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CHAPTER 7

Risk from Nature in the City

Duane D. Baumann and Robert W. Kates

The modern city is the ultimate human artifact. Yet 3,800 years after the city of Mohenjo-Dara disintegrated in the rising of the Indus River, 1,900 years after Vesuvius engulfed Pompeii, and 215 years after earthquakes destroyed Lisbon, risk from nature persists in the city of man. The natural hazardousness of cities arises from the impact of natural events on an urban structure that at best is only partly designed to absorb, buffer, or reflect such events, and that at worst exacerbates them. The degree of hazard is a result of the frequency, duration, magnitude, and timing of natural events as well as of the extent of human adjustment to those events. The burden of hazard is twofold: (1) death and damage from events that exceed the human adjustments to hazards and (2) the continuing cost of adjustment in terms of wealth and energy.

Man is subject to numerous natural hazards, many of which are listed in Table 7.1. All of these common hazards can affect cities or their populations, depending upon regional location. Research into the nature and occurrence of natural hazards has in the last 15 years been closely linked to studies of human perception of these hazards and the adjustments people make to them. It has been recognized by both geographers and psychologists that the environment is viewed in varying ways by different individuals and societies. Even within a given society, the general public and the decision-makers – technicians, scientists, and administrators – may perceive environmental events in very

Table 7.1. Common natural hazards by principal causal agent. (After Burton and Kates 1964.)

Geophysical		Biological	
Climatic and Meteorological	*Geological and Geomorphic*	*Floral*	*Faunal*
Blizzards and snow Droughts Floods Fog Frost Hailstorms Heat waves Hurricanes Lightning strokes and fires Tornadoes	Avalanches Earthquakes Erosion (including soil erosion and shore and beach erosion) Landslides Shifting sand Tsunamis Volcanic eruptions	Fungal diseases *For example:* Athlete's foot Dutch elm Wheat stem rust Blister rust Infestations *For example:* Weeds Phreatophytes Water hyacinth Hay Fever Poison Ivy	Bacterial and viral diseases *For example:* Influenza Malaria Typhus Bubonic plague Venereal disease Rabies Hoof and mouth disease Tobacco mosaic Infestations *For example:* Rabbits Termites Locusts Grasshoppers Venomous animal bites

different ways. In short, the manner in which a society perceives its environment will significantly influence the adaptations that are made.

In attempting to understand man's perception of environment, investigators have focused on natural hazards – "those elements in the physical environment harmful to man and caused by forces extraneous to him" (Burton and Kates 1964, p. 413). There are several advantages to studying hazards: (1) hazardous events have greater than normal magnitude and require many adjustments to mitigate or prevent damage and loss of life; (2) hazardous events are often catastrophic (in terms of damage) and, therefore, loom large in terms of human interest and priorities; and (3) they hence make a great impression on the human memory, and thus are particularly amenable to scientific investigation of human perception and values regarding nature.

This chapter assesses the natural hazardousness of urban areas and the trends in risk from natural causes. It is useful first to review differences that exist between the actual magnitude and frequency of hazardous events and the affected populations' perceptions of the magnitudes and frequencies. A discussion of several hazards then follows. Finally, some answers are provided to the question: Is natural hazard increasing in the city, and if so, what actions can be taken to reduce human risk?

THE NATURAL HAZARDOUSNESS OF A PLACE

The Example of London, Ontario

To appreciate the meaning of natural hazards to an urban population, it is useful to describe the experiences of a "typical" city. Studies by Hewitt and Burton (1971) indicate that London, Ontario, is such a place. But the discussion cannot focus on the city alone. To understand natural hazards in this city of some 200,000 people, it is necessary to consider the entire southwestern region of Ontario, because the spectrum of events giving rise to natural hazards results from environmental conditions throughout the area, the bulk of which stem from meteorological and related hydrological processes.

Ontario is significantly affected by severe convectional storms and tornadoes. In addition, London lies on the fringe of a heavy, lakeshore snowfall belt and, like all of southern Ontario, is highly susceptible to glaze storms. A major stream runs through London (the Thames, naturally), and it frequently floods owing to high spring runoff aggravated by ice jams. Hurricanes pose significant wind, rain, and flood hazards in late summer and autumn. Hailstorms, though frequent, cause little urban hazard, and drought, though rare, is basically a threat only to agriculture.

How can we characterize this complex of natural hazards? Within the region of southwestern Ontario, Hewitt and Burton expect (on the basis of past records and with differing degrees of assurance) the following severe events over a 50-year period: 1 drought, 2 windstorms, 5 snowstorms, 8 hurricanes, 10 glaze storms, 16 floods of the Thames, 25 hailstorms, and 39 tornadoes. What does that mean for the resident of London? For example, although a tornado will occur about every 1.3 years somewhere within the region, its recurrence is estimated at 400 years for urbanized areas and 2,000 years at any given point location within the region!

Let us personalize the London data. If we were young adults spending the rest of our lives in London, we should expect sometime to see one truly great snowstorm, one hurricane, two major floods in the Thames, and at least three paralyzing glaze storms in which we would be without electricity for more than a week. We should not be greatly surprised by a tornado, nor by any of the other rare but possible disasters, such as a hurricane centered over the Thames basin or a glaze storm followed by a paralyzing snowfall.

How threatening, therefore, is nature to the London resident? In absolute terms it would not appear to be very threatening, if the experience of the past is a key to the future. At most, six natural disasters have been recorded in the past 100 years. Is, then, nature only a minor threat relative to hazards introduced by man? London was almost destroyed by fire in 1845; 180 died in the capsize of a ferryboat in 1881; and 19 died when the second floor of the City Hall collapsed in 1898. Further, a major fire occurs less than once per year and an explosion occurs once in 4 years. Where disasters are concerned, man and nature seem to be about equal threats.

A comparison of the occurrence of both man-made and natural disasters at London to similar events at other urban places bears out this assessment of the relative threats of nature and man. Hewitt and Burton examined the 1958 to 1967 occurrence of disaster (loss of 10 or more lives or $500,000 damage, or both) for 57 cities of about London's population (see Table 7.2). Disasters, it appears, occur about equally from natural and man-made causes, with an expectancy of slightly over three from each cause per century. This accords well with the experience of London over the past 100 years as well as with the record of disasters for all North America in a single year. Using 1967 as a reference year, we can calculate that disasters should occur once in 21 years. London, therefore, approximates the mean of hazardousness as measured by the disaster definition.

Table 7.2. Average frequencies of disasters, 1958-1967, for 57 cities. (After Hewitt and Burton, 1971).

	Natural	*Man Made*	*Total*
Total city-years	570	570	570
No. of disasters	17	18	35
Return period (years)	33.5	30.0	16.3

The Magnitude-Frequency Concept

It is apparent from the discussion of London, Ontario, that at most places only a few natural events will occur during a human lifetime that are deemed "disasters" by the affected populace. Most natural events – for example, rainstorms – occur very frequently but are of low magnitude. In other words, *most* storms are relatively small and do not seriously disrupt human beings or the terrain on which they live. Occasionally, however, a storm of great magnitude will occur, causing serious damage to the landscape and its inhabitants, loss of life, and disruption of the economy. Such a rare and spectacular work of nature is, in human perspective, a catastrophic event. We do not quickly forget such disasters, and our lexicon of environmental events is replete with examples of nature's destructive force – such as the Johnstown flood, the San Francisco earthquake, the Galveston hurricane, or the Donora smog.

Very often such events carry the names of cities, for the greatest destruction of life and property is in urban areas. Nature, however, does not draw fine distinctions between city and countryside; in both places events occur with varying degrees of intensity and frequency. The *magnitude* of an event refers to its size. Examples are the height of water attained during a flood, the rating of an earthquake on the Richter scale, or the depth of snow accumulated in a winter storm. *Frequency* refers to the number of times a given event occurs during some time period. Magnitude and frequency usually are inversely related; that is, events of great magnitude and force occur infrequently, and vice versa.

It is important that the magnitude and frequency of natural events be understood if scientists are to understand physical processes sufficiently to predict them. To intelligently prepare for natural hazards, communities must be aware of the frequencies at which events of different sizes are likely to recur. An effective image of these potentials has been created in the following analogy by Wolman and Miller (1960, p. 73):

> A dwarf, a man, and a huge giant are having a wood-cutting contest. Because of metabolic peculiarities, individual chopping rates are roughly inverse to their size. The dwarf works steadily and is rarely seen to rest. However, his progress is slow, for even little trees take a long time, and there are many big ones which he cannot dent with his axe. The man is a strong fellow and a hard worker, but he takes a day off now and then. His vigorous and persistent labors are highly effective,

but there are some trees that defy his best efforts. The giant is tremendously strong, but he spends most of his time sleeping. Whenever he is on the job, his actions are frequently capricious. Sometimes he throws away his axe and dashes wildly into the woods, where he breaks the trees or pulls them up by the roots. On the rare occasions when he encounters a tree too big for him, he ominously mentions his family of brothers – all bigger, and stronger, and sleepier.

Although the natural event of great magnitude (like the giant above) is seldom at work, it can cause great disaster in the city. An event of lesser magnitude (like the force of the man above) is generally less destructive, and also more easily prepared against; however, such events occur more frequently than those of great magnitude and, hence, they may *in total* cause more damage. Ordinary events (like the work done by the dwarf) are usually harmless, because they are of slight magnitude and because they occur so frequently that most communities have routinely adopted protective measures against them. Thus, over a term of decades the relative destructiveness of a natural hazard is clearly seen to be a function of its magnitude and frequency and the degree of community preparedness.

CLIMATIC AND HYDROLOGIC HAZARDS

It often is difficult to separate a climatic event from a hydrologic event because one is so closely connected to the other. Flooding, drought, hurricanes, and winter storms are excellent examples. In some cases, however, damage results directly from atmospheric components of the event – in the case of tornadoes, from pressure differentials and very high winds. The purpose of this section is to describe several climatic and hydrologic hazards that significantly affect urbanized places. The first part, on flooding, demonstrates the important relationship that exists between the frequency of a natural hazard event and adjustments that communities may make to combat the hazard. The second part, on tornadoes, illustrates that damage from natural hazards and adjustment to them is not merely a function of understanding the physical process, but is also a reflection of differing human perceptions and cultural attitudes. A discussion of drought in the city then focuses on problems faced by urban planners and other decision-makers. Finally, a section on winter storms briefly defines some problems encountered in communities where perception of and adjustment to a hazard is relatively high.

Flooding

Many urban places are situated on flood plains; these sites usually are level, fertile, on transportation routes, and, of course, near accessible water. Frequently – every few years or so – there is too much water, and flood plain cities are flooded (see Figure 7.1). More than 2,000 cities in North America are located on flood plains. A graph constructed from available flood frequency data on a fourth of these urban places shows a log-normal distribution (Figure 7.2). The figure shows that flooding in a city located on a flood plain occurs, on the average, once every two or three years.

Three insets in Figure 7.2 illustrate perception and adjustment in three cities: Desert Hot Springs, California, LaFollette, Tennessee, and Darlington, Wisconsin. These cities represent places of low, intermediate, and high flood probability, respectively. Response to the

Figure 7.1. A city in flood. The waters of the Red Lake River periodically flood Crookston, Minnesota (shown here on April 23, 1950; population 7,400). (Courtesy of U.S. Department of Agriculture.)

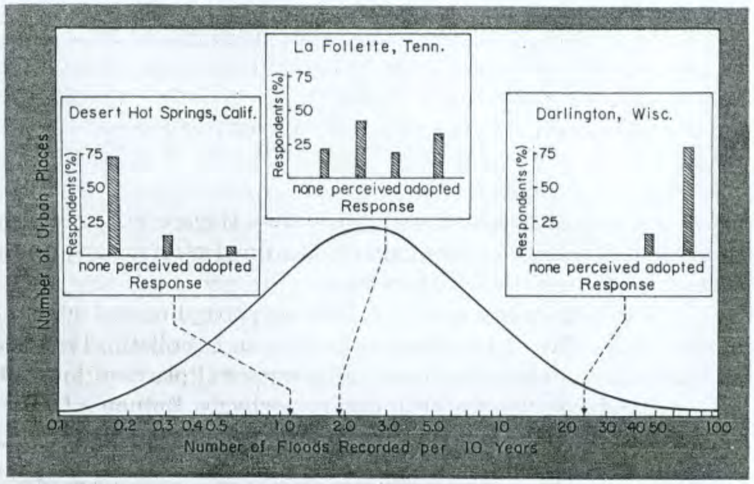

Figure 7.2. Flood frequencies for 496 urban places in the United States. Insets show response in three communities, each experiencing different flood frequencies per ten years. Response ranges from total ignorance (none), to two levels of perception (perceived), to adoption of countermeasures (adopted).

floods (illustrated by the bar graphs) is scaled from total ignorance (none), through two levels of perception (perceived), to adoption of measures to prevent and counteract flooding (adopted). The variation in people's perception of the associated hazard and adjustment to floods relates to the probable frequency of these events. For example, where floods occur often, as in Darlington, people make adjustments; where floods are infrequent, as in Desert Hot Springs, people make few, if any, adjustments in anticipation of flooding events. The majority of places, however, experience 1.4 to 4.0 floods per 10-year period; as exemplified by the LaFollette data, the inhabitants in such places are relatively uncertain whether to adjust to the hazard or not.

The log-normal distribution of places relative to extreme events has not been verified for other hazards, but many studies support the notion of increasing variation in perception and adjustment in areas of great uncertainty. Communities that experience disruptive natural events infrequently are generally those least prepared to cope with the event. If the residents and managers of a city recognize or perceive that a potentially hazardous event is the exception and not the rule, they are generally unwilling to invest in protective measures. In these places floods of a given magnitude will, therefore, cause greater damage than in communities that are prepared.

An interesting corollary that people often accept is exemplified in the expression "lightning doesn't strike twice in the same place." Once a major hazard – such as a 50-year or 100-year flood – has been experienced, there is an assumption that the place is "safe" for another 50 or 100 years. But flood probabilities are based on short-term stream records (see Chapter 5, pp. 101–102) and are not immutable. Also, nature is capricious and a 100-year flood one year may be followed by another 100-year flood the next year. Indeed, a community may find itself on the extremes of the probability curve during a short period of time. Finally, with respect to flood frequency, it must be remembered that urbanization may lead to positive feedback whereby flood hazards increase with city growth (see Chapter 5). Recognition of increased flood dangers may not keep pace with local urban development, and necessary protective measures may be ignored.

Generally speaking, urban and rural flood plain users perceive flood hazards differently (Burton and Kates 1964, p. 428). Urban users of flood plains are less sensitive to hazard potentials than are agricultural users, even where the frequency of hazard is approximately the same for both locations. This difference is largely attributable to the fact that agriculturists are directly affected by floods in the pursuit of their livelihoods and therefore have heightened awareness.

Tornadoes

Tornadoes are among the most feared and destructive natural events. These small funnel-shaped storms can generate winds up to 500 miles per hour and wreak awesome devastation in their path. Atmospheric pressure in the vortex of a tornado is so low that closed buildings may literally explode owing to the pressure differential. The path of tornadoes is erratic and cannot be predicted with precision; several blocks may be destroyed where tornadoes touch down in urban areas, whereas structures only a street away remain virtually undamaged (see Figure 7.3). As cities spread across the landscape, the probability of settled areas being struck by tornadoes increases.

Deaths caused by tornadoes have been continually declining in the United States, although the number of tornadoes has apparently been increasing (see Figure 7.4). The apparent increase in tornadoes is

Figure 7.3. Destruction by a tornado in Oak Lawn, Illinois, a southwestern suburb of Chicago. The arrow marks part of the 16-mile path of this April 21, 1967, storm, which destroyed 129 homes and killed 31 people. (Courtesy of the *Chicago Tribune*.)

largely accounted for by a growing and widespread tornado observation network. From 1916 through 1966 the annual average number of tornado-caused deaths was 193, but for 1953 through 1966 the average was only 122 deaths per year.

The exceptions to this decline, however, are dramatic – not only for a single year, but for a single storm. On April 11, 1965, 271 people were mortally injured by tornadoes that touched down in six midwestern states. In that year, over 300 persons were killed by tornadoes. However, even the peak years, when higher than average deaths result from tornadoes, show a pattern of decline. This is remarkable in light of increased urbanization and population growth.

The development of a national warning system has been influential in the steady decrease of tornado-caused deaths. Prior to 1952,

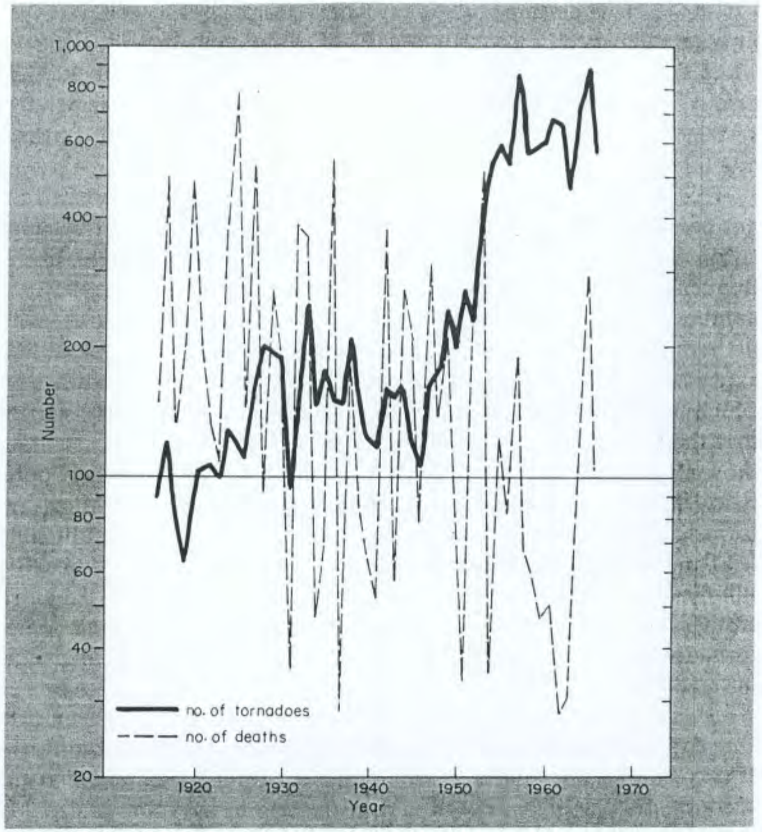

Figure 7.4. Frequency of tornadoes and tornado-caused deaths in the United States.

tornado watches and warnings were not issued by the U. S. Weather Bureau, partly because of a belief by some that widespread panic would spread throughout the public (Bates 1962). However, numerous lives were saved at a U. S. Air Force base in a tornado-prone area after a warning system was instituted in the late 1940's. In 1952 the Weather Bureau undertook the responsibility of forecasting tornadoes. Consequently, as a more elaborate observation network was installed throughout the United States, the number of recorded tornado occurrences rose sharply, while the number of tornado-caused deaths declined

(Figure 7.2). The efficiency of tornado watches and warnings may be illustrated in specific occurrences. For example, on June 8, 1966, when a tornado swept through a densely settled area of Topeka, Kansas, only 17 deaths were recorded; the combination of an efficient warning system and appropriate response to it by the citizenry kept deaths much lower than might have been expected.

From a spatial viewpoint the effects of the tornado hazard have not been uniform throughout the country, even if variations in population density and tornado frequency are considered. The greatest frequency of tornado deaths has occurred in the South. By 1953, the number of tornado deaths in the South was five times the average for the remainder of the nation (Linehan 1957, p. 17). One apparent explanation for the concentration of deaths is that the South has both a high population density and a high tornado frequency; this suggests that the highest *potential* casualties occur there. Potential casualties are those that theoretically would occur under given conditions of population density, the frequency of tornadoes, and the area of the average tornado. The potential casualties from tornadoes are highest in zones (1) from Dallas, Texas, through Topeka, Kansas; (2) from Chicago, Illinois, to Detroit, Michigan; and (3) in the densely populated Northeast (Sadowski, 1965). This contradicts the actual highest incidence of tornado-caused deaths, which, as we have seen, is located predominantly in the South.

Several possible explanations of this anomaly have been offered. One explanation focuses on the physical characteristics of the tornado. It may be that the storms in the South are more violent and that this accounts for the higher death rate. If the storms are more violent, one might expect a higher property damage rate along with the higher death rate. However, except for Georgia, the states with the highest property damage were not in the South; on the contrary, most of the Southern states are not even on the list of the ten states that incur the highest property damage from tornadoes (Flora 1954).

Some other hypotheses, instead of focusing upon variations in the physical characteristics of tornadoes, emphasize variations in the human environment. One frequently mentioned explanation stresses the type and quality of housing. In the South, for example, are homes more or less likely to have storm cellars than in other areas of the country? Or are homes in the South less well constructed? The relationship between quality of housing and tornado-caused deaths is not easily identified and measured, although it has been suggested that the average quality of housing in the South has been inferior and hence more susceptible to damage.

It has also been suggested that the efficacy of tornado warning systems may be of less value in the South than in other areas with equal or higher potential tornado casualties. In 1953, the first year in which the U. S. Weather Bureau made tornado forecasts available to American communities, the South recorded the greatest intensity of tornado-caused deaths. From 1953 on, the information on tornado forecasts has been available to all communities. Indeed, radio and television stations have regularly broadcast the warnings sent from the Severe Local Storm Center in Kansas City or by local observers. Not all communities employ civil defense sirens or have a tornado preparedness plan, however, and such measures are especially lacking in the South.

A person's perception of the hazard is an important factor related to the value of a warning system. People adjust to their environment, and the process of adjustment is influenced by individual personality, culture, and physical environment. Once ideas or perceptions are established, a person tends to maintain his personal set of ideas or cognitions about a particular phenomenon. Thus, a person's perception of environment accommodates both reality and his personal needs and dispositions.

By analogy to the previous discussion of flood frequency, one would expect the greatest adoption of adjustments to mitigate the effects of tornadoes in Oklahoma and Kansas, where the frequency of tornadoes per unit area is highest. Such adjustments logically include a higher proportion of storm cellars or basements, a public more sensitive to warnings, a public more informed of alternative strategies of action, and even a more complex and intricate organizational warning network. In general, these expectations are fulfilled in Oklahoma and Kansas. In contrast, along the eastern seaboard tornadoes occur so infrequently that many suggested measures for protection are never adopted. Communities do not test or utilize their civil defense sirens in preparation for an actual tornado; knowledge of adjustment alternatives is low, although fear of the tornado may be quite high.

In seeking an answer to why the South has a higher death rate, a study by Baumann and Sims (1972) considered areas with different degrees of tornado hazard. Personal interviews (420 in all) were completed in: Kansas and Oklahoma, a high hazard area; Connecticut and Massachusetts, a low hazard area; and Alabama and Illinois, representative of the middle range of tornado hazard where ambiguity is greatest. Each respondent was given a sentence-completion test to assess environmental perception.

Though findings are tentative, populations in areas with similar probability of tornado occurrence (Alabama and Illinois) have fundamental differences in perception of adjustments to the hazard. The Illinois resident, unlike the Alabama respondent, sees himself as personally responsible for directing his own life, whereas the Alabaman typically views himself as being more moved by external forces, especially God. The Alabama respondent's lower confidence apparently leads to the belief in "what ever will be, will be." The study also reveals that people in Illinois are more action-oriented, display more adaptive behavior when confronted with a tornado, and are more willing to accept available technology and recommended adjustments than are the Alabamans.

In summary, the data suggest that in environments with similar degrees of tornado hazard culture in part determines the effectiveness of a tornado forecast system. Attitudinal variations from city to city and from region to region must be considered in planning ways to minimize damages from tornadoes.

Drought

Most people think of drought as an agricultural phenomenon, an event from which the urban dweller is somehow immune. By and large this has been true in humid areas of the world, where natural supplies historically have been sufficient to meet demands for water. But in many areas of the world drought is a seasonal, or even nearly continual, facet of climate. Cities in such regions may have to draw water from great distances to assure their survival. This was true of ancient Mesopotamian cities, and it is true of Los Angeles today. The situation has become more serious as growing urban populations demand more and more water. Few modern cities, even in humid regions, are exempt from some threat of drought. Early Dutch settlers could hardly have guessed, for example, that someday New York City restaurants would stop serving water with meals and that the city's male residents would give up shaving in rather futile gestures to reduce the severity of periodic droughts.

Urban drought is not necessarily caused by insufficient precipitation, although that sometimes may be the case. Many droughts are caused by inadequate storage of available water to meet seasonal needs. Thus, drought in the city in part reflects inadequacies in water supply planning. Problems of municipal water supply have already been addressed in Chapter 5, particularly in terms of fluctuations in water demand, fluctuations in natural water supply, and the storage-yield relationship. In this chapter, urban water supplies and associated drought risks are viewed from the perspective of the water supply planner.

Alternative water management plans can be illustrated by four cities in Massachusetts (Fitchburg, Fall River, Worcester, and Pittsfield; see Figure 7.5). In the face of variable rainfall and in response to actual and anticipated demands for water, the planner seeks out and examines available, alternate sources of supply. In the genesis of water supply systems, these alternatives may be limited by the myopic vision of the planners, and, in existing systems, further constraints are implied by past decisions. Nevertheless, there is almost always a choice of size and timing of development and also of source (for example, groundwater or surface water; location, size, and quality of stream). Almost always, the question of development size and timing is one of balancing the costs of expansion against some notion of the costs of shortages to be expected in the absence of expansion.

Given these fundamental influences, then, the historical growth of a typical water system might take the following form (as illustrated by the demand and yield curves for Fitchburg in Figure 7.5A). Demand, as the product of innumerable individual decisions, varies continuously and generally upward, reflecting both a growing urban population and increases in per capita water use. In contrast, the development of reservoir systems occurs in large, discrete steps. This leads to a characteristic pattern of system growth whereby "overcapacity" is periodically introduced. Steady demand growth causes the eventual elimination of the overcapacity cushion, and this, in turn, leads sooner or later to further spurts in supply.

Now, it is reasonable to suppose that the impact of a given climatic event (for example, a period of abnormally low precipitation) will be different for systems with different relations between supply and demand. Thus, a system that has just completed a large addition to its capacity should probably be able to meet the demands of its customers better than one that has allowed demand to outrun supply. This notion is at the heart of our model of drought impact.

The basic supply capacity of a water system is a product of its

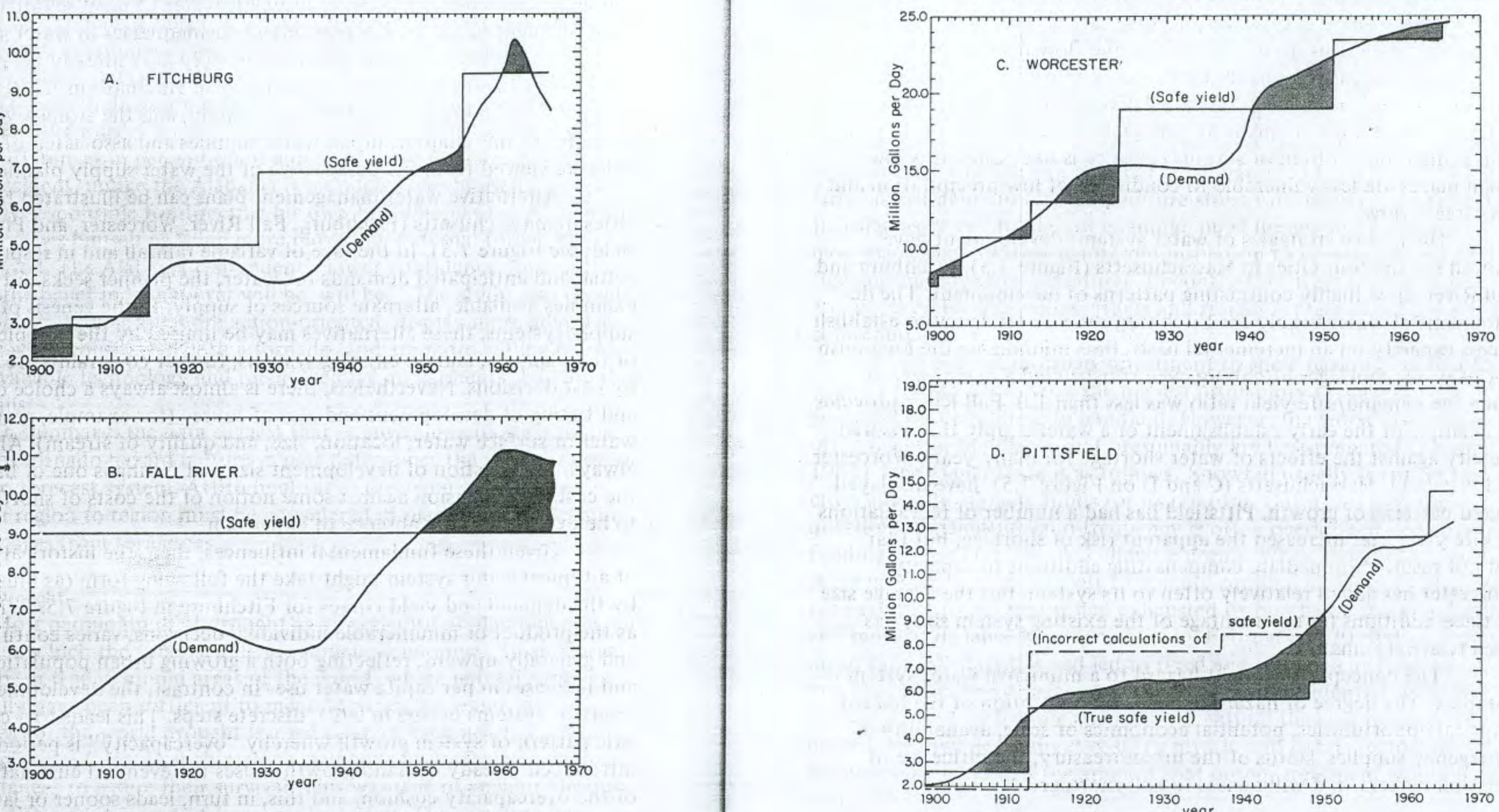

Figure 7.5. Comparison of average daily water demand with safe yield in four Massachusetts cities: (A) Fitchburg, (B) Fall River, (C) Worcester, and (D) Pittsfield. Shaded areas represent demand in excess of safe yield. Abrupt vertical changes in safe yield curves result from reservoir construction.

flow and storage characteristics. The term *safe yield* is generally used to refer to the supply capabilities of both groundwater and surface water sources. There is, however, nothing safe about safe yield, and for our purpose we might define its value as the flow per day of water that a system might reasonably be expected to provide 95 percent of the time. We may now measure the relative adequacy of an urban water system by the ratio of demand to safe yield. When demand/safe-yield ratio is high, the cushion of surplus capacity is low; when it is low, urban places are less vulnerable to conditions of low precipitation and low stream flow.

Distinctive strategies of water systems development have evolved for the four cities in Massachusetts (Figure 7.5). Fitchburg and Fall River show highly contrasting patterns of development. The development of water supply for Fitchburg shows a tendency to establish excess capacity on an incremental basis, thus minimizing the long-term risk of water shortage. Fitchburg even constructed a new reservoir when the demand/safe-yield ratio was less than 1.0. Fall River provides an example of the early establishment of a water supply that insured the city against the effects of water shortage for many years. Worcester and Pittsfield, Massachusetts (C and D on Figure 7.5), have displayed mixed patterns of growth. Pittsfield has had a number of reevaluations of safe yield that increased the apparent risk of shortage, but that did not result in immediate compensating additions to capacity. Worcester has added relatively often to its system, but the average size of these additions (as a percentage of the existing system size) has been relatively small.

The concept of drought hazard to a municipal water system is complex. The degree of hazard depends on perception of the hazard, physical opportunities, potential economics of scale, availability of emergency supplies, status of the urban treasury, the influence of decision-makers, and willingness to risk shortage.

Winter Storms

The winter storm is a natural hazard particularly disruptive to urban life. Cities, which are dependent on fast transportation and communication, can be crippled by a heavy snowfall or glaze ice accumulation. Spatial interaction within the city and with its tributary areas may be curtailed or stopped; emergencies may arise as supplies and distribution lines are cut (Rooney 1967, pp. 539–540). Heavy financial losses may also accrue – both from lost or reduced economic activities and from the direct costs of combatting the hazard.

Cities respond to winter storms in different ways, and there is a high variability of investment in equipment and labor for snow removal. Places with much snowfall, such as Montreal, are geared to continuing snow removal throughout the winter; a two-inch snowfall is routinely cleared and life goes on "as usual." The same amount of snow may bring activities in San Francisco or Washington, D.C., to a halt. Similarly, adjustments to low temperature stress vary from region to region. In Tallahassee or Mobile, for example, most homes and buildings have inadequate heating plants and insulation to protect against near-freezing and lower temperatures. In contrast, Detroit and Chicago are prepared for low temperatures and residents regard cold periods as commonplace.

The pattern of urban adjustment to snow hazard is similar to that for floods. Cities with the highest probability of snowfall are generally best equipped to handle it. However, the worst disruptions often occur in the places that presumably are best prepared (Rooney 1967). One explanation is as follows: Snowfall usually is anticipated and cities annually allocate funds for its removal. Unfortunately, the question of magnitude and frequency is often overlooked and advance funding is based on so-called climatic norms. When snowfall exceeds these norms, no money is left to operate equipment. Detroit, Michigan, for example, found that it had exhausted its purchased salt supplies* and most of its labor appropriations by February 1970. Reliance on mean snowfall statistics had led to fixed and insufficient funding in a year of above-average snowfall. As a result, residential streets remained packed with snow and ice until natural thawing removed the hazard. Meanwhile, indirect costs to private and public sectors of the economy exceeded the amount that proper treatment would have cost.

GEOLOGIC AND GEOMORPHIC HAZARDS

Geologic and geomorphic hazards in the city have been discussed in Chapter 2 (earthquakes and subsidence), Chapter 5 (sedimen-

*Ironically, Detroit is situated directly over one of the largest salt mines in North America.

tation), and Chapter 6 (slope instability and erosion). Some less common hazards that depend upon regional location and specific site characteristics are volcanic eruptions, avalanches, and the breaching or collapse of natural lake impoundments. It is not the purpose of this section to discuss these hazards further on an individual basis; instead specific hazard events in cities are presented as case examples of hazard perception and adaptation.

Earthquakes are an excellent case in point. They occur suddenly and, for all practical purposes, without warning. Earthquakes also are responsible for some of the worst devastation wrought on cities and their populations. Although there has been considerable progress in the development of earthquake warning systems, there is little likelihood that a workable prediction method will be devised in the near future. Thus, although people generally know if they live in earthquake-prone zones, structural adaptations to mitigate earthquake effects, rather than evacuation, remain the normal precautionary response.

Over 150,000 earthquakes occur annually throughout the world. Most of these are small tremors imperceptible to humans, but about one earthquake a year (on the average) is of sufficient magnitude to cause serious destruction in cities. The number of people affected is related to how important man considers an individual earthquake to be. In 1958 one of the major earthquakes of the twentieth century occurred in Alaska. Because the epicenter and major repercussions were located in a practically unpopulated area, little notice was taken of the event – except by seismologists and other earth scientists. In contrast the 1964 Alaska earthquake, which struck with great force in the Anchorage area and other settled parts of the state (killing 115 people), was the focus of worldwide attention. Tsunamis (tidal waves) generated by the seismic shock caused major destruction or loss of life, or both, in Valdez, Kodiak, and Seward, Alaska, as well as in such distant points as Hilo, Hawaii, and Crescent City, California. Destruction of buildings, primarily due to collapse and movement of unstable soils and mantle, caused over $290 million damage in Anchorage alone (Rogers 1970).

Although Anchorage residents had long been aware that they lived in an earthquake zone, they took few precautions before 1964. Homes, schools, hospitals, and parts of the downtown business district were constructed on unstable earth materials – despite the fact that the U.S. Geological Survey had published information about the sliding potential of these areas (Kates 1970, p. 17). Once a destructive earthquake has occurred, it might be expected that careful attention would be given to the location and design of future buildings. This was indeed the case – at first. Three categories of danger areas were scientifically identified: high risk, nominal risk, and provisional nominal risk. What followed tells us something about the rapid changes in individual and societal attitudes that may occur once a disaster has passed:

> The area initially classified as high-risk was gradually reduced, strictly on scientific grounds. However, a major concession in the high risk area was the decision to provide funds to restore buildings but not to construct new ones. Other concessions have followed, leading to a major policy change in February, 1967, when FHA [the Federal Housing Administration] removed its restrictions on mortgage insurance in the two major risk areas, requiring only the promise that mortgage lenders make clear to prospective buyers the nature of the risk and their financial responsibility in case of earthquake recurrence. Local zoning of risk areas has not taken place. On the contrary, building permits have been issued for about $6 million worth of new construction in and adjacent to the L-K-Street-slide area. (Kates 1970, p. 26)

Thus the attitude of many individuals in Anchorage became: "We've had our earthquake; there won't be another in our lifetime." Apparently the institutions created to protect the populace also were swept along in the wave of new optimism or could not resist political and economic pressures.

Ideally, recent experience with a hazard should improve perception and lead to better adaptation. This is illustrated by differing responses to tsunami warnings issued in Crescent City, California, and Hilo, Hawaii, at the time of the 1964 Alaska earthquake. Previous to that date Hilo had experienced a tsunami generated by the May 23, 1960, Chilean earthquake, which killed 61 people and injured 282. This disaster has been attributed to failure to heed warning sirens, the inexplicable reluctance of some persons to leave the danger area, and the belief of some persons that they were in a safe zone (Lachman and others 1961). A carefully designed alert system was subsequently established. It defined clear lines of responsibility and action for public officials, disaster workers, and the public. Thus, when the 1964 tsunami alert was sounded, Hilo residents evacuated danger areas in a safe and orderly manner; no deaths resulted.

In Crescent City, the first alert – estimating the midnight arrival of a tsunami – was received at 11:08 P.M. Door-to-door warning of residents in dangerous areas did not begin until a second alert was received at 11:50 P.M. and was still in progress when the first wave hit (Anderson 1970, p. 119). At least 11 lives were lost and 29 city blocks suffered damage. Less than a year later, Crescent City was issued another nighttime tsunami alert. Because of lessons learned in 1964 and because officials were sensitive to disaster cues, low-lying areas were quickly evacuated and much property was saved. Thus, as in the case of tornadoes, the effectiveness of a warning system depends on a combination of factors: efficiency and organization of the alert system, action of public officials, and public perception of and response to the hazard.

IS NATURAL HAZARD INCREASING IN THE CITY?

What are the trends of risk from nature in urban areas of North America? In absolute terms, damage and the cost of adjustment have increased as a function of the increase and concentration in wealth and population accompanying urbanization (Dacy and Kureuther 1969). At the same time, corresponding increases in deaths have not occurred; indeed deaths have decreased both in absolute and in per capita terms. For many hazards, the number of damage-causing events (some not recorded) may have diminished with the population's increased capacity for adjustment. But the potential for catastrophic events (in terms of impact on man and his cities) has clearly increased. Extrapolating the impact of an earthquake of the same magnitude and low per capita death and damage ratio as the Alaska earthquake of 1964 to California would forecast a super disaster of 2,000 dead and $6 billion damage. Calculations for an intense hurricane stalled over New Orleans provide a similar estimate of death and damage.

The potential for serious but noncatastrophic damage is even more clearly on the increase. This was demonstrated for floods by Roland Holmes (1961), who suggested that urbanization of previously unoccupied flood plains causes increased risk. Other hazardous effects of urban growth – brush fires, floods, earthslides, and land slips – have been identified for Los Angeles (Van Arsdol and others 1967). All are characteristic of the fast-growing areas of southern California.

Finally there are urban environmental hazards that are quasi-natural in origin. Principal among these are man-made pollutants, conveyed or concentrated by natural processes of air and water, discussed in Chapters 3, 4, and 5. In most urban parts of the country, their presence is clearly increasing, although there are some notable exceptions.

It is difficult to obtain time series data of any sort. It is especially difficult to obtain adequate time series of damage data (clearly our recording and perception of damage improves in time) and costs of adjustment (we are still trying to define these costs for most hazards). Yet it appears worthwhile to draw up a tentative balance sheet at present – to estimate both the current death and damage rates from different natural hazards and the public and private costs of adjustment to them. These data then can be contrasted with quasi-natural and man-made hazards. We know that deaths have decreased and damage increased from natural hazards. Although we do not know, we do suspect that per capita damage rates (discounted for growth in wealth and total social costs) have moved upwards in toto – especially if one considers the long-term increase in catastrophic potential, the new sources of hazards, and the rising costs per unit of adjustment for certain hazards.

SOME RECOMMENDED ACTIONS

In light of the continued increase in population and urbanization, what strategies can man implement to mitigate the expected losses from natural hazards? One course is to develop a greater thrust by the federal government. This is not novel. Already, examples can be found in federal policy regarding water quality standards and the National Flood Insurance Act of 1968. If the federal government would initiate guidelines and regulations concerning the type of human occupance and human response necessary in hazard zones, then a further decrease in deaths and property damage might be expected. The initial effect of governmental regulations should be to reduce the great variation that now exists in human adjustment to specific natural hazards. As in the formulation and development of water quality standards, the federal government could call upon each state to formulate specific regulations that a given federal agency, such as the Office of Emergency Preparedness, could then evaluate and either approve or return for modification. In the event of a disaster, federal assistance could be withheld from those states, local governments, and individuals who did not comply. In fact, one proposal for a suggested national disaster insurance program requires participants to purchase insurance within one year if they wish to be eligible for federal disaster assistance.

Let us now be more specific by providing examples related to floods, tornadoes, and drought. As mentioned previously, the National Flood Insurance Act was passed in 1968. In addition to provisions for flood loss compensation, the act includes plans to control future occupance of flood plains so that there will be a reduction in flood damage potential. Similarly, local governments and states could be required to enact specific zoning ordinances near the flood plains, to formulate emergency plans, and to require individuals to adopt specific flood-proofing measures. The effect would be a decrease in the damage potential, which since 1936 has continued to increase.

A few strategies can reduce the magnitude of tornado-caused damage. If tornado shelters were required for new home construction in hazardous areas, a further reduction in loss of life could be expected. Communities could be required to develop preparedness and emergency plans, which are either absent or woefully inadequate in most communities today. For example, installation of sirens *throughout* the area of cities or alarms installed in television or radio sets could reduce loss of life – especially for tornadoes that occur at night. Moreover, if residents would merely open their windows, damage on the periphery of a tornado path might be significantly lessened. And it could be required that all new housing be constructed according to minimum standards of safety, decency, and sanitation, as prescribed by the Secretary of Housing and Urban Development, and in conformity with applicable building codes and zoning regulations. Finally, public school curricula could easily include a program on the human implications of the tornado storm. Again, disaster assistance could be withheld from those communities that did not develop and implement approved tornado preparedness plans.

Concerning municipal water supply, the focus should be not solely on the effects of drought, but also on efficiency in the provision of the municipal water supply. Assistance could be granted only to those communities that maintained a specified water-use/safe-yield ratio and a demonstrated efficiency in the provision and distribution of water. Concerning distribution, for example, only specified low levels of unmetered (and hence unpaid-for or wasted) water would be tolerated, a frequently monitored metering system would be maintained, and price mechanisms would be changed to reduce peak demands. With respect to the source of supply, communities could be directed to seek and select the least-cost alternative in the provision of a specified safe yield, and if they did not comply, they could be deprived of federal assistance to the amount of the chosen, more costly, alternative.

These suggested remedies are partial and somewhat speculative, but unless federal and state governments act, losses from natural hazards in our ever growing urban areas will continue to set new records.

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