; hurricane Camille (1969) destroyed over $1.4 billion in property and caused 256 deaths; the South Dakota flash flood of 1972 killed 236; the Alaska earthquake (1964) claimed 131; and Agnes, the hurricane and tropical storm of 1972, caused 118 deaths and the loss of more than $3.1 billion in property. Also, on a single day in 1974, tornadoes caused 318 deaths in several southern and midwestern states. Two years later, a major earthquake occurred in Tangshan, China, and resulted in an estimated 750,000 deaths (Frazier, 1979).

Although less dramatic in their impact, a variety of other natural hazards during these same time periods also produced considerable property damage and substantial annual economic losses. These hazards include expansive soils, land subsidence, landslides, the erosion of river and shore banks, droughts, and storms of hail, ice, snow, and rain.

In our efforts to mitigate the effects of exposures to natural hazards, population warning systems have been placed in operation, and rivers have been dammed, deepened, and diked. Coastlines have been equipped with seawalls; storm cellars have been dug in backyards; buildings have been elevated above the level of expected flood heights; and a variety of means have been employed to strengthen structures and thereby reduce their vulnerability to the forces exerted by winds, land movement, and other natural hazards. Sadly, however, these efforts have produced less than satisfactory results.

Construction of flood control facilities has seemed to prompt heavy migration into flood-prone areas and has thereby increased the real costs of flood exposures. Governmental provision of disaster relief, low cost loans, and subsidized insurance has seemed to encourage, rather than inhibit, private risk-taking activity. A public unwillingness to acknowledge the threat of future loss-producing occurrences in high-hazard areas, and an accompanying faith that government will somehow protect them, have contributed to a continuing population movement into such high-hazard areas as the hurricane and flood-prone belts of water-adjacent areas along the Gulf Coast and South Atlantic. Similar population movements have occurred in seismically active areas and along the shores of rivers and lakes subject to periodic flooding. As a result, the United States now faces the probability that one or more major community catastrophes, each far greater in loss of life and property than any previous one, may occur during the next several decades. But similarly, we also face the risk of overreacting to the threats posed by natural hazards, through implementation of public policies that may produce costs far in excess of their potential benefits.

Numerous types of building strengthening, area protection, site development, and other technologies are available to reduce the risks associated with exposure to natural hazards, and the mandatory application of these technologies can be forced through federal, state, and local public policies.

Hazard-mitigating amendments to building codes, subdivision standards, and land use regulations can be enacted. Hazard zone identification measures can be adopted, and legally sanctioned systems for avoidance of development in such areas can be inaugurated. The risk of loss may be spread through use of insurance schemes, and the impact of catastrophic hazardous occurrences on exposed populations may be reduced through community safety plans, disaster relief, and recovery measures financed by nonimpacted parties.

What mix of these measures to employ, when, where, at what cost, and to whom, has therefore become a major public policy question, influenced greatly by the public attitudes and emotions of the moment. Public and governmental responses to hazardous natural occurrences vary. Studies performed by other researchers have shown that the immediate aftermath of a severe, disaster-scale event is characterized by high levels of public support for governmental action to avert future disasters. Such support may be exhibited both by hazard area residents and people far removed from the disaster site. Indeed, media exaggerations of disaster impacts increase with distance from the disaster site, and "outsiders," in general, tend both to overestimate the recovery needs and exaggerate the real impacts on the affected communities. Those who did not experience the disaster tend to deny that they too may be threatened by a similar future occurrence on their home turfs, but for a while tend to support governmental action to aid those less fortunately located.

Within the hazard area, the immediate time period following the occurrence of a severe natural event may be characterized by a high level of public interest in ways to avert future disasters and a flurry of public policy proposals may be generated. However, between natural disasters, there is generally a lack of public interest in hazard-related legislation and a corresponding lack of legislative activity. In contrast, during the emotional period immediately following a disaster, many hazard-targeted legislative proposals may be advanced and enacted into law, many of which may be imprudently drafted. Moreover, the magnitude and social impacts of the event may be grossly exaggerated.

Depending on the nature of the hazard, the immediate postevent period may see a variety of public policy actions. Hillside lots may be zoned to limit the use of slide-prone areas by all but the most carefully engineered structures; building