2

Natural and Technological Hazards and Risk Assessment

WHAT YOU WILL LEARN

- Natural and technological hazards that often result in emergencies and disasters
- Scales and systems used to measure the strength of hazards and the magnitude of disasters
- The terrorist threat, including weapons of mass destruction
- How hazards are identified and risks are assessed
- The influence of social and economic factors on community risk

Introduction

A *hazard* is defined as a "source of danger that may or may not lead to an emergency or disaster" (National Governors Association, 1982), and it is named after the emergency or disaster that could be so precipitated. Each hazard carries an associated *risk*, which is represented by the likelihood of the hazard leading to an actual disaster event and the consequences of that event should it occur. The product of realized hazard risk is an event or an emergency, which is typically characterized as a situation exhibiting negative consequences that require the efforts of one or more of the emergency services (fire, police, EMS, public health, or others) to manage. When the response requirements of an event or an emergency exceed the capabilities of those established emergency services in one or more critical areas (e.g., shelter, fire suppression, mass-care), for a particular local government or even for a region, the event is classified as a *disaster*. And ultimately, when the response requirements in one or more critical areas of assistance are unable to be met at all levels of government responding, the incident is classified as a catastrophe (catastrophes are measured only at the national level or greater) (Fig. 2.1).

Hazard identification is the foundation of all emergency and risk management activities. When hazards interface with the human or built environments, it is risk that is the result. For each risk, there exists an associated likelihood that an actual event will occur, and a measure of expected consequences. It is accurate knowledge about risk posed by identified hazards that most effectively guides preparedness, planning, and mitigation processes. And it is the realization of this risk, such as occurs when earthquakes, tornados, floods, or other hazards strike, that requires the many different emergency response and recovery stakeholders to act upon their plans and draw upon their capabilities and resources. For the contemporary emergency manager, faced with a diverse portfolio of hazards and a finite budget with which to manage them, effectiveness and efficiency is fully predicated on the accurate and effective hazard identification and risk assessment.

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FIGURE 2.1 Long Beach, N.Y., Nov. 8, 2012—Aerial views of Hurricane Sandy damage to homes on Long Beach, New York. Following the hurricane, a nor'easter struck the area causing more power outages and additional flooding. FEMA is working with state and local officials to assist residents who were affected by Hurricane Sandy. *Andrea Booher/FEMA.*

This chapter discusses the most common disaster-triggering hazards, both natural and technological, and presents common methods by which risk from these hazards may be assessed. A brief description is provided for each hazard, as are the common effects and information about detection and classification.

Natural Hazards

Natural hazards are sources of risk exposure that derive from the natural environment as a result of hydrological, meteorological, seismic, geologic, volcanic, mass movement, or other natural processes. They are a threat because the energy they exert poses a threat to human and animal populations, agriculture, physical structures (including infrastructure), or the social and economic functioning of communities. Both the likelihood and consequence factors of natural hazard risk are often exacerbated by human activities, including such things as development, settlement patterns, modification of the landscape, emissions of carbon gases, and other actions. For example, the construction of communities in the floodplain or on barrier islands almost always increases risk associated with hurricane-force winds, flooding, and storm surge. When structures are constructed on or around seismic faults, the likelihood that they will be destroyed in a future earthquake event is greatly increased. Even earthquakes themselves have been attributed to human activities, predominantly the use of deep wastewater disposal and hydraulic fracturing (fracking) in the oil and gas industry (Rubinstein and Mahani, 2015). By increasing our understanding of natural hazards and the processes by which they affect us, societies can more appropriately plan for these stressors and reduce vulnerability (see Chapter 3: The Disciplines of Emergency Management: Mitigation examines how humans can better live with hazards).

Floods

A flood is an overabundance of water that engulfs land and other property that is normally-dry. There are a number of different reasons floods occur, including sustained or heavy rainfall, melting snow, obstruction of a natural waterways (e.g., by beavers, ice, debris, or landslides), among other generative factors. Major floods affecting wide geographic areas are typically the result of large-scale weather systems capable of generate prolonged rainfall and onshore winds (in the case of coastal flooding), but events of equally significant magnitude can occur in much less time following intense thunderstorms with exceptionally heavy precipitation rates or dam failures, for example. Floods are capable of undermining buildings and bridges, eroding shorelines and riverbanks, tearing out trees, washing out access routes, and causing loss of life and injuries. Flash floods, which can reach full peak in only a few minutes, are a distinct category of flood characterized by the lack of warning that is possible given their rapid generation (Fig. 2.2).

Floods are the most frequent and widespread disaster in many countries around the world, including the United States, due to the prevalence of human development along coasts and in the floodplain. Between 2010 and 2015, all fifty states experienced floods or flash floods (FEMA, 2016). The close relationship between societies and water is primarily the result of commerce (the transportation of goods has most commonly been conducted by water), agriculture, fishing, and access to drinking water. And as global populations continue to grow and urbanize, so does exposure to flood events. The US Army Corps of Engineers estimate that 94 million acres of US land, which represents about 7% of the total land area and 15% of urban centers, are at-risk for flooding (Office of the Assistant Secretary of the Army for Civil Works, 2016). FEMA estimates that within this flood-prone area there are approximately 8–10 million households that are exposed to flood risk, and these homes and

FIGURE 2.2 Quechee, Vt., Sep. 11, 2011—The Quechee bridge is a main thoroughfare and an integral part of the town. Residents cried as they watched their beloved bridge battered by flash flood waters caused by tropical storm Irene. *Photo by Wendell A. Davis Jr/FEMA.*

Table 2.1 Top Ten US Flood Disasters, 1900–2016 (by Total Cost of National Flood Insurance Program Losses Paid)

Event	Date	Number of Paid Losses	Amount of Paid Losses
Hurricane Katrina	Aug. 2005	167,978	$16,317,519,550
Hurricane Sandy	Oct. 2012	129,888	$8,147,841,619
Hurricane Ike	Sep. 2008	46,661	$2,696,552,100
Hurricane Ivan	Sep. 2004	28,296	$1,612,094,924
Hurricane Irene	Aug. 2011	44,263	$1,339,381,261
Tropical Storm Allison	Jun. 2001	30,671	$1,105,003,344
Louisiana Flood	May 1995	31,343	$585,071,593
Hurricane Isabel	Sep. 2003	19,938	$500,265,018
Hurricane Rita	Sep. 2005	9,528	$474,688,462
Hurricane Floyd	Sep. 1999	20,439	$462, 326,389

Source: FEMA. 2016. *Significant Flood Events*: 1978–Apr. 2016. National Flood Insurance Program. http://1.usa.gov/1UYm2lj.

other articles of personal property sustain an average of $3.5 billion in losses each year, but perhaps more illustrative of the long-term risk is the fact that FEMA's National Flood Insurance Program has paid over $50 billion in flood insurance claims since it was created in 1978 (FEMA, 2016) (Table 2.1).

Flooding on a body of water is normally measured according to an established flood stage, which refers to the level at which inundation of normally-dry areas occurs. This elevation corresponds to an annualized likelihood of reaching such heights. For example, a flood stage that has a 1% chance of being reached or could be expected to occur once across a 100-year period would encompass a land area referred to as the "100-year floodplain" and an event that impacted this area would be called a 100-year flood event. Typically, structures contained within areas that carry a 1% annualized risk of flooding are considered to exist within the floodplain. A widespread misconception is that a 100-year flood is something that occurs only once per century, but it is not uncommon for multiple floods of such magnitude to occur even within a single decade in a single locale. Governments in many countries maintain river and stream gauges to monitor floodwater elevations and to provide information on rising water for use in sandbagging and dike construction. Such information also allows for early warning and evacuation to occur.

ADDITIONAL RESEARCH

The following reports provide supplemental information about annualized flood losses in the United States:

- *Compilation of Weather-Related Fatalities; 1940–2015* (The National Weather Service): http://bit.ly/1MgGivl
- *Flood Damage in the United States, 1926–2003—A Reanalysis of National Weather Service Estimates* (Pielke, Roger A., Mary W. Downton, and J. Zoe Barnard Miller, 2002): http://bit.ly/1SC1GIg
- FloodSmart.Gov Flood Facts (National Flood Insurance Program): http://1.usa.gov/1PVNVSN

■■ Critical Thinking ■

Why do you think that maps detailing the floodplain can change over time? What activities might influence changes in a community's floodplain? How can flooding occur outside of the floodplain?

Earthquakes

An earthquake is a sudden, rapid shaking of the earth's crust caused by the breaking and shifting of tectonic plates beneath the earth's surface. This shaking can cause the collapse of buildings and bridges; cause disruptions in gas, electric, and phone services; and trigger landslides, avalanches, flash floods, fires, and huge, destructive ocean waves (tsunamis). Structures constructed on unconsolidated landfill, old waterways, or other unstable soils are generally at greatest risk unless seismic mitigation has been utilized. Seismicity is not seasonal or climate-dependent and can therefore occur at any time of the day or year (Fig. 2.3).

Each year, knowledge about the location and behavior of the earth's seismic zones increases thanks to improvements in seismic detection and monitoring. It is a significant and growing risk because over one billion people worldwide live in seismic zones and population risk becomes concentrated as societies are shifting towards patterns of high-density urban settlement. Earthquake damage can be extensive, especially when buildings have been

FIGURE 2.3 Napa, California, Aug. 24, 2014. This building was damaged by the magnitude 6.0 earthquake that struck Napa, resulting in a fenced-off street and closed businesses in the area. *Photo by Ellis Maynard/FEMA.*

constructed without incorporation of seismic resistant materials and design. Earthquakes can cause secondary fire hazards when gas lines are severed and storage sites containing flammable materials are compromised. These fires can spread rapidly among damaged buildings because water systems may be damaged and fire services are either unable to access the fire or are overwhelmed by other response requirements. Fire was a leading cause of thousands of deaths in 1995 when an earthquake struck Kobe, Japan, after debris from damaged and destroyed buildings blocked many access points for firefighters and equipment.

Earthquakes remain sudden events with little to no options for actionable advance warning despite scientists' and soothsayers' best efforts to accurately predict their onset. At present the best resource for prediction remains data on return intervals (average rates of recurrence) along known active faults—and even these can vary by decades or even centuries. Seismic-sensing technology is effective at measuring and tracking seismic activity, but given the nature of seismic events this technology can offer little more than a precious minute or two of notice. That being said, early-detection systems have proven useful in helping to reduce some forms of damage such as automatically shutting down infrastructure systems including railway transportation and nuclear reactors.

Each year hundreds of earthquakes occur in the United States, although the vast majority of these are barely perceptible. As earthquake strength increases, the likelihood of occurrence decreases. Major events, which are considered to be those with a magnitude greater than 6.5−7 on the Richter scale, occur in the United States only once every decade or so. But when events like these have occurred, they have ranked among the most devastating in the nation's experience. The Northridge earthquake that struck California in 1994, for instance, is the second most expensive natural disaster to ever occur in the United States as ranked by FEMA relief costs, resulting in almost $7 billion in federal funding (and second only to Hurricane Katrina). The costliest disaster of all time remains the 2011 Tohoku Earthquake in Japan, which generated damages exceeding $210 billion as measured by international reinsurance company Munich Re (with some estimates placing the total cost of reconstruction closer to $250 billion) (Munich Re, 2012; Conca, 2016)

The strength and effects of earthquakes are commonly described by the Richter and Modified Mercalli Intensity (MMI) scales. The Richter scale, designed by Charles Richter in 1935, assigns a single number to quantify the strength and effect of an earthquake across the entire area affected according to the strength of ground waves at its point of origin (as measured by a seismograph). Richter magnitudes are logarithmic and have no upper limit. The MMI also measures the effects of earthquakes, but rather than applying a single value to the event, it allows for site-specific evaluation according to the effects observed at each location. The MMI (Table 2.2) rates event intensity using Roman numerals I through XII. Determinations are generally made using reports by people who felt the event and observations of damages sustained by structures.

The primary structural mitigation measure employed in defense of earthquake risk is the use of resistant design and materials. Building codes have long guided seismic resistant construction, and those communities and countries that have strict building codes and effective monitoring measures to enforce those codes tend to fare better when earthquakes strike. There has been a traditional tug of war when it comes to seismic codes given that construction costs almost always rise with the stringency of code-dictated protections. As such, code provisions have tended to track seismic shake maps—where seismicity is believed or known to exist,

Table 2.2 Modified Mercalli Intensity Scale

MMI Intensity	Damages Sustained and Sensations Experienced	Richter Scale Equivalent
I–IV (Instrumental to Moderate)	No damage sustained. Sensation ranges from imperceptible to that of a heavy truck striking the building. Standing motor cars may rock.	≤4.3
V (Rather Strong)	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.	4.4–4.8
VI (Strong)	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.	4.9–5.4
VII (Very Strong)	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.	5.5–6.1
VIII (Destructive)	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.	6.2–6.5
IX (Ruinous)	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.	6.6–6.9
X (Disastrous)	Most masonry and frame structures/foundations destroyed. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Sand and mud shifting on beaches and flat land.	7.0–7.3
XI (Very Disastrous)	Few or no masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Widespread earth slumps and landslides. Rails bent greatly.	7.4–8.1
XII (Catastrophic)	Damage nearly total. Large rock masses displaced. Lines of sight and level are distorted. Objects are thrown into the air.	8.1 or greater

Source: USGS, 2009. Magnitude/Intensity Comparison. Earthquake Hazards Program. http://on.doi.gov/1rqcjFM.

more stringent codes are enacted. In the past, USGS shake maps only included seismicity that results from natural processes, but in Mar. of 2016 the agency began adding human-induced factors into risk calculations. This had the effect of increasing the seismic risk factors for over 7 million people, the number of people who live in areas with seismic risk. Because the American Society of Civil Engineers (an organization that provides guidance on construction codes) is in the final stages of publishing their guidelines, which are released every 6 years, man-made seismicity will not be accounted for. Given the scope of increases in seismicity from manmade impacts, including an increase in the state of Oklahoma from two earthquakes of 3.0 or greater magnitude in 2008 to 907 in 2015, there is a good chance that these factors will play a prominent role in future guidance (Mastroiani, 2016).

■■ Critical Thinking ■

It is possible to assign Modified Mercalli Intensity values to historical earthquakes, but Richter magnitudes cannot be retroactively assigned. Why do you think this is true? Which of these scales is more useful in terms of disaster planning? Why?

Hurricanes

Hurricanes are cyclonic storms that begin as tropical waves that grow in intensity and size. Tropical waves continue to progress in size and intensity to become tropical depressions, and then tropical storms. These designations are determined according to maximum sustained wind speeds. Eventually, a warm-core tropical depression can become a tropical storm if its maximum sustained surface wind speeds exceed 39 miles per hour (but remain under 73 miles per hour (mph)). Tropical cyclonic storms are further defined by their low barometric pressure, closed-circulation winds originating over tropical waters, and an absence of wind shear. It is interesting to note that the spinning of a cyclonic storm is influenced by the Earth's rotation, and as such winds always rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. This also means that they cannot form within five degrees north or south of the equator, and their path is always in a direction that takes them away from the equator.

A hurricane is a cyclonic tropical storm with sustained winds measuring at least 74 mph. These hurricane-force winds extend outward in a spiral pattern as much as 400 miles around a relatively calm center of up to 30 miles in diameter known as the "eye." Hurricanes are fed by warm ocean waters. As these storms make landfall, they often push a wall of ocean water known as a "storm surge" over coastal zones. Once overland, hurricanes cause further destruction by means of torrential rains and high winds. A single hurricane can last for several weeks over open waters and can run a path that extends the entire length of the eastern seaboard.

Hurricane season runs annually from Jun. 1 through Nov. 30, with Aug. and Sep. considered the peak months. Hurricanes are commonly categorized using the Saffir—Simpson scale (Table 2.3).

Hurricanes are capable of causing great damage and destruction over vast geographic areas. Hurricane Floyd in 1999 first threatened the states of Florida and Georgia, made landfall in North Carolina, and damaged sections of South Carolina, North Carolina, Virginia, Maryland, Delaware, New Jersey, New York, Connecticut, Massachusetts, and Maine. The damage was so extensive in each of these states that they all qualified for federal disaster assistance. Single hurricanes can affect multiple countries that fall into their path, as was the case with Hurricane Mitch. This very large hurricane resulted in widespread death and destruction throughout Nicaragua, Guatemala, El Salvador, and Honduras.

The costliest disaster in US history in pure dollar figures (approximately $80 billion; Reuters, 2009) and one of the deadliest in terms of lives lost and injuries sustained (1836 killed) was Hurricane Katrina (Table 2.4). Katrina reached Category 5 status with sustained winds of more than 175 mph—making it the fourth strongest hurricane recorded at the time—before making landfall as a Category 3 hurricane along the Gulf of Mexico coast. With strong winds and a storm surge reaching 28 feet, Katrina devastated coastal communities in Alabama, Florida, Mississippi, and Louisiana. Flooding and near total destruction occurred across almost 80% of New Orleans and much of Biloxi/Gulfport, Mississippi. The storm went on to cause further destruction in several other states as it made its way north toward Canada.

More recent hurricanes, including Hurricanes Irene in 2011 and Sandy in 2012, served as reminders that even storms of weaker intensity can wreak considerable destruction from storm surge and flooding effects, and can devastate urban and rural areas alike. Hurricane Sandy, the largest recorded hurricane, spanning 1.8 million square miles (though second-largest after the 2001 Hurricane Olga with regards to the extent of its tropical-force winds),

Table 2.3 The Saffir–Simpson Scale

Category	Conditions	Effects
1	Wind Speed: 74–95 mph Storm Surge: 4–5 feet above normal	Primary damage to unanchored mobile homes, shrubbery, and trees. Some coastal flooding and minor pier damage. Little damage to building structures.
2	Wind Speed: 96–110 mph Storm Surge: 6–8 feet above normal	Considerable damage to mobile homes, piers, and vegetation. Coastal and low-lying area escape routes flood 2–4 h before arrival of hurricane center. Buildings sustain roofing material, door, and window damage. Small craft in unprotected mooring break moorings.
3	Wind Speed: 111–130 mph Storm Surge: 9–12 feet above normal	Mobile homes destroyed. Some structural damage to small homes and utility buildings. Flooding near coast destroys smaller structures; larger structures damaged by floating debris. Terrain continuously lower than 5 feet above sea level (ASL) may be flooded up to 6 miles inland.
4	Wind Speed: 131–155 mph Storm Surge: 13–18 feet above normal	Extensive curtain wall failures, with some complete roof structure failure on small residences. Major erosion of beaches. Major damage to lower floors of structures near the shore. Terrain continuously lower than 10 feet ASL may flood (and require mass evacuations) up to 6 miles inland.
5	Wind Speed: Over 155 mph Storm Surge: Over 18 feet above normal	Complete roof failure on many homes and industrial buildings. Some complete building failures. Major damage to lower floors of all structures located less than 15 feet ASL and within 500 yards of the shoreline. Massive evacuation of low-ground, residential areas may be required.

Source: NOAA. 2016. Saffir–Simpson Extended Hurricane Wind Scale. National Hurricane Center. http://1.usa.gov/1NaMYpVhttp://bit.ly/1MV2oDJ.

Table 2.4 Top Ten Most Expensive US Hurricanes, 1900–2013 (Ranked by non-NFIP insurance claims)

Hurricane	Year	Category	Damage (in millions, 2014 dollars)
Hurricane Katrina—AL, FL, GA, LA, MS, TN	2005	3	$48,383
Hurricane Andrew—FL, LA	1992	5	$23,785
Hurricane Sandy—NC, VA, DC, MD, PA, OH, CT, NY, MA	2012	1	$19,307
Hurricane Ike—AR, IL, IN, KY, LA, MO, OH, PA, TX	2008	4	$13,639
Hurricane Wilma—FL	2005	5	$12,125
Hurricane Charley—FL, NC, SC	2004	4	$9,083
Hurricane Ivan—AL, DE, FL, GA, LA, MD, MS, NJ,NC, NY, NC, OH, PA, TN, VA, WV	2004	3	$8,639
Hurricane Hugo—GA, NC, PR, SC, VA, USVI	1989	4	$7,055
Hurricane Rita—AR, AL, FL, LA, MS, TN, TX	2005	5	$6,624
Hurricane Francis—FL, GA, NC, NY, SC	2004	4	$5,583

Sources: Insurance Information Institute. 2016. Hurricanes. III Website. http://bit.ly/23eQv35.

was only a Category 1 storm when it made landfall and soon after decreased to tropical storm intensity. Despite its weaker strength, Sandy ranks as the third most expensive hurricane in US history.

CASE STUDY: THE IMPACT OF THE STORM

Hurricane Katrina impacted different areas in different ways. Along the Mississippi Gulf Coast, Katrina generated a 25- to 30-foot tidal surge that swept away structures and vehicles in its path. Hotels and casinos located on the Gulf were severely damaged, and in some cases entire communities disappeared. In New Orleans, the principle impact was the flooding caused by the breaches in the levees that left almost 80% of the city underwater for up to 6 weeks.

However, some sections of the city—notably those areas closest to the river such as the French Quarter—experienced very little if any flooding. Tidal surge was only a factor in the city's Lower Ninth Ward, which together with St. Bernard Parish experienced a tidal surge that had traveled up the Mississippi River Gulf outlet. Wind and rain caused considerable damage to homes and businesses throughout the region.

Critical infrastructures such as water, power, communications, schools, hospitals, and childcare centers were severely damaged and disrupted in all impacted areas. Government facilities and private industry suffered massive losses. The White House report on Hurricane Katrina entitled, "The Federal Response to Hurricane Katrina: Lessons Learned", estimated damage to housing to be $67 billion, while business property suffered $20 billion in damages and government property suffered an estimated $3 billion in damages (Townsend, 2006). Insured losses from Katrina are estimated to be the greatest ever in US history.

Over 1.3 million people evacuated before Katrina even made landfall, and an estimated 800,000 people were displaced for an extended period of time. One year after the hurricane, over one half of the 452,170 people that resided within the city limits remained evacuated, reducing its population to 223,388. The 2010 Census found that only 343,829 people claimed the city as their home, which meant a full 25% of the population had not returned in the 5 years that followed the event. Between 2010 and 2013, an inflow in recovery dollars resulted in drastic improvements in employment prospects, and coupled with the availability of services this made the city one of the nation's fastest growing in 2012 as rates of returning residents placing growth at about 5% per year (Bass, 2012). Since that time it has slowed considerably to less than 1% per year, but this is more likely the shadow of 2012's rapid influx (Adelson, 2015).

A SANDY TIMELINE

The following is a timeline of events starting with the initial formation of Hurricane Sandy as Tropical Depression 18 through the first days following landfall in the United States on Nov. 29, 2012. This timeline was compiled from several sources including FEMA, CNN, and National Geographic.

- *Monday, Oct. 22*: A tropical wave forms in the Western Caribbean Sea south of Jamaica and just off the coast of Nicaragua. It quickly grows to tropical depression status, becoming the eighteenth tropical depression of the season. Later the same day, the storm grows to tropical storm strength exhibiting 40 mph winds, thus earning it the title Tropical Storm Sandy.
- *Tuesday, Oct. 23*: Sandy strengthens to Category 1 hurricane status (sustained winds greater than 74 mph) and becomes the tenth hurricane and second major hurricane of the year.
- *Wednesday, Oct. 24*: Hurricane Sandy develops an eye, and crosses over Jamaica. The storm causes 2 fatalities, including one from a landslide and another from electrocution. $100 million

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in damages are sustained, and more than 1000 people require shelter (in addition to thousands of homes that lost roofs).

- *Thursday, Oct. 25*: Hurricane Sandy grows to Category 2 status (sustained 110 mph winds) and crosses Cuba. 11 people are killed, and over $2 billion in damage is sustained including almost 133,000 homes damaged or destroyed.
- *Friday, Oct. 26*: The periphery of Sandy passes over Haiti and the Dominican Republic. Primarily as a result of flooding, the storm causes 54 fatalities and $750 million in damages in Haiti, and 2 fatalities and $30 million in damages in the Dominican Republic. Rain fell for 4 days in these two countries, leaving hundreds of thousands of people homeless, many of whom had been impacted by the 2010 Haiti earthquake. In anticipation of the storm, which is predicted to hit the central to northern East Coast, Governors in New York, Maryland, Maine, Washington (mayor), Pennsylvania, and North Carolina declare emergencies.
- *Saturday, Oct. 27*: Sandy weakens back to tropical storm status, and passes near the Bahamas, causing two deaths and $700 in damages. This same day, the governors of Connecticut, New Jersey, and Massachusetts declare states of emergency. In New Jersey, residents of barrier islands and coastal casinos are ordered to evacuate.
- *Sunday, Oct. 28*: Sandy passes near Bermuda, though damages are minimal and there are no attributed fatalities. A state of emergency is declared in Rhode Island, and all rail services in and through New York are suspended at 7 pm. Rail services are also suspended in parts of Pennsylvania and New Jersey. Flights are suspended in the affected states. Evacuations are ordered in coastal areas of New York and Connecticut (see Fig. 2.4). A Presidential Disaster Declaration is issued for Connecticut, Washington DC, Delaware, Maryland, Massachusetts, New York, and Rhode Island.
- *Monday, Oct. 29*: Sandy continues to track several hundred miles off the Atlantic coast, but because of its massive size there are impacts in several Atlantic states and in Washington, DC. As it approaches New England, it changes course towards a more northwesterly direction, interacting with other storms in the area which increase its energy and size. Sandy makes landfall as a posttropical cyclone that evening, but despite its weaker wind strength it pushes a massive storm surge onto land in Connecticut, New York, and New Jersey.
- *Tuesday, Oct. 30*: Because of the storm's massive size, it continues to impact New York and New Jersey for several more hours as it moves into Pennsylvania. Assessments of damage begin to reveal the extent of impacts including 109 fatalities. Almost 8 million homes remained without power in 15 states and in Washington DC (and several areas did not see power return for over a week). Several area airports, including LaGuardia and Newark, remain closed due to storm damage while John F. Kennedy International Airport opens only for limited services. The stock market remained closed for the second day for the first time since 1888.
- *Wednesday, Oct. 31*: Sandy dissipates over Western Pennsylvania. Newark Airport reopens, as does the Federal Government which had been closed for the previous 2 days. Over 6.3 million households remain without power.
- *Thursday, Nov. 1*: Over 4.8 million households still have no power. LaGuardia airport reopens with limited capacity. Many public schools in the impacted areas remain closed.
- *Friday, Nov. 2*: Gas shortages begin affecting several states, and rationing policies are put in place. 3.3 million households remain without power and many schools remain closed.
- *Sunday, Nov. 4*: 2.2 million households remain without power, and many school districts announce that they will not be ready to open the following day. New York Mayor Bloomberg announces that as many as 40,000 New York City residents may be without housing as a result of the storm.
- *Wednesday, Nov. 7*: Over 600,000 households remain without power. Gas rationing is still in effect.

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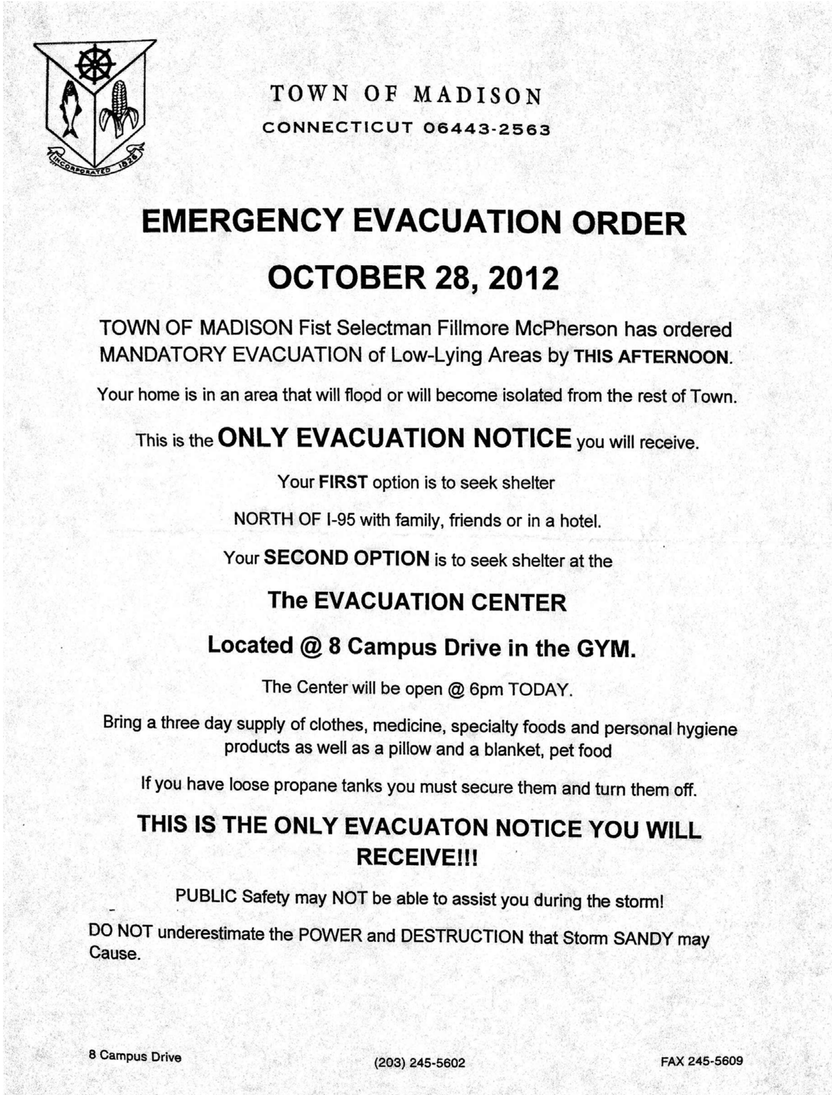

TOWN OF MADISON
CONNECTICUT 06443-2563

EMERGENCY EVACUATION ORDER

OCTOBER 28, 2012

TOWN OF MADISON Fist Selectman Fillmore McPherson has ordered MANDATORY EVACUATION of Low-Lying Areas by **THIS AFTERNOON**.

Your home is in an area that will flood or will become isolated from the rest of Town.

This is the **ONLY EVACUATION NOTICE** you will receive.

Your **FIRST** option is to seek shelter

NORTH OF I-95 with family, friends or in a hotel.

Your **SECOND OPTION** is to seek shelter at the

The EVACUATION CENTER

Located @ 8 Campus Drive in the GYM.

The Center will be open @ 6pm TODAY.

Bring a three day supply of clothes, medicine, specialty foods and personal hygiene products as well as a pillow and a blanket, pet food

If you have loose propane tanks you must secure them and turn them off.

THIS IS THE ONLY EVACUATON NOTICE YOU WILL RECEIVE!!!

PUBLIC Safety may NOT be able to assist you during the storm!

DO NOT underestimate the POWER and DESTRUCTION that Storm SANDY may Cause.

8 Campus Drive (203) 245-5602 FAX 245-5609

FIGURE 2.4 Image of evacuation flyer distributed in advance of Hurricane Sandy (2012) in coastal areas expected to be impacted by a storm surge. *Author (2012).*

Source: CNN Library. 2015. Hurricane Sandy Fast Facts. http://cnn.it/1WQ5A67; Drye, William. 2012. A Timeline of Hurricane Sandy's Path of Destruction. National Geographic. November 12. http://bit.ly/1SmncEP; FEMA. 2012. New Jersey – Hurricane Sandy. Disaster Declaration 4086. October 30. http://bit.ly/2fMETSl.

In recent years, significant advances have been made in hurricane tracking technology and computer models. The National Hurricane Center in Miami, Florida, now tracks tropical waves from the moment they form off the coast of West Africa through their development as a tropical depression. Once the tropical depression grows to the strength of a tropical storm, the Hurricane Center assigns the storm a name. After the sustained wind speed exceeds 74 mph, the storm officially becomes a hurricane. The National Hurricane Center uses aircraft to observe and collect meteorological data on the hurricane and to track its movements across the Atlantic Ocean. It also uses several sophisticated computer models to predict the storm's path. These predictions are provided to local and state emergency officials to help them make evacuation decisions and to predeploy response and recovery resources.

Historically, high winds and flooding caused by storm surge have been the principal contributors to the loss of life and injuries and the property and infrastructure damage caused by hurricanes. A 14-foot storm surge caused by Hurricane Sandy in 2012 caused significant flooding in downtown Manhattan and along the densely populated New Jersey coast, bringing transportation in the area to a standstill and wiping out whole neighborhoods. Inland flooding caused by hurricane rainfall has also resulted in large losses of life and severe property damage, especially in zones of hilly or mountainous topography—as occurred in 2011 in Vermont during Hurricane Irene. Damage to the environment is another important factor related to hurricane-force winds and flooding. For instance, storm surges cause severe beach erosion, most notably on fragile barrier islands. Inland flooding from Hurricane Floyd inundated waste ponds on hog farms in North Carolina, washing the hog waste into the Cape Fear River and ultimately into the ocean. The storm surge created by Hurricane Katrina has had a profound impact on the environment—in some cases completely erasing or altering coastal areas. Dauphin Island was literally pushed toward the land by the force of the surge, and the Chandeleur Islands were completely destroyed. Breton National Wildlife Refuge, one of 16 wildlife refuges damaged by the storm, lost over half of its area. Much of this lost land had served as breeding grounds for marine mammals, reptiles, birds, and fish.

Storm Surges

Storm surges are defined as masses of water pushed toward and onto the shore by meteorological forces. They are the primary cause of the injuries, deaths, and structural damages associated with hurricanes, cyclones, nor'easters, and other coastal storms. When an advancing surge of water coincides with a high tide, the resulting increases in coastal sea levels are further exacerbated. Storm surges can reach several dozen feet under the right conditions, most notably when they coincide with an astronomical high tide or when they interfere with riverflow. In a surge, wind-driven turbulence becomes superimposed on the storm tide, thereby causing further damage to structures that are inundated through wave action (each cubic yard of water exerts 1700 pounds of pressure on affected structures). The surge height at landfall is ultimately dictated by the expanse and intensity of the storm, the height of the tide at the time of landfall, and the slope of the sea floor approaching land. The longer and shallower the sea floor, the greater the storm surge will be.

Because much of the United States' densely populated Atlantic and Gulf Coast coastlines lie less than 10 feet above mean sea level, storm surge risk is extreme. Hurricane Katrina served as a reminder of the speed and intensity of the storm surge threat that persists in greater part due to increasing coastal development. After crossing southern Florida, Katrina followed a westward track across the Gulf of Mexico before turning northwest toward the Gulf Coast. The storm made its second landfall as a strong Category 4 hurricane in Plaquemines Parish, Louisiana, on Aug. 29, 2005. When the storm made its third and final landfall along the Mississippi/Louisiana border, its hurricane-force winds extended up to 190 miles from the center of the storm, and tropical storm-force winds extended for approximately 440 miles. The strength and wide geographical area affected by the storm resulted in a surge greater than anything previously recorded along the Gulf Coast. A 30-foot storm surge, combined with very strong wave action and constant high winds, resulted in a magnitude of destruction never before experienced in the United States. The enormous pressure by the force of the storm surge on the levee system that protected New Orleans caused several breaches that flooded the city with as much as 20 feet of water in some areas. The National Hurricane Center developed an animation showing how a hurricane causes a storm surge: http://1.usa.gov/1MjtHI1.

The National Hurricane Center operates a computerized model, called SLOSH (Sea, Lake, and Overland Surges from Hurricanes), to estimate storm surge heights and winds resulting from historical, hypothetical, or predicted hurricanes. When making calculations, SLOSH takes into account pressure, size, forward speed, track, and wind. The model's output is a color-coded map indicating storm surge heights for defined areas in feet above the model's reference level. These calculations are applied to a specific locale's shoreline, incorporating the unique bay and river configurations, water depths, bridges, roads, and other physical features. When SLOSH is used to estimate storm surge from predicted hurricanes, forecast data are entered every 6 hours over a 72-hour period and updated as new forecasts become available. SLOSH is accurate within a range of 20% plus or minus what is actually observed. The model accounts for astronomical tides, but it does not consider rainfall, riverflow, or wind-driven waves. However, this information can be combined with the model's output to create a more accurate analysis of at-risk areas.

The National Weather Service also runs a storm surge model for extratropical storms called ET-SURGE (also known as ETSS). This model is a variation of SLOSH that works with nonhurricane systems.

Tornadoes

A tornado is a rapidly rotating vortex or funnel of air extending groundward from a cumulonimbus cloud, exhibiting wind speeds of up to 300 mph. Approximately 1200 tornadoes are spawned by thunderstorms each year in the United States. Most tornadoes remain aloft, but the few that do touch the ground are devastating to everything in their path. The forces of a tornado's winds are capable of lifting and moving huge objects, destroying or moving whole buildings, and siphoning large volumes from bodies of water and ultimately depositing them elsewhere. Because tornadoes typically follow the path of least resistance, people living in valleys have the greatest exposure to damage.

Tornadoes have been measured using the Fujita-Pearson Tornado Scale since its creation in 1971 (Table 2.5). In 2006, research indicated that tornado damage was occurring from winds of much weaker intensity than previously thought, so the National Weather Service created an enhanced scale to measure them (Table 2.6). First used in Jan. 2007,

Table 2.5 Original Fujita-Pearson Tornado Scale

Category	Conditions	Effects
F-0	40–72 mph	Chimney damage, tree branches broken
F-1	73–112 mph	Mobile homes pushed off foundation or overturned
F-2	113–157 mph	Considerable damage, mobile homes demolished, trees uprooted
F-3	158–205 mph	Roofs and walls torn down, trains overturned, cars thrown
F-4	207–260 mph	Well-constructed walls leveled
F-5	261–318 mph	Homes lifted off foundation and carried considerable distances, autos thrown as far as 100 m

Table 2.6 Enhanced Fujita-Pearson Tornado Scale

Category	Conditions	Effects
F-0	65–85 mph	Minor to light damage to structures and vegetation
F-1	85–110 mph	Moderate damage to structures and vegetation
F-2	111–135 mph	Heavy damage to structures and vegetation
F-3	136–165 mph	Severe damage to structures and vegetation
F-4	166–200 mph	Extreme damage to structures and vegetation
F-5	Over 200 mph	Complete destruction of structures and vegetation

this scale expands upon the original system's measure of damage to homes by adding 18 new damage indicators, including those that affect trees, mobile homes, and several other structures (giving a total of 28 indicators studied in the classification of a tornado). Under the enhanced Fujita-Pearson scale, a tornado that does not affect houses can still be classified.

Tornado damage occurs only when the funnel cloud touches down on land. In the United States, the states with the greatest tornado risk are Texas, Oklahoma, Arkansas, Missouri, and Kansas. Together these states occupy what is commonly known as "tornado alley." In recent years, however, tornadoes have struck in cities that are not regularly frequented by tornadoes, including Miami, Nashville, and Washington, DC. Tornadoes can also touch down in several places in succession, as occurred in Washington, DC in 2001. In that event, a single tornado first touched down in Alexandria, Virginia, just south of the city and then again in College Park, Maryland, just north of DC On May 22nd of 2011, an E-5 tornado with a width of approximately 1 mile touched down in Joplin, Missouri, wiping out a sizeable portion of the town. The short-lived event killed 158 people and injured over 1100, making it the most deadly tornado in over a half-century.

Tornado season generally falls between Mar. and Aug., although tornadoes can occur at any time of the year. Tornadoes tend to occur in the afternoon and evening, with more than 80% of all tornadoes striking between noon and midnight. Building collapse and flying debris are the principal factors behind the deaths and injuries tornadoes cause. Early warning is key to surviving tornadoes, as warned citizens can protect themselves by moving to structures designed to withstand tornado-force winds. Doppler radar and other meteorological tools have drastically improved the ability to detect tornadoes and the amount of

FIGURE 2.5 Rowlett, TX, Dec. 28, 2015. Rowlett Fire Battalion Chief does a wellness check on residents in tornado-stricken Rowlett neighborhood. *Photo by Andrea Booher/FEMA.*

advance warning time available before a tornado strike. Improved communications and new technologies have also been critical to giving people advanced warning.

Buildings that are directly in the path of a tornado have little chance of surviving unless they are specifically designed to withstand not only the force of the winds but also that of the debris "missiles" that are thrown about (Fig. 2.5). "Safe room" technology developed by FEMA and Texas Tech University, which retrofits a portion of a structure to withstand such winds through engineered resistant design and special resilient materials, offers those in the path of a tornado much greater survival likelihoods (Fig. 2.6). Safe rooms are often the most cost-effective way to mitigate tornado risk in communities that are already heavily developed, since they can be built into an existing (or new) structure for a small cost (estimated between $3000 and $5000).

In order to greatly expand the mitigation benefits of safe rooms, similar technology is being developed for use in community mass-care shelters. New technologies in building design and construction are also being developed by FEMA and others to reduce the damage to buildings and structures not located directly in the path of a tornado. Many of the same wind-resistant construction techniques used effectively in high-risk hurricane areas have been found to be equally effective when applied to new and retrofitted structures located in tornado-prone areas.

Wildfires

Wildfires (often called "wildland fires") are classified into three categories: *surface fires*, the most common type, which burn along the floor of a forest, moving slowly and killing or

FIGURE 2.6 Tulsa, Oklahoma, Nov. 23, 2001. Disaster Ally in the Eastland Mall. Safe rooms can be designed with many different materials. Shown are concrete block walls, formed concrete walls, and a special ceiling framing. *Photo by Kent Baxter/FEMA News Photo.*

damaging trees; *ground fires*, which are usually started by lightning and burn on or just below the forest floor; and *crown fires*, which burn through the forest canopy high above the ground and therefore spread much more rapidly due to wind and direct contact with nearby trees. Wildland fires are an annual and increasing hazard due to the air pollution (primarily smoke and ash that travel for miles, causing further hazards to health and mechanical or electrical equipment), risk to firefighters, environmental effects, and property destruction they cause.

As residential areas expand into relatively untouched wildlands (called the "wildland-urban interface"), the threat to the human population increases dramatically. Protecting structures located in or near the wildland poses special problems and often stretches fire-fighting resources beyond capacity. Wildland fires also cause several secondary hazards. For instance, when heavy rains follow a major fire, landslides, mudflows, and floods can strike on or downhill from the newly unanchored soil. These fires can also severely scorch the land, destroying animal habitats and causing barren patches that may persist for decades, increasing the likelihood of long-term erosion. Thousands of out-of-control wildfires on the Indonesian island Sumatra in 2015 produced a thick haze that choked all of Singapore and Brunei and large regions of Indonesia, Malaysia, Vietnam, Cambodia, the Philippines, and Thailand for weeks. Tens of millions of people were affected, hundreds of thousands experienced respiratory distress, and dozens died as a result of their exposure. The haze required closure of schools and businesses, a reduction in agricultural production, and production of greenhouse gases that equaled Germany's estimated annual carbon emissions in the few weeks that the crisis persisted.

Several terms are used to classify the source and behavior of wildland fires:

- *Wildland fires*. Fueled almost exclusively by natural vegetation, these fires typically occur in national forests and parks, where federal agencies are responsible for fire management and suppression.
- *Interface or intermix fires*. These fires occur in or near the wildland-urban interface, affecting both natural and built environments and posing a tactical challenge to firefighters concerned with the often conflicting goals of firefighter safety and property protection.
- *Firestorms*. Events of such extreme intensity that effective suppression is virtually impossible, firestorms occur during extreme weather and generally burn until conditions change or the available fuel is exhausted.
- *Prescribed fires and prescribed natural fires*. These are fires that are intentionally set or selected natural fires that are allowed to burn for the purpose of reducing available natural fuel.

Severe drought conditions and the buildup of large quantities of "fuel" (dead trees and flammable vegetation) on the forest floors have led to a steady increase in the prevalence of wildfires in the United States. Since the National Interagency Fire Center began tracking the number and acreage of fires in 1960, the average number of fires has fallen (presumably due to fire-prevention programs), while the annual acreage burned has risen. In other words, the fewer fires that are occurring are larger and more destructive on average. Before 2004, no year had seen more than 7 million acres burned, and few experienced greater than 4 or 5 million acres burned. Yet, from 2004 to 2007, each year exceeded 8 million and in 2006, 2007, and 2012, rates exceeded 9 million acres burned. In 2015, the number of acres burned exceeded 10 million for the first time (see Table 2.7) (NIFC, 2013). A number of factors have been attributed to these increases, the most significant of which include heat associated with El Niño and ongoing climate change effects (Mann and Gong, 2015). In addition to the doubling of acres burned annually, experts claim that the annual period of higher-than-normal risk called 'Fire Season' has increased from 5 months in the 1970s to 7 months today (Breslin, 2016). For some parts of the country and the world—most notably in Australia—there is no longer a fire season given that new fires are breaking out even in the traditionally-safe winter months (Richtel and Santos, 2016).

Mass-Movements

Mass-movements is a general category that includes several distinct hazards that are characterized by a horizontal or lateral movement of large quantities of physical matter. Mass movements inflict damage and loss of life through several different processes, including the pushing, crushing, or burying of objects in their path, the damming of rivers and waterways, the subsequent movement of displaced bodies of water (typically in the form of a tsunami), destruction or obstruction of major transportation routes, and alteration of the natural environment in ways in which humans are negatively impacted. Mass-movements are most prevalent in areas of rugged or varied topography, but they can occur even on level land as is

Table 2.7 Total Wildland Fires and Acres Burned 1996–2016

Year	Number of Fires	Acres Burned
2015	68,151	10,125,149
2014	63,312	3,595,613
2013	47,579	4,319,546
2012	67,774	9,326,238
2011	74,126	8,711,367
2010	71,971	3,422,724
2009	78,792	5,921,786
2008	78,979	5,292,468
2007	85,705	9,328,045
2006	96,385	9,873,745
2005	66,753	8,689,389
2004	65,461	*8,097,880
2003	63,629	3,960,842
2002	73,457	7,184,712
2001	84,079	3,570,911

*2004 fires and acres do not include state lands for North Carolina.
Source: National Interagency Fire Center. 2016. Total Wildland Fires and Acres (1960–2015). NIFC Website. http://1.usa.gov/1MlSmM7.

typically the case with subsidence. The following hazards are each considered to be mass-movements:

- *Landslides.* Landslides occur when masses of relatively dry rock, soil, or debris move in an uncontrolled manner down a slope. Landslides may be very highly-localized or massive in size, and they can move at a creeping pace or at very high speeds. Many areas have experienced landslides repeatedly since prehistoric times. Landslides are activated when the mechanisms by which the material was anchored become compromised (through a loss of vegetation or seismic activity, for example).
- *Mudflows*. Mudflows are water-saturated rivers of rock, earth, and other debris that are drawn downward by the forces of gravity. These phenomena develop when water rapidly accumulates in the material that is moved, like during heavy rainfall or rapid snowmelt. Under these conditions, solid or loose earth can quickly change into a flowing river of mud, or “slurry.” These flows move rapidly down slopes or through channels, following the path of least resistance, and often strike with little or no warning. Mudflows have traveled several miles in many instances, growing in size as they pick up trees, cars, and other materials along the way.
- *Lateral spreads*. Lateral spreads occur when large quantities of accumulated earth or other materials spread downward and outward due to gradual hydrologic and gravitational forces. Spreads can affect rock, but they also occur in fine-grained, sensitive soils such as clays.
- *Liquefaction.* When saturated solid material becomes liquid-like in constitution due to seismic or hydrologic activity, it can exacerbate lateral spreading.

- *Rockfalls.* Rockfalls occur when masses of rock or other materials detach from a steep slope or cliff and descend by freefall, rolling, or bouncing. Topples consist of the forward rotation of rocks or other materials above a pivot point on a hill slope. Rockfalls can occur spontaneously when fissures in rock or other materials cause structural failure or due to seismic or other mechanical activity (including explosions or the movement of heavy machinery).
- *Avalanches.* An avalanche is a mass of ice or snow that moves downhill at a high velocity. Avalanches can shear trees, cover entire communities and highway routes, and level buildings in their path. Avalanches are triggered by a number of processes, including exceeding critical mass on a steep slope or disturbances caused by seismicity or human activity. As temperatures increase and snowpack becomes unstable, the risk of avalanches increases. The primary negative consequences associated with avalanches are loss of life (mostly to backcountry skiers, climbers, and snowmobilers) and obstruction of major transportation routes. Around 10,000 avalanches are reported each year in the United States. Since tracking began in 1790, an average of 144 people have become trapped in avalanches annually, and of these an average of 14 sustain injuries and 14 die. The average annual value of structural damage is $500,000, though the secondary costs associated with disrupted commerce can be much greater.
- *Land subsidence.* Land subsidence is the loss of surface elevation caused by the removal of subsurface support. Subsidence can range from broad, regional lowering of large landmasses to severe localized collapses. The primary cause of this hazard is human activity, including underground mining, extraction of groundwater or petroleum, and the drainage of organic soils. The average annual damage associated with subsidence in the United States is estimated to be at least $125 million (USGS, 1999).
- *Expansive soils.* Soils and soft rock that tend to swell or shrink when their moisture content changes are referred to as expansive soils. These changes are extremely detrimental to transportation routes (including highways, streets, and rail lines) and structures that are built above the affected soils. The most extensive damage affects highways and streets. Two rock types that are particularly prone to expansion and that are prevalent in the United States (primarily in the West) are aluminum silicates (e.g., ash, glass, and rocks of volcanic origin) and sedimentary rock (e.g., clay and shale).

Tsunamis

A tsunami is wave or series of waves that is generated by a mass displacement of sea or lake water. The most common generative factor behind tsunamis is undersea earthquakes that cause ocean floor displacement, but large tsunamis have been caused by volcanic eruptions and landslides as well. Tsunami waves travel outward as movements of kinetic energy (rather than traveling water) at very high speeds in all directions from the area of the disturbance, much like the ripples caused by a rock thrown into a pond. As the waves approach shallow coastal waters, wave speed quickly decreases and the water is drawn upward and onto land. Tsunamis can strike at heights exceeding 100 feet and can extend for a mile or more onto land as determined by topography. The force of a tsunami causes near total destruction of everything in its path.

FIGURE 2.7 Yuriage Port, Tohoku, Japan, Mar. 16, 2015. A resident of Yuriage Port, which was destroyed in the 2011 Great East Japan Earthquake, displays before and after photographs of the community to illustrate the scope of damage. *Photo by Damon Coppola.*

Areas that face the greatest risk from tsunamis are those that lie less than 50 feet above sea level and within 1 mile of the shoreline. Successive crests (high water) and troughs (low water) can occur anywhere from 5 to 90 minutes apart. Tsunamis travel through deep water at approximately 450 mph, so the areas closest to the point of origin experience the greatest destruction and have the least amount of forewarning. Most tsunami-related deaths are the result of drowning, while the loss of services and related health problems associated with the incredible destruction of the infrastructure (including the loss of hospitals and clinics, water pollution, contaminated food and water stocks, and damaged transmission lines) adds to these statistics (see Fig. 2.7).

ADDITIONAL RESEARCH

The Woods Hole Oceanographic Institute has developed a highly illustrative website about the causes and dynamics of tsunamis. This website also provides significant information about mitigation techniques, historical tsunami events, warning systems, modeling, and much more. The site can be accessed at http://bit.ly/1RWWq26.

(*Continued*)

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The *New York Times* has created a 'slider' graphic that allows users to see the impact of the 2011 Great East Japan Earthquake Tsunami on affected communities by alternating between before and after satellite imagery of the most heavily impacted towns. This site can be accessed at: http://nyti.ms/1NfXnAx.

CASE STUDY: RECENT MAJOR TSUNAMI EVENTS

On Dec. 26, 2004, following an earthquake off the coast of the Banda Aceh region of Indonesia that measured 8.9 on the Richter scale, a series of tsunamis devastated vast coastal regions in 11 countries as far away as East Africa. The earthquake was the most powerful to occur in 4 decades, and it generated waves reaching as high as 60 feet on coastal shorelines. The devastation from this event in terms of the geographical range and number of people affected within the brief timeframe is virtually unprecedented in modern history.

Due to an almost complete lack of regional tsunami warning capabilities, little advanced notice of the presence or severity of these impending waves was possible for the affected populations, many of whom included foreign tourists. As a result, most people had no opportunity to move to higher ground—an action that surely would have prevented the high number of injuries and fatalities that occurred. While the exact number of people killed will never be known, it is assumed to be greater than 150,000 and possibly more than 200,000. Over 500,000 injuries were reported, and ten times as many people were left homeless.

Almost 5 years after this terrible event, another quake struck in the nearby South Pacific region, causing large tsunamis in the islands of Samoa, American Samoa, and Tonga. These events were caused by an 8.0 magnitude earthquake near the Samoan Islands on Sep. 29. While significant infrastructure had been put into place to detect tsunamis and warn the at-risk populations, communication failures prevented many people from being informed. Upon personally observing now-familiar telltale signs of a coming tsunami, including the earthquake itself, and changing off-tide water levels, many residents fled to higher ground. However, 189 people still lost their lives, most of whom lived in hardest-hit Samoa.

On Mar. 11, 2011, a massive magnitude 9.0 earthquake struck off the coast of Japan near Tohoku. This quake, which ranks among the five most powerful earthquakes known, triggered tsunamis throughout Japan reaching heights as great as 133 feet. Tsunamis traveled throughout the Pacific, reaching as far as Chile, which saw a 6-foot wave. Prior to this event, Japan was arguably the nation most prepared for the tsunami threat, having endured dozens of major tsunami events in its recorded history. However, planning underestimated the potential height and severity of tsunamis and defenses were quickly overtopped. In some areas, tsunami water traveled as far as 6 miles inland. In addition to causing a major nuclear accident, over 15,800 people were killed, more than 6100 were injured, and thousands remain missing. The ongoing recovery effort has proven monumental given the extent of debris that exists from over one million buildings either totally or partially collapsed. The World Bank estimated in 2011 that the total economic impact from the event would be about $235 billion, while more recent figures show reconstruction has already topped $250 billion (making it the most expensive natural disaster to have ever occurred (Nakamura, 2011; Conca, 2016).

Volcanic Eruptions

A volcano is a break in the earth's crust through which molten rock from beneath the earth's surface (magma) erupts. Over time, volcanoes will upward and outward, forming mountains, islands, or large, flat plateaus called "shields." Volcanic mountains differ from mountain chains formed through plate tectonics (movement of the earth's crustal plates) because they are built through the accumulation of materials (lava, ash flows, and airborne ash and dust) rather than being pushed up from below. When volcanic material exits the earth, it is called lava, and the nature of its exit determines the land formations that result. Thinner lava typically moves quickly away from the source and becomes a large shield (as in the case of the Hawaiian Islands), while thicker lava and other materials form steeper volcanic formations.

When pressure from gases and molten rock becomes strong enough to cause an explosion, violent eruptions may occur. Gases and rock shoot up through the opening and spill over or fill the air with lava fragments. Volcanoes cause injuries, death, and destruction through a number of processes, including direct burns, suffocation from ash and other materials, trauma from ejected rocks, floods and mudflows from quickly melted snow and ice, burial under burning hot "pyroclastic" ash flows, and others. Airborne ash can affect people hundreds of miles away from the eruption and influence global climates for years afterward. Because airborne ash damages jet engines when it melts and forms glass on the engine surface, volcanic eruptions can and do cause significant travel disruptions across wide geographic regions. Regions affected by ash-related travel disruptions include Southeast Asia (Nov., 2015 from Mount Raung, Indonesia), South Pacific (Aug. 2014, Mt. Tavurvur, Papua New Guinea), and Northern Europe (Apr., 2010 from the Eyjafjallajokull volcano, Iceland).

Volcanic ash contaminates water supplies, causes electrical storms, and can cause roofs to collapse under the weight of accumulated material. Eruptions may also trigger tsunamis, flash floods, earthquakes, and rockfalls. Sideways-directed volcanic explosions, known as "lateral blasts," can shoot large pieces of rock at very high speeds for several miles. These explosions can kill by impact, burial, or heat. They have been known to knock down entire forests. Most deaths attributed to the Mount St. Helens volcano were a result of lateral blast and trees that were knocked down. Volcanic ash also has some positive implications because it can be used for construction or road building, as abrasive and cleaning agents, and as raw materials for many chemical and industrial uses. Ash-covered land is also rich in mineral nutrients and ideal for agricultural production.

Severe Winter Storms

Severe winter storms occur when extremely cold atmospheric conditions coincide with high airborne moisture content, resulting in rapid and heavy precipitation of snow and/or ice. When combined with high winds, the event is known as a blizzard. In the United States, these hazards originate from four distinct sources:

- In the Northwest, cyclonic weather systems originate in the North Pacific Ocean or the Aleutian Island region.
- In the Midwest and Upper Plains, Canadian and Arctic cold fronts push ice and snow deep into the heart of the nation—in some instances, traveling as far south as Florida.

Table 2.8 NESIS Values

Category	NESIS Value	Description
1	1–2.499	Notable
2	2.5–3.99	Significant
3	4–5.99	Major
4	6–9.99	Crippling
5	10.01	Extreme

Source: *NOAA, 2006.* http://bit.ly/2ewROpy.

- In the Northeast, lake-effect snowstorms develop when cold weather fronts pass over the relatively warm surfaces of the Great Lakes.
- The eastern and northeastern states are affected by extratropical cyclonic weather systems in the Atlantic Ocean and the Gulf of Mexico that produce snow, ice storms, and occasional blizzards.

On Jan. 1, 2006, the federal government began to use a new scale, similar to the scales used to measure the magnitude and intensity of hurricanes and tornadoes, to measure severe winter storms. The Northeast Snowfall Impact Scale (NESIS) provides a numerical value to storms based on the geographical area affected, the amount of snow accumulation, and the number of people affected. The minimum threshold for a storm's inclusion in the scale is 10 inches of snow falling over a wide area.

NESIS values range from 1 to 5 and include associated descriptors (from most to least severe) of Extreme, Crippling, Major, Significant, and Notable. The NESIS scale differs from other meteorological indices in that it considers population data. It uses the following formula:

$$\text{NESIS} = \sum_{n=4}^{n=30} \left[\frac{n}{10} \left(\frac{A_n}{A_{\text{mean}}} + \frac{P_n}{P_{\text{mean}}} \right) \right]$$

where A equals the area affected and P equals the population affected. Table 2.8 shows the categories assigned to severe winter storms using this formula.

Drought

Drought is defined as a prolonged shortage of available water, primarily due to insufficient rain and other precipitation or because exceptionally high temperatures and low humidity cause a drying of agriculture and a loss of stored water resources. Drought hazards differ from other natural hazards in three ways:

1. A drought's onset and conclusion are difficult to determine because the effects accumulate slowly and may linger even after the apparent termination of an episode.
2. There is no precise or universally accepted determination of what conditions constitute official drought conditions or the degree of drought severity
3. The drought's effects are less obvious and spread over a larger geographic area.

In very poor countries, drought is associated with famine, which is widespread starvation brought about by limited access to food resources. However, in the United States, where mechanisms are in place to move resources quickly from region to region, the threat of famine no longer exists. Drought does, however, impact food and other crops, and can severely hamper commerce on major rivers. A 2012–13 drought which exceeded anything experienced in over a half-century almost completely halted barge and other commercial traffic on the Mississippi River impacting billions of dollars of cargo and thousands of jobs (Fears, 2013).

The Southwest region saw a sustained severe drought between 2011 and 2016 (see Fig. 2.8). This represented the driest period in California's history, and the impacts prompted Governor Jerry Brown to institute a first-of-its-kind mandatory 25% water restriction beginning in 2015. The restriction remained in place for more than 1 year. So bad was this drought that by late 2015, California's largest lake (the 350-square mile Salton Sea) had receded so far from its normal shores that it began producing giant clouds of toxic dust. Hydrogen sulfide gas produced by decaying organic matter was also released, resulting in a rotten-egg smell that was experienced up to 130 miles away in urban centers like Los Angeles. As the lakebed dried and turned to dust, wind kicked it up and created smog that triggered asthma and contained arsenic and other poisons that were inhaled (Iovenko, 2015). Emerging hazards like these are often cited as harbingers of things to come if climate change trends are not reversed.

The Climate Prediction Center of the National Weather Service monitors nationwide drought conditions and provides visual reports on a weekly basis and seasonal reports on a monthly basis. A report of current drought conditions in the United States, referred to as the US Drought Monitor, can be viewed at http://1.usa.gov/1RWYEys.

FIGURE 2.8 Lovelock, NV, Feb. 7, 2014. State park rangers burned weeds on the exposed lakebed of the Rye Patch Reservoir in Nevada, which was at 3.5% capacity amid a drought that has caused the worst water shortage the region has faced in more than a century. *Photo by Max Whittaker, FEMA Website.*

Extreme Temperatures

Major diversions in average seasonal temperatures can cause injuries, fatalities, and major economic impacts when they are prolonged or coincide with other natural or technological events. Extreme heat, called a heat wave, occurs when temperatures of ten or more degrees above the average high temperature persist across a geographic region for several days or weeks. Humid or muggy conditions, which add to the discomfort of high temperatures, can occur when a "dome" of high atmospheric pressure traps hazy, damp air close to the ground. Excessively dry conditions that coincide with extreme heat can provoke wind and dust storms.

When little rain occurs in conjunction with extreme heat, droughts are likely to occur. Prolonged periods of heat have resulted in hundreds of thousands of deaths in single instances, including 600 in the Chicago area in 1995 and almost 37,500 in Europe in 2003. In most years, more than 1500 people die from exposure to excessive heat in the United States, making it the number one weather-related killer of humans.

While there is no widely accepted standard for extreme cold temperatures, periods of colder than normal conditions exhibit a range of negative consequences, depending on where they occur and exactly how cold temperatures fall. Any time temperatures fall below freezing, there is the risk of death from hypothermia to humans and livestock, with the degree to which populations are accustomed to those temperatures a primary factor in resilience. Extreme cold can also lead to serious economic damages from frozen water pipes; the freezing of navigable rivers, which halts commerce and can cause ice dams; and the destruction of crops.

The increased prevalence and severity of periods of both extreme heat and extreme cold are often considered in conjunction with rising average annual temperatures as being clear evidence of global climate change. The World Meteorological Organization (WMO) established Intergovernmental Panel on Climate Change (IPCC) reports that world climates have altered in such a way that heat waves now involve higher temperatures, last longer in duration, and are more frequent in their occurrence (IPCC, 2013). Furthermore, the number of days considered "extremely hot" have increased over a majority of the United States and are expected to worsen throughout the century. Rising summer temperatures coupled with reductions in soil moisture will lead to more sustained heat waves, especially in the western and central regions. What is perhaps the most shocking is that temperature extremes which occurred only once per 20 years (5% annual likelihood) on average prior to 1980 are increasing at rates that will reach as high as 7 out of every 10 years (70% annual likelihood) by 2035 (US National Climate Assessment, 2014).

Coastal Erosion

Coastal erosion, which is the loss of land bordering a body of water, is measured as the rate of change in the position or horizontal displacement of a shoreline over a period of time. It is generally associated with storm surges, hurricanes, windstorms, tsunamis, and flooding hazards, and it can be exacerbated by human activities such as boat wakes, shoreline hardening, and dredging. El Niño and climate change effects (e.g., sea level rise) are also contributing factors. The primary concerns with regards to coastal erosion relate to the economic

FIGURE 2.9 Staten Island, NY, Nov. 12, 2012, Aerial view of beach erosion on Coney Island, New York. Storm surge from Hurricane Sandy caused flooding and power outages throughout the island. *Photo by Andrea Booher, FEMA.*

impacts that result when property and infrastructure located very close to the eroding coasts lose their natural protection from the water and waves or are affected by destabilization of the land upon which they were constructed (see Fig. 2.9).

Environmental impacts from erosion include the loss of animal habitats and esthetic losses. Fishing industries that are dependent on coastal habitats can suffer great losses from changes caused by coastal erosion, and the loss of tourism can result in similar economic impacts. Coastal features like dunes and mangroves also provide a natural defense against several hazards, including tsunami waves and storm surges, so their loss may signal an increase in vulnerability from these hazards. Major disasters can damage or destroy these natural buffers, or simply cause direct erosion that equates to years of nondisaster-related erosion in a single event.

In California, 86% of the coastline is eroding at a rate that ranges from just a few inches to as much as 10 feet per year. While some homeowners have spent hundreds of thousands of dollars to strengthen their property from erosion, there are few permanent solutions and most at-risk properties must eventually be relocated or torn down. The problem is a perpetual one that is confounding development officials in many coastal towns that must determine the best ways to reduce future risk without changing the esthetic nature of the coastline or causing undue stress on the natural environment (Olney, 2010).

Thunderstorms

Thunderstorms are meteorological events that bring heavy rains, strong winds, hail, lightning, and tornadoes. Thunderstorms are generated by atmospheric imbalance and turbulence caused by a combination of several conditions, including: unstable, warm air rising rapidly into the atmosphere; sufficient moisture to form clouds and rain; and upward lift of air currents caused by colliding weather fronts (cold and warm), sea breezes, or mountains.

A thunderstorm is classified as severe if its winds reach or exceed 58 mph, it produces a tornado, or it drops surface hail at least 1 inch in diameter. Thunderstorms may occur singly, in clusters, or in lines. Thus, it is possible for several thunderstorms to affect one location in the course of a few hours. These events are particularly devastating when a single thunderstorm affects one location for an extended period. Such conditions lead to oversaturation of the ground and subsequent flash flooding and slope erosion.

Lightning is a major secondary threat associated with thunderstorms. In the United States, between 75 and 100 Americans are hit and killed by lightning each year. Many air disasters have been linked to thunderstorms because of the unpredictable and turbulent wind conditions they cause and the threat of electronic or mechanical failure caused by lightning strikes. When humans or structures are hit by lightning, the effect is devastating to both.

Hail

Hail is frozen atmospheric water that falls to the earth. Moisture in clouds becomes frozen into crystals at high temperatures and begins to fall under its own weight. Typically, these crystals melt at lower temperatures, but in the right conditions they pick up more moisture as they fall and are then lifted to cold elevations, which causes refreezing. This cycle may continue until the individual hailstones reach several inches in diameter under the right conditions. Because of the strength of severe thunderstorms and tornadoes, both can cause this cyclic lifting, and therefore they are often accompanied by hail. Hailstorms occur more frequently during late spring and early summer when the jet stream migrates northward across the Great Plains. When they fall, they can damage crops, break windows, destroy cars and other exposed properties, collapse roofs, and cause other destruction totaling nearly $1 billion each year in the United States (Insurance Information institute, 2016) (Table 2.9).

Table 2.9 Top 10 States by Hail Losses 2000–13

Rank	State	Total Claims
1	Texas	$859,184,000
2	Minnesota	$252,245,000
3	Oklahoma	$217,950,000
4	Colorado	$186,511,000
5	Illinois	$180,037,000
6	Ohio	$177,108,000
7	Georgia	$166,875,000
8	Tennessee	$153,966,000
9	Kansas	$150,539,000
10	Indiana	$148,635,000

Source: Verisk Insurance Solutions. 2014. Property Claims in the United States, 2000–2013. http://vrsk.co/1qdXN5b.

■■ Critical Thinking ■

- Do you know what disaster-causing hazards your community is exposed to? Are there any hazards that haven't resulted in any disasters during your lifetime but still pose a significant threat? What hazards pose little or no threat to your community?
- Has your community ever experienced a disaster that required outside assistance (from neighboring communities, or the regional or national government)? What types of assistance did the outside resources provide? Were there any functions that the community was able to manage fully on its own (using local emergency management resources)?
- Are there any recurrent natural hazards in your community? If so, what actions has your community taken to mitigate these recurrent hazards? Have these actions been successful in reducing the consequences or likelihood of the hazards?
- Is climate change causing any changes in your community's hazard profile? How is risk changing, and to what effect?

Technological Hazards

Technological (or "man-made") hazards are an inevitable product of technological innovation and human development. These hazards, which are associated with the failure, misuse, or unintended consequences of engineered structures, technologies, manufacturing processes, and other aspects of modern life, tend to be less understood than their natural counterparts. They are also trending in a direction of increasing frequency as the scope of and dependence on technology expands. The emergency and disaster events most commonly precipitated from technological hazards are those that arise in the transportation sector, are the result of failed infrastructure, occur in the course of industrial accidents or processes, or relate to a failure of a building or structure to protect inhabitants and contents.

Structure Fires

A structure fire is a fire that affects one or more of the different structural components of a building whether it is residential, commercial, industrial, or some other use. Structure fires threaten not only the building but also its contents and any living things that may be inside at the time (including responders). In high-density environments, structure fires can spread easily from building to building if they are not contained quickly. When wildfires occur along the wildland-urban interface, structural fires are a common secondary hazard that results from containment difficulties.

Archeological discoveries indicate that civilizations have been coordinating governmental resources to fight structure fires since the first century AD (Coppola, 2006). Structural fires can be triggered or exacerbated both by natural processes, including lightning, high winds, earthquakes, volcanoes, and floods, or by human origins, including accidents and arson, for example. Lightning is the most significant natural contributor to fires affecting the built environment. Buildings with rooftop storage tanks containing flammable liquids are particularly susceptible. Fire departments responded to almost 1,298,000 fires in the United States in 2014. These fires resulted in 3275 fatalities, 15,775 injuries, and $11.6 billion in property loss. Of these, 47.0% were outside and "other" fires, 38.1% were structural fires, and 14.9% were vehicle fires.

Residential fires represented 28.3% of all fires and 74% of structural fires. Of all civilian fire fatalities, 84% occurred in the home, where a home is defined as a one- or two-family dwelling or an apartment. Intentionally set structure fires occurred approximately 19,000 times and represented 3.8% of structural fires and $613 million in structural property losses. Approximately 8000 vehicle fires were deliberately set, causing an estimated $116 million in property damage (Haynes, 2015).

Current statistics and information on fires in the United States are maintained by the National Fire Protection Agency at http://bit.ly/1uwzxeC.

Dam Failures

Dams are constructed for many purposes, the most common being flood control and irrigation. When dams that retain large quantities of water fail, large-scale uncontrolled releases of stored water occur and threaten anything located downstream. Dam failures pose an extreme flood risk due to the sudden and severe impacts that can result. Failure is uncommon, but when it occurs it is most often the result of poor or improper maintenance; overtopping (as in the case of a flood); poor design; or structural damage caused by a major event such as an earthquake, collision, or blast. Dams may be either publicly or privately owned and maintained, and as such monitoring them can pose a challenge to the various government offices tasked with assessing and managing their associated hazard risk. The United States boasts the second-greatest number of dams, exceeded only by China. In 2013, the American Society of Civil Engineers, which rates US infrastructure, gave US dams a grade of D given that the number of deficient dams exceeds 4000 (of about 84,000 that exist in the country), including almost 2000 of which that are considered to be "high-hazard dams." ASCE estimates that for everyone dam that is repaired or made more resilient, two more are declared deficient.

More information on the status of US dam infrastructure can be found by viewing the ASCE report at: http://bit.ly/1VRbkvw.

Hazardous Materials Incidents

Hazardous materials are chemical substances that if released or misused can pose a threat to property, the environment, or health. Such chemicals are prevalent in many industries and products, including agriculture, medicine, research, and consumer product development. Hazardous materials may be explosive, flammable, corrosive, poisonous, radioactive, or otherwise toxic or dangerous. Releases typically occur as a result of transportation accidents or accidental releases at production and storage facilities. Depending on the nature of the chemical, the result of a release or spill can include death, serious injury, long-lasting health effects, and damage to buildings, homes, the environment, and other property.

While hazardous materials spills occur most commonly in homes, the quantities released are almost always too small to cause more than a highly-localized hazard. It is the transportation or industrial use of such products that leads to major disaster events upon release. At present, hazardous materials are manufactured, used, or stored at an estimated 4.5 million facilities in the United States—ranging from major industrial plants to local dry cleaning establishments or gardening supply stores.

More information about hazardous materials and related incidents in the United States can be found at the US Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) website: http://bit.ly/2ewV9Vt.

Nuclear and Radiation Accidents

Radioactive materials, whether naturally occurring or technologically enhanced, have provided significant benefits since their discovery. These include the generation of power, scientific treatments and experiments, new detection, and imaging technologies, and many other benefits. However, because the ionization caused by these materials can result in immediate and lasting tissue damage to humans and animals upon exposure, radioactive materials must be handled and contained using specialized techniques, materials, and facilities. National and international law strictly dictates who may possess these materials, how they can be used, and how and where they must be disposed of.

Exposure to radioactive materials can be the result of an accidental or intentional spill, breach of a containment vessel, escape of gasses, or an explosion. Radioactive material remains radioactive until it has shed all of its ionizing particles, called radio nuclides. This process, called radioactive decay, is the primary source of health risk to life. When released quickly, dust or gasses may rise into the atmosphere in a characteristic "plume," which carries the contaminants far from the point of origin with atmospheric currents, depositing it as radioactive fallout along its course.

In the United States, the greatest threat of exposure to radioactive materials comes from an accident or sabotage at one of the nation's many nuclear power plants. As the distance to a nuclear power plant decreases, the risk of exposure increases, and the likelihood of surviving in the event of a large-scale release of materials decreases. Since 1980, utilities operating commercial nuclear power plants in the United States have been required to maintain on- and off-site emergency response plans as a condition of maintaining their operating licenses. On-site emergency response plans are approved by the Nuclear Regulatory Commission (NRC). Off-site plans (which are closely coordinated with the utility's on-site emergency response plan) are evaluated by FEMA and provided to the NRC, who must consider the FEMA findings when issuing or maintaining a license.

A catastrophic failure of a nuclear reactor is called a meltdown, indicative of the failure of the reactor's containment due to the incredibly high heat caused by a runaway nuclear reaction. The worst nuclear accident to date was the result of a reactor core meltdown that occurred at the Chernobyl Nuclear Power Plant in the Ukraine on Apr. 26, 1986. So great was the radioactive plume and resultant fallout, which traveled as far as and landed primarily in neighboring Belarus, that more than 336,000 people had to be evacuated and permanently resettled. Thirty years later, the area is still uninhabitable. Following the Great East Japan Earthquake in Mar. of 2011, several nuclear reactors suffered failures or meltdowns, causing only the second nuclear disaster to register a Level 7 (of a possible 7) "Major Accident" designation on the International Nuclear Event Scale (http://bit.ly/1SLXdCI).

In the United States, the most dangerous radioactive event, which was ultimately contained (thereby preventing any realized threat to human life), was the partial core meltdown at the Three Mile Island Nuclear Generating Station in Pennsylvania on Mar. 28, 1979. The accident happened when a system that cooled the nuclear reaction, and therefore controlled the temperature of the reactor core, failed to operate correctly. While some nuclear material was released, the effect on people exposed was similar to that of receiving one or two medical X-rays. The public reaction to this event, however, significantly changed the course of the nuclear power industry in the United States, as expansion abruptly ended.

ADDITIONAL RESEARCH

The Nuclear Regulatory Commission released a report on the Three Mile Island nuclear accident. This report provides a summary of the events that occurred on Mar. 29, 1979, and describes the health effects of the resulting release. Most significantly, it provides insight into the changes that the event ultimately had on the industry and on society's perception of the safety of nuclear power. This report site may be accessed at http://bit.ly/23CZCHz.

For a full description of the events that occurred during and following the Great East Japan Earthquake at the Fukushima nuclear power plants, visit the World Nuclear Association site that summarizes research that has been conducted on the incident. This site is interesting because the organization maintains that very little risk remains and that the evacuation itself is causing more harm than the exposure posed by radiation. This page can be accessed at: http://bit.ly/1oVWXZL.

Terrorism

Terrorism is defined as the use of force or violence against individuals (civilians) or property for purposes of intimidation, coercion, or spreading fear in pursuit of political, religious, or ideological goals. Radical or militant political and religious groups, which include or have included (for example) the Islamic State of Iraq and the Levant (ISIL, or ISIS), al Qaeda, the Khmer Rouge, the Revolutionary Armed Forces of Colombia (FARC), and Sendero Luminoso, typically lack sufficient military means or public support to fully realize broad societal change that favors their representative views. These groups turn to the use of terrorism as a low-cost way to raise awareness of their message and influence the attitudes and actions of those presumably at-risk from subsequent attacks. Terrorism, like war, is an influential tool that has been used by civilizations since the dawn of recorded history, and it will likewise always exist as a threat that must be mitigated and likewise managed.

Terrorism has been prevalent in the United States since long before the Sep. 11, 2001 attacks on New York and the Pentagon, but the vast majority of these events originated from individuals or domestic organizations, used simple explosives, and were small in scale and effect. Some of the most notorious terrorists and groups that were labeled as "terrorist organizations" are the McNamara Brothers (who bombed the *LA Times* building in 1910), the so-called "Unabomber" Theodore Kaczynski, Eric Rudolph (the "Centennial Olympic Park bomber"), Timothy McVeigh (the mastermind behind the Oklahoma City bombing), the Animal Liberation Front, the Ku Klux Klan, and the Army of God.

The Al Qaeda terrorists who performed the simultaneous terrorist attacks in Arlington, Virginia; New York City; and Shanksville, Pennsylvania, elevated the perception of terrorism as a hazard risk and thus ensured its high placement on the public, policy, and media agendas. The highly graphic, violent, and devastating impact of the attacks which killed almost 3000 people, caused billions of dollars in damages, and had immeasurable effects on the national and world economies, were all credited with this monumental shift. So prominent were these attacks that the persistent threat from domestic terrorists and terrorist organizations—which have been successful in bringing about several attacks since 9/11 including the 2001 anthrax attacks, the Washington, DC sniper attacks in 2002, and many bombings and shootings at courthouses, abortion clinics, research centers, military recruitment centers, to name a few, is often given far less attention.

The primary method by which governments manage the terrorist threat is through both covert and overt intelligence gathering. Monitoring methods have improved and expanded as technological advancements in tracking, imaging, and recording have occurred. Expanded statutory authorities have also enabled more effective monitoring of phone calls, bank transactions, and other activities (to the dismay of civil rights groups who oppose such controls). Clearly, the ability of a government to monitor the terrorist risk challenges the delicate balance that exists between personal privacy and national security.

Containment of the terrorist threat is another method of control, exhibited in the form of checkpoints (like in commercial airports worldwide), barriers at public and secure buildings, and security cameras and personnel placed in strategic locations. The US government has developed agreements with many other national governments to coordinate transnational terrorism through the use of cargo safety initiatives, traveler tracking, and monitoring of groups known to harbor terrorist intentions against the United States.

The Federal Bureau of Investigation (FBI) is the government agency in charge of tracking and preventing terrorist activities in the United States. The FBI categorizes terrorism according to two subgroups: (1) domestic terrorism, which involves groups or individuals whose terrorism activities are directed at elements of government or population without foreign direction; and (2) international terrorism, which involves groups or individuals whose terrorist activities are foreign-based and/or directed by countries or groups outside the United States or whose activities transcend national boundaries.

CBRN INCIDENTS

There is a distinct class of weapons that has the potential to bring about an extraordinary degree of deaths, injuries, and property destruction. Several names have been used to describe this special class, including weapons of mass destruction (WMD), NBC (nuclear, biological, and chemical) weapons, and ABC (atomic, biological, and chemical) weapons, but the conventional acronym used in contemporary practice is CBRN (pronounced “see-burn”), representing the acronym formed by the first letters of the chemical, biological, radiological, and nuclear devices that the category includes. Although these weapons are considered weapons of mass destruction because of their potential for creating such widespread destruction, it should be noted that they can also be distributed in such a way as to harm or kill only one or a very few individuals.

CBRN weapons may be possessed and used by both terrorists and foreign national governments. The processes by which control and containment are conducted, however, differ greatly between the two. In the case of official governments, mitigation is generally performed through the use of diplomacy, international agreements, and sanctions. With terrorist groups, such measures have little or no effect, so control must be performed through the use of raw materials regulation and monitoring, surveillance and other intelligence gathering, and, at times, military action (usually not until all other options have failed).

Chemical Weapons

Chemical weapons use naturally occurring or man-made liquids, gasses, or solids (typically in the form of dust), called chemical agents, to inflict toxic or destructive effects on humans, animals, plants, or property through exposure. Chemical agents are most commonly created for the sole purpose of killing, injuring, or incapacitating people. These agents must be delivered directly onto or in close proximity to intended victims in order to have the intended effect, but there are many ways that this can be accomplished. For instance, chemical agents may be aerosolized, dropped, splashed, poured into water supplies or foods, released by bombs, or sprayed from containers or vehicles (including aircraft, boats, or vehicles).

One of the greatest challenges facing emergency management and response officials is the detection of chemical agents that have been delivered via covert means. Chemical weapons can be invisible, odorless, and tasteless, and they may have an immediate identifiable effect (a few seconds to a few minutes) or have a delayed effect. The presence of a chemical agent is often easy to detect because of several telltale signs, including a sudden difficulty breathing; nausea; a burning sensation in the skin, eyes, or lungs; disorientation or loss of consciousness; or seizures.

In the case of common chemicals, such as chlorine gas, personnel familiar with the chemical's characteristics can often identify what chemical was released by smell or sight and the presence of certain effects as just listed (as well as the presence of specific containers or delivery mechanisms). However, with most chemical agents, identification of the specific chemical once detection has occurred is only possible using advanced technology. Because different chemicals have unique processes by which they are neutralized or their effects treated, identification is key to response and remediation.

These are the six primary categories of chemical agents, distinguished by their effect on humans:

- Pulmonary, or "choking," agents
- Blood agents
- Vesicants or blister agents
- Nerve agents
- Incapacitating agents
- Irritants (typically used for riot control but capable of spreading panic when used by terrorists)

Biological Weapons

Biological weapons use biological agents (live organisms or the toxins produced by live organisms—either naturally occurring or genetically engineered) to kill or incapacitate people, livestock, and crops. There are three primary categories of biological agents: bacteria, viruses, and toxins.

As with chemical agents, biological agents can be delivered covertly or overtly. But unlike chemical agents, most biological agents have delayed effects. In fact, it may take days or even weeks before the presence of an attack involving a biological agent is recognized. This is especially true with bacteria and viruses, which have a defined period of delayed "incubation" following exposure where no symptoms may be exhibited by victims. Toxins, on the other hand, typically exhibit the same rate of effect as seen with chemical agents.

Recognition of a biological attack is most likely to be made by the public health service, which monitors illnesses and deaths nationwide, and which would therefore see an unexplained upsurge in similar yet abnormal (or even unidentifiable) causes of illnesses and death. Other methods of detection include threat identification, communication from perpetrators (terrorists often take credit for their attacks), the discovery of the agent or delivery and production materials, and intelligence gathering.

Biological agents are difficult to grow and maintain. Although many of these agents decay rapidly when exposed to sunlight and other environmental factors, others (such as anthrax spores) are resilient and can survive for decades or longer even in harsh conditions. Biological agents are particularly dangerous when they involve transmissible (contagious) illnesses like smallpox because the effect can quickly spread beyond the initially-exposed victims.

Human-to-human transmission has been the primary source of infection in past epidemics that involved pathogens capable of use as a biological weapon, including smallpox, plague, and the Lassa virus. When biological agents target plants or animals, they can devastate economic sectors (including agriculture and livestock) and instill fear equal to that of agents that affect humans and can have crossover effects on humans. For instance, in 1918, the German army spread anthrax and other diseases by distributing infected livestock and animal feed.

As with chemical weapons, the primary defense lies with rapid and accurate recognition and identification. Each agent has a highly specific treatment and decontamination method associated with it. Biological agents are grouped into three categories: Category A agents are those that have great potential for causing a public health catastrophe and are capable of being disseminated over a large geographic area. Examples of category A agents are anthrax, smallpox, plague, botulism, tularemia, and viral hemorrhagic fevers. Category B agents are those that have low mortality rates but may be disseminated over a large geographic area with relative ease. Category B agents include salmonella, ricin, Q fever, typhus, and glanders. Category C agents are common pathogens that have the potential for being engineered for terrorism or weapon purposes. Examples of category C agents are hantavirus and tuberculosis.

Radiological Weapons

Radiological weapons use radiological agents (materials that cause harm by emitting ionizing energy) are sought by terrorists because of their potential to instill fear, cause sickness or death in exposed victims, and contaminate property. Unlike nuclear weapons, radiological weapons actually require very little technological innovation to use since the materials themselves are naturally hazardous and therefore need only be dispersed. The primary factors behind their infrequent use include the limited quantities with which they exist in nature and the great monitoring and control that is associated with their possession. The most common locations where radiological materials may be found include research laboratories, medical institutions, and hazardous waste containment facilities.

The greatest threat from a radiological agent is associated with a terrorist's dispersal of radiological materials using either an explosive device (commonly called a "dirty bomb") or another nonexplosive method like spraying or aerosolization (called a "radiological dispersion device," or RDD). Most experts agree that the greatest physical risk associated with a dirty bomb is the explosive blast itself rather than the exposure that follows from the inclusion of radiological materials. However, the fear and panic that would likely result once detection of radioactive materials occurred on victims and in the debris could have far-reaching economic impacts in the immediate area of the attack and throughout the country—or even the world.

An alternative threat to the dirty bomb or RDD that concerns many governments is a terrorist attack on a nuclear facility. Such an attack could result in far greater dispersal of radiological materials and based on past nuclear accidents could devastate a large geographic area for decades. While most nuclear facilities were designed to withstand great impacts and large explosions (including several constructed to withstand a direct hit by a commercial airliner), the possibility of sabotage on safety and cooling systems or the use of an explosive strong enough to breach containment exists. Additionally, the radioactive waste produced at these facilities is usually stored on-site. While this material is of little use for power generation, it would be extremely valuable to a terrorist who wanted to cause harm.

Nuclear Weapons

Nuclear weapons are highly engineered and difficult to produce weapons that cause great harm by initiating a fission or fusion chain reaction explosion. Nuclear explosions are attainable only through the acquisition of construction of highly advanced weapons technologies, and using only the most refined nuclear materials (and in quantities necessary to sustain a blast effect). A nuclear blast emits intense light, heat, and damaging pressure and disperses radioactive debris over a widespread area, leading to the contamination of air, water, and ground surfaces for miles around. While the likelihood of a terrorist organization developing an operational nuclear weapon is almost nil, there is always the possibility that rogue states known to support terrorist organizations or states unable to monitor and protect their nuclear weapons caches could become a source of such weaponry for terrorist groups with great financial means.

The effect of successful terrorist use of a nuclear weapon would almost certainly include the death of thousands of people and the destruction of billions of dollars in property, especially if it was detonated in a major urban center. The detonation of atomic weapons in Hiroshima and Nagasaki provide some insight into the massive power of a nuclear weapon given that these two bombs resulted in the death of over 220,000 people and almost total destruction of the city centers in these two metropolises. It is important to note that the two nuclear bombs used in World War II are by today's standards considered small given the availability of much more powerful weapons in the modern global arsenal.

ADDITIONAL INFORMATION ABOUT CBRN

For more information on weapons of mass destruction, visit the following websites:

- Federal Bureau of Investigation: http://1.usa.gov/1oW51K5
- Central Intelligence Agency: http://bit.ly/1oW5dco
- Ready.Gov: http://1.usa.gov/1qH7XMb

■■ Critical Thinking ■

- What technological hazards affect your community? What are the sources of those hazards?
- Society accepts certain technological hazards because they enjoy the benefits associated with the action or process that causes the hazard. For instance, nuclear power plants produce inexpensive electricity with almost no carbon emissions. However, in the event of an accident, a major disaster could result. What benefits does your community enjoy despite the existence of associated technological hazards, and what are those hazards?

Hazards Risk Management

The process by which individuals, communities, and countries deal with the hazard risks they face is known as hazards risk management (HRM) or Disaster Risk Management (DRM) in the international context. Management of major hazard risks is primarily a function of government, though the private and nonprofit sectors are to an increasing degree including disaster risk mitigation in their enterprise risk management efforts. Several frameworks and processes have been developed in the United States and throughout the world to systematically and effectively manage hazard risk in order to decrease the likelihood and consequences of disasters. Even within the United States, it is not uncommon to come across different approaches to hazard risk management utilized in agencies at the same level of government, as is true with the Federal Emergency Management Agency (FEMA) and the Department of Defense. Regardless of the specific processes used, almost all HRM methodologies include the following four steps:

1. Identify the hazards.
2. Assess the risks for each hazard identified.
3. Analyze the hazards risks in relation to one another.
4. Treat the hazards risks according to prioritization.

Differences in authority and accountability, terminology, technologies, stakeholder input, monitoring and reporting, funding streams, and other issues differentiate the various methods encountered.

Hazard identification, as the name suggests, is the process through which hazards that have or could affect an area of focus are identified and described. This can be achieved using a variety of methods, including historical study, brainstorming, scientific analysis, and subject matter expertise. For more commonly-occurring hazards, such as snowstorms or tornadoes, the presence of the hazard will be obvious and identification assured. However, for new or emerging hazards, such as many in the technological and intentional categories (including terrorism), only the knowledge or opinion of experts can provide insight into the presence and range of these rare, yet real, hazards. The identification process results in an exhaustive list of hazards if done properly. The effort becomes increasingly effective if it considers each hazard not only in an individual context but also as it relates to the entire hazards portfolio. The presence of one hazard tends to influence or even create other hazards within the same geographic area. For instance, an area that is prone to landslides due to stark topography is even more likely to experience landslides if seismicity or heavy rainfall is also a concern.

In order to best assess and analyze a hazard, a hazard profile should be created. Profiles are concise reports that explain what the hazard is but also how it exists within the area of concern and other key information. The following are examples of information that are often investigated:

- General orientation overview of the hazard
- The location of the hazard within and surrounding the area of study and the spatial extent of its effects
- The duration of an event caused by the hazard
- Seasonal or other time-based patterns followed by the hazard
- Speed of onset of an actual hazard event
- Availability of warnings for the hazard

Assessment is conducted in order to understand the nature of the threat posed by each identified hazard. Hazard risk is calculated according to two primary measures: hazard likelihood and hazard consequence. When viewed in conjunction, these two factors enable prioritization for treatment. One might assume that the higher the likelihood/consequence combination, the more likely it is that a hazard will be treated—but there is more to the calculation. Communities consider other factors including the cost of mitigation, esthetics, some loss of services or resources, and other factors. Communities and countries must consider a range of options to achieve the greatest reduction in lives lost and property damaged per financial and human cost units expended.

Risk assessment methodologies may incorporate both qualitative and quantitative measurement systems, as well as computer-assisted models that enable accurate prediction of natural hazard risk (e.g., the FEMA-supported HAZUS model predicts the consequences of user-defined earthquakes, floods, and hurricanes). The validity and utility of any risk assessment outcome is defined by the quality and availability of the data provided. Emergency managers rely on a range of sources to develop accurate likelihood and consequence measures, despite the fact that these factors are constantly changing as a result of human development, access to new information, changes in climate and demographics, and many other factors that complicate the equation. Furthermore, it can be impossible to extrapolate exact numerical values that are representative of these two factors for each, or even any, of the hazards that have been identified.

As previously mentioned, there are a variety of unique risk assessment methodologies that have been developed independently of each other—however the similarities are numerous. In the United States, Australia, and New Zealand, for instance, the qualitative assessment methods that government guidance espouses are almost identical in their format while their wording and appearance differ only slightly. These systems simplify the process by enabling users to limit the need for intensive mathematical calculation by grouping together ranges of values into a limited number of possible likelihood and consequence designations (typically five to seven designations). Qualitative systems are not exact, but they facilitate a process that might otherwise be too difficult or time-consuming and therefore disregarded.

Another risk assessment method is the Composite Exposure Indicator (CEI) approach, which is based on the effects of a single or multiple hazards on a series of indicator variables focused primarily on infrastructure, such as roads, pipelines, hospitals, public water supply, and so on. This system, which relies on databases maintained by FEMA and other sources, is a measure of exposure of 14 variables that produces a number that is then correlated to the population affected.

Hazard risk analysis is performed in order to determine the relative seriousness of hazard risks that have been identified and assessed. Using the processes just listed to identify the hazards that threaten the community or country, to characterize them, and to determine their likelihoods and consequences, those tasked with risk management will have gathered all of the information necessary to determine how these risks compare to one another. It is important that each hazard has been identified, described, mapped, and analyzed according to its likelihood of occurrence and its consequences (should a disaster occur) for comparison to be possible.

Hazard risk analysis is vital because communities have a range of competing budgetary pressures and are therefore unable to fully mitigate all hazard risks. Each of the community's natural, technological, and intentional hazards requires a different degree of mitigation and risk reduction, and those that show the greatest benefit per unit of cost are typically the best choice. Ultimately, the goal is to lower the number of deaths, injuries, and damage to property and the environment associated with hazards to an acceptable degree, so it is important that time and resources are dedicated to the actions and activities that give the greatest results overall.

The outcome of risk analysis is often illustrated with the help of a risk matrix (also called a 'heat map' when colors are used). To create a risk matrix, the user draws a graph wherein the x- and y-axes represent risk likelihood and consequence respectively. The values of highest $x-y$ value appear placed in the upper right quadrant while those with the lowest values appear in the bottom left quadrant. If a quantitative system has been used, the defined values selected for each of the two risk factors are transferred onto this matrix. Otherwise, if quantitative representations of likelihood and consequences have been used, the minimum and maximum of all hazards analyzed represent the high and low limits of the two graph axes. Then, all of the hazards are plotted onto this matrix together, thereby providing a visual illustration of a community, country, or even an organization's hazard risks in relation to one another. Using the results of the risk matrix, a prioritized ranking of risks is created. This list becomes the basis of the final step, which is the treatment of identified hazard risks.

The prioritization capability of the risk analysis process is significantly increased when it is performed in conjunction with supplemental methodologies. For instance, a vulnerability analysis can help to determine what is causing risks, why certain risks rank above others, and what can be done to increase resilience or decrease vulnerability through the various risk treatments identified in the fourth and final step.

Hazard vulnerability considers four distinct factors: social vulnerability, environmental vulnerability, physical vulnerability, and economic vulnerability. Hazards can also be prioritized according to the degree to which the at-risk population accepts them. For instance, despite the fact that more people are exposed to one particular hazard or that the hazard causes more fatalities or damages each year than any other, it might still be more palatable to the exposed population than another much less dangerous or damaging one. This is often due to real or perceived benefits that are associated with the existence of the hazard risk and which would be lost if the risk was partially or fully mitigated. For example, transportation accidents cause over 1 million fatalities each year, while accidents at nuclear power plants have resulted in far fewer than 10,000 across all the years that nuclear power has existed. Despite this contrast, there are very few people that oppose the use of automobiles while millions oppose nuclear power.

The SMAUG methodology is one of a number of systems developed to gage risk acceptability issues and to help risk managers further analyze previously-assessed risks along social, political, and other lines. SMAUG is an acronym that stands for five analytical factors including:

- Seriousness, or the relative impact on the community in terms of deaths, injuries, and damages
- Manageability, which refers to the ability of, or availability of options for, the community to manage the risk
- Acceptability, which investigates the willingness of the affected population to tolerate the existence of a particular hazard risk
- Urgency, which looks at how critical it is to safety and security that the risk immediately be addressed
- Growth, which refers to how quickly the hazard risk is increasing over time
- In recent years, SMAUG has been expanded to include two new factors:
- Frequency, which is typically addressed through the risk assessment process
- Awareness, which refers to the level to which different community stakeholders are informed about the hazard, and how closely their knowledge about the hazard reflects its true risk

The acceptability factor from the original SMAUG acronym was outrage, but still refers to the political and social acceptance of the hazard risk. The new acronym for this method is FSMAUGO.

Hazard risk treatment is the process by which either the likelihood of a disaster risk is reduced or eliminated or measures are taken to reduce the impacts of those hazard events that do actually occur. Hazard risks are treated through hazard mitigation and disaster preparedness (the topics of Chapters 3: The Disciplines of Emergency Management: Mitigation and Chapter 4: The Disciplines of Emergency Management: Preparedness, respectively). The selection of risk treatment options takes the risk assessment methodology beyond process to decision making and action. At this point, risk reduction options have been analyzed not only for their cost effectiveness but also for their acceptability by society and their long-term positive and negative impacts. The treatment process then becomes a technical and political one by which funds are finally dedicated, laws are changed or enacted and likewise enforced, and solutions are implemented.

ADDITIONAL RESEARCH

FEMA-developed and released a series of "Mitigation How-To Guides" between 2002 and 2008 that explained and guided the hazard risk management process from inception to implementation for local community leaders. This nine-part series, available on the FEMA website, explains municipal HRM from building support for planning through using the Hazard Mitigation Plan to design and implement risk reduction projects. The guides can be found at: http://1.usa.gov/1TQwDxf. In 2011, the Department of Homeland Security released the Homeland Security Risk Management Doctrine titled *Risk Management Fundamentals*. This document was released in an attempt to standardize risk management throughout the department and to ensure that risk management was considered in relevant decisions and actions. This document can be found at: http://bit.ly/1VnZk6u.

Risk Management Technology

The nation's ability to track and manage hazards risks has significantly improved in the last 15 years. Through vast technological advancement, emergency managers are now much more capable of plotting hazards spatially, targeting the areas of greatest risk, and identifying and implementing appropriate risk reduction solutions.

Imaging and sensing technology, including satellite imagery and aircraft-based systems (such as radar, LIDAR, and FLIR), have given risk managers a much better visual representation of risk. These systems, and their associated information management and display systems, allow for spatial and temporal (time-based) representation of risk across whole communities and down to a level of granularity that allows consideration of risk on an individual property or structure. In doing so, the process of risk identification and the spatial plotting of hazard risk across risk zones has become much more tangible and, likewise, accurate.

Risk modeling systems, which include software such as the FEMA-developed HAZUS-MH (Hazards United States—MultiHazard) program and expert-based systems such as the products produced by the National Infrastructure Simulation and Analysis Center (NISAC—www.sandia.gov/nisac) and the US Army Corps of Engineers (http://bit.ly/2fMKUOR), allow not only predisaster estimation of impacts and response requirements but also early disaster estimation of likely damages and needs (before actual assessment data can be collected). The connectivity of the Internet has allowed for greater sharing of information and ideas across regions where similar problems are encountered and mitigated, and for risk estimation models to thus be generated.

The wide availability of GIS-based mapping software makes the plotting of risks and resources using layers of information that would have required much more significant resources to obtain only decades ago much easier today. Even commonly used web-based programs such as Google Earth have increased the ability of emergency managers with few resources to better understand the nature of the risk their communities face, including the plotting of floodplains and the proximity of various structures to known hazards. The research and scientific agencies of the federal government and the university community continue to develop new approaches to measuring, mapping, and predicting natural hazards. Since the Sep. 11, 2001, attacks, federal- and university-based funding dedicated to the advancement of emergency management technology has reached into the billions and is helping to develop even more methods to detect, understand, and treat natural, technological, and, most notably, terrorist hazards.

Social and Economic Risk Factors

It has long been recognized that a strong correlation exists between disasters and poverty. Because of several factors, including the inability to afford preparedness and mitigation measures, the lower rental and purchase costs associated with high-risk land and a general lack of knowledge concerning risk and its sources, the poor are more vulnerable to disasters and therefore find themselves repeatedly subject to them. While this is much more apparent in the developing countries, where the bulk of annual disaster deaths occur, risk factors based on poverty and social conditions also exist within countries.

In the United States, little has been done to address the social and economic factors of risk that make one group more vulnerable than another. Risk assessments have generally considered populations to be homogeneous for risk-planning purposes, thereby neglecting to address individual problems of certain social and economic groups that may not benefit as much, or at all, from the plans and capacities that are developed. Social advocacy groups have been working for years to raise awareness of the increased disaster vulnerability of "special populations" (which include, among others, the disabled, the elderly, the poor, children, and immigrants) with mixed success. However, Hurricane Katrina brought the reality of the socioeconomic vulnerability divide into every living room in the country via the mass media. Numerous social and political groups contend that it was poverty that caused Katrina's high number of victims and that the poor shouldered an undue portion of the region's risk, while the wealthy escaped relatively unharmed (a claim that was later refuted). Others called it a race disaster, claiming that the government neglected to bring about a more significant immediate response because a majority of the victims were African American. Regardless of the validity of these claims, it is clear that the majority of the people who failed to leave New Orleans did so because they lacked reliable transportation options, they were afraid to leave their property and possessions behind, or they had few to no resources with which to acquire shelter outside of the wide zone of risk. And in the aftermath of this disaster, these same social and economic risk factors impacted victims' abilities to quickly and effectively recover.

A population's social character is driven by a diverse set of factors that include education, culture, form and effectiveness of local government, standard of interaction, common values and beliefs, laws, and other aspects that define society. Within most communities, the hazard vulnerabilities of different groups vary due to a range of sociocultural factors that help or prevent individuals in those groups from taking mitigation or preparedness actions that provide protection. The effect of epidemics on different groups, and on people in different countries, is an example of a hazard whose event outcome is heavily influenced by social factors. Certain religious, cultural, or traditional practices and beliefs are other things that tend to reduce or exacerbate impacts by helping or hindering resilience drivers. For instance, religious beliefs that define disasters as being the "will of God" are more likely to negatively influence mitigation and preparedness behaviors than those that promote the responsibility of individuals and governments to protect life from dangers that exist in the environment. And though it may not be evident to the people practicing such behaviors, the mitigation or preparedness actions they take may be the product of some previous social adjustment to a hazard. Disaster managers must be able to recognize when social interactions are either helping or hindering people in reducing their vulnerability to hazards, and they must also recognize what aspect of that social process is causing the alteration.

Financial status deeply affects a population's and its members' individual abilities to achieve protection from the consequences of disaster. Financial wellbeing, however, does not indicate that an individual or society *will* protect themselves; rather, it is just a measure of their ability to do so. There are other factors that may also be learned from the economic profile. For instance, the poor are often marginalized and forced to live on more dangerous land. Their housing is more likely to be constructed of materials that are unable to withstand environmental pressures. They are more likely to have zero tolerance to delays in basic necessities that often follow disasters.

When considering the definition of a disaster and the concept of vulnerability, it is easy to understand why the poor are more vulnerable. Because an event only becomes a disaster when the capacity to respond to the event is exceeded, requiring external assistance to manage the consequences, the poor—who survive on the brink of disaster each day—are much quicker to exhaust their resources when unforeseen events arise.

■■ Critical Thinking ■

- Select a hazard that affects you or your community. Describe the characteristics of the hazard (how it would affect you or the community—including strong winds, ground shaking, etc.). Assess the risk associated with this hazard for you or your community, including the frequency of the hazard affecting you and the consequences if a disaster were to occur.
- What aspects of a community's geographic profile influence the hazards they face (e.g., proximity to a coast, slope of terrain)? What human practices influence these hazards (e.g., damming of rivers, filling in wetlands)? What natural processes influence these hazards (e.g., annual rainfall, temperature)?

Conclusion

In the HRM process, hazard identification is the foundational step in determining what preparative and preventive measures will be taken by a community. In other words, a community needs to know and understand their risks if they are to effectively manage them.

Through the monitoring of hazards, emergencies, and disasters that occur throughout the world, and through the conduct of research into the mechanism by which natural, technological, and intentional hazards operate, greater understanding of risk is being achieved. Societies are increasingly capable of managing low-likelihood, high-consequence events for which they have little or no experience—such as tsunamis or weapons of mass destruction. And for more common hazards, risk management is becoming a central aspect of not only the emergency management community but also the development and the private sector. Moreover, it is has become accepted as good policy by a wide range of government agencies given the benefits of sustainability and economic stability it provides. Information is power, and armed with better information about hazards and their associated risk, societies are finding they have the power to act effectively in reducing or even eliminating many of the threats that have jeopardized their way of life.

Of course, all of these tools provide nothing without the acceptance of responsibility among those tasked with managing risk and leading the drive towards a more resilient society. The provision of hazard information and management tools to states and communities is but one necessary step in the risk reduction process. Success in risk management hinges upon the political buy-in and subsequent support of decision makers who must support not only the risk management effort itself, but also the recommendations that result. Oftentimes, the actions required are not popular among one or more groups and resistance or conflict is encountered. Emergency management is typically the organization best suited for providing the impetus for incorporating these considerations, popular or otherwise, into the planning and governing of our communities in the pursuit of safer, sustainable living.

It must be stressed that the existence of hazards will persist. Some, particularly technological hazards, may be reduced by our efforts, but our ability to control or eliminate natural hazards is questionable. Recent efforts to undo some of the former channelization and flood control projects undertaken by the US Army Corps of Engineers, once thought to be an effective measure to eliminate flood risk, are vivid examples of our inability to control nature. However, there is still a strong argument for an increased emphasis on improved science in hazard identification and increased financial support for hazards mapping, both of which have been effective components in community HRM efforts.

As our knowledge about hazards continues to expand, the economic and social logic of applying long-term solutions for reducing the risks posed by these hazards through mitigation and preparedness will gain momentum. The cost-to-benefit ratios of mitigation and preparedness efforts will become more attractive to local decision makers, and, eventually, disaster losses will begin to fall substantially. However, each and all of these local successes will be wholly dependent on the ability of the emergency management professional to serve as a motivational champion for disaster risk reduction.

Important Terms

Avalanche
Blizzard
CBRN weapons
Coastal erosion
Dam failure
Disaster
Earthquake
Expansive soil
Extreme cold
Extreme heat
Flood
FSMAUGO
Hail
Hazard
Hazardous materials
Hazards risk management
Hurricane
Landslide
Lateral spread
Mass movement
Mudflow (or debris flow)
Natural hazard
Risk
Rockfall
Safe room
Severe winter storm
Storm surge
Technological hazard
Terrorism

Thunderstorm
Tornado
Tropical cyclone
Tropical storm
Tsunami
Volcano
Wildland fire (or wildfire)

Self-Check Questions

1. How is a hazard different from a disaster?
2. What is the most frequent and widespread disaster-causing hazard?
3. What scale is commonly used to describe the effects of earthquakes?
4. How are earthquakes measured?
5. Describe the process by which hurricanes form.
6. What scale is used to describe the intensity of hurricanes?
7. What are the various ways that hurricanes cause damage to a community?
8. What is a SLOSH model used to measure?
9. Why was the Fujita-Pearson Tornado Scale updated in 2006, and what changes were made?
10. What are the three categories of wildland fires?
11. How are severe weather storms measured?
12. What single disaster type caused nine of the top ten natural disasters ranked by FEMA relief costs?
13. What is the source of most hazardous materials incidents?
14. List and describe four categories of weapons of mass destruction.
15. What six steps are common to most risk assessment methodologies?
16. Name several of the social factors emergency managers must consider when assessing a community's risk.
17. What are some of the factors that make up a community's economic profile? How do these factors influence that community's disaster risk?
18. What is the purpose of the FSMAUGO methodology?

Out-of-Class Exercises

Visit FEMA's disaster declaration archive at http://bit.ly/2fa2BEb. View the disaster declarations for your state. Beginning with 1998 and moving forward to the present year, view the disaster declarations to determine what disasters affected your county. What hazards affected your county during this time? How many times did each occur? If possible, determine what assistance the federal government provided in response to the disaster.