

Introduction to Natural Disasters

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Words You Should Know:

Earthquake – An event in which the breakage of rock along a fault within the earth causes the release of energy in the form of seismic waves.

Disaster reduction engineering – Construction practices that are designed to reduce the impact of a natural disaster.

Hurricane – A highly energetic, individual tropical storm that develops over warm ocean waters.

Natural disaster – A natural event that causes loss of life or property, either directly or indirectly, as a result of the aftermath.

Population growth – The increase in human population over time.

Tsunami – Meaning “harbor wave” in Japanese, a tsunami is an energetic ocean wave generated by a physical event (earthquake, volcano, landslide) on the earth’s surface.

Volcano – The geographic feature resulting from the release of lava and/or solid ejecta from a vent in the earth.

1.1 What Is a Natural Disaster?

Humans seek to protect their lives at all costs. Major efforts and enormous amounts of money are devoted to medications and medical procedures that can increase human life by even a short amount of time. These efforts have increased the average life span worldwide and protected people from many natural threats. This increased protection has led to a sense of security among many of not having to worry about the threats, especially in the developed world. Increased feelings of security have also given humans the courage to inhabit areas of the planet that might otherwise be too subject to threats of nature to be safe. But natural disasters are not controlled by human will and continue to be threats to safety and security. On the other hand, some people do not have the finances or resources to live in areas other than those that are subject to natural disasters and face risks without expectations of security.

Very few people want to be involved in a natural disaster, but most people are mesmerized by them and marvel at their destructive force. In an attempt to find reasons for these catastrophic events, some cultures choose to explain them through folklore and religious beliefs, whereas scientists seek to understand the processes behind them and ultimately to forecast them and reduce their destruction.

Natural disasters are defined as any catastrophic loss of life and/or property caused by a natural event or situation. This definition could include biologic issues such as disease, injurious viral or bacterial colonization, invasion of dangerous plants, and infestations of insects and other vermin. However, this book solely focuses on disasters involving the physical properties of the shallow earth, the atmosphere, and those from extraterrestrial sources. These disasters include earthquakes, volcanoes, tsunamis, avalanches, landslides, tropical storms, tornadoes, floods, and extraterrestrial impacts (Figure 1.1). The difference between these physical threats and the biological threats is that humans have virtually no control over the physical threats, whereas they may have some control on the biological threats. All people can do to prepare for these physical threats is to choose safe locations, engineer structures to withstand the impact, and/or evacuate areas before the threat produces a disaster.

In terms of the planet earth and its history, the processes that produce natural disasters are not extraordinary events. They occur on a daily basis and have done so since the beginning of time. Many large events go unnoticed because they do not impact humans. Unlike the way many ancient and primitive cultures regarded these events as being imposed by supernatural forces as a punishment, they are part of the natural sequence of events of planet earth. They are governed by the physical and chemical processes that define the planet and can be explained in those terms. That is one part of natural disasters. The other part is the impact on humans and response of society to these natural events.

Single natural disasters have changed the course of human history in profound ways. The dual components of natural disasters make them complex issues in modern society. In any evaluation of natural disasters, both aspects must be considered. This means that an understanding of the controlling science is the first part of appreciating a natural disaster. The human aspect is more difficult to generalize because each situation is different. The best way to appreciate the full meaning of a natural disaster is through case studies in the context of the controlling science.



FIGURE 1.1 Collage of natural disasters which come in a number of forms that have varying abilities to wreak havoc on human communities. Source: Images from top, left to right courtesy of US National Park Service, Langevin Jacques/Getty Images, Getty Images, NOAA, David Mabe/Almay Stock Photo, Phys.org.

CASE STUDY 1.1 464 BCE Sparta, Greece Earthquake

Earthquake that Changed History

A major earthquake took place in 464 BCE that forever changed the course of Greek history. The estimated magnitude of this earthquake is 7.2, and the destruction from ground shaking is estimated at X on the Modified Mercalli Scale of earthquake intensity as interpreted from historical records of the damage it caused. A magnitude-7.2 earthquake is considered to be strong. The strongest earthquake ever measured was of magnitude 9.6. The shaking intensity of X is on a scale of XII and is designated “extreme.” The probable result of the earthquake was a 20-km-long north-south normal fault scarp or small cliff that lies a few miles east of Sparta (Figure 1.2). The earthquake is estimated to have produced a death toll of 20 000 people in the Greek city-state of Sparta. Prior to this, the Spartans established themselves as the most formidable army in the region by defeating the invading Persian (now Iran) force which was previously considered the most fearsome. However, the earthquake so weakened the Spartans that they allowed troops from the nearby and allied city-state of Athens to help with the rescue and relief operations. The Athenians learned that the Spartans had partially enslaved the Helots, another group of Greeks, by forcing them into an agrarian existence to supply the Spartans with food. The Athenians protested based on a regional agreement that all Greeks should be free and, as a result, were immediately expelled from Sparta. The removal of the Athenians, however, did not end the Spartans’ troubles. The Messenians, yet another group of Greeks, came to the aid of the Helots in a revolt against the weakened Spartans which lasted for years. Resentment from these issues eventually led to the Peloponnesian War, a major and defining event in Greek history.



FIGURE 1.2 Map of ancient Greece showing the cities of Sparta and Athens as well as the location of the Messenians.

1.2 Why Do People Live in Dangerous Areas?

Certainly, by this point in modern society, the geographic areas dominated by specific natural disasters are well known. Some areas are even informally named for the most common disasters such as “Tornado Alley” in the Midwestern United States (Figure 1.3). In addition, systems to warn people of impending disasters have been established worldwide so that residents can make preparations and escape harm. Some of these preparations include engineering solutions to reduce the impact of the disaster. This is in sharp contrast with the vast majority of human history where people were commonly completely unprepared for natural disasters and surprised by their appearance. Only modern science has changed the situation. However, in terms of preventing natural disasters from occurring, humans have made no progress.

There are two main reasons why people are now inhabiting areas that are subject to natural disasters. The first is human population growth. The human population worldwide has quickly ballooned from about 1 billion in 1800 to 7.7 billion today. In order to accommodate this large number, urban areas have sprawled into less safe locations. Settlements now encroach the damage zones of volcanoes with recent activity, inviting disaster. For example, despite the 79 AD (CE) Mount Vesuvius eruption that completely destroyed the cities of Pompeii and Herculaneum, the city of Naples has now reached nearly 3.1 million people and encroached the danger area of the volcano to a much greater degree than in ancient Rome (Figure 1.4). Populations of many urban areas have increased to such densities that events that may have not been so catastrophic in the past are now disasters. New Orleans, Louisiana has been struck repeatedly by major hurricanes throughout its history, yet Hurricane Katrina in 2004 was more devastating than previous storms. The population and development sprawl occurred dramatically between the last two major storms. A major earthquake struck Port-au-Prince, Haiti in 2010 that is estimated to have killed between 100 000 and 316 000 people, making it one of the deadliest of all natural disasters. It caused such chaos that the actual death toll may never be known. The reason for so much devastation was the population of Port-au-Prince boomed to more than 10 million people despite previous earthquakes that destroyed the city in 1770 and 1842 and a tsunami that devastated the harbor area in 1946.

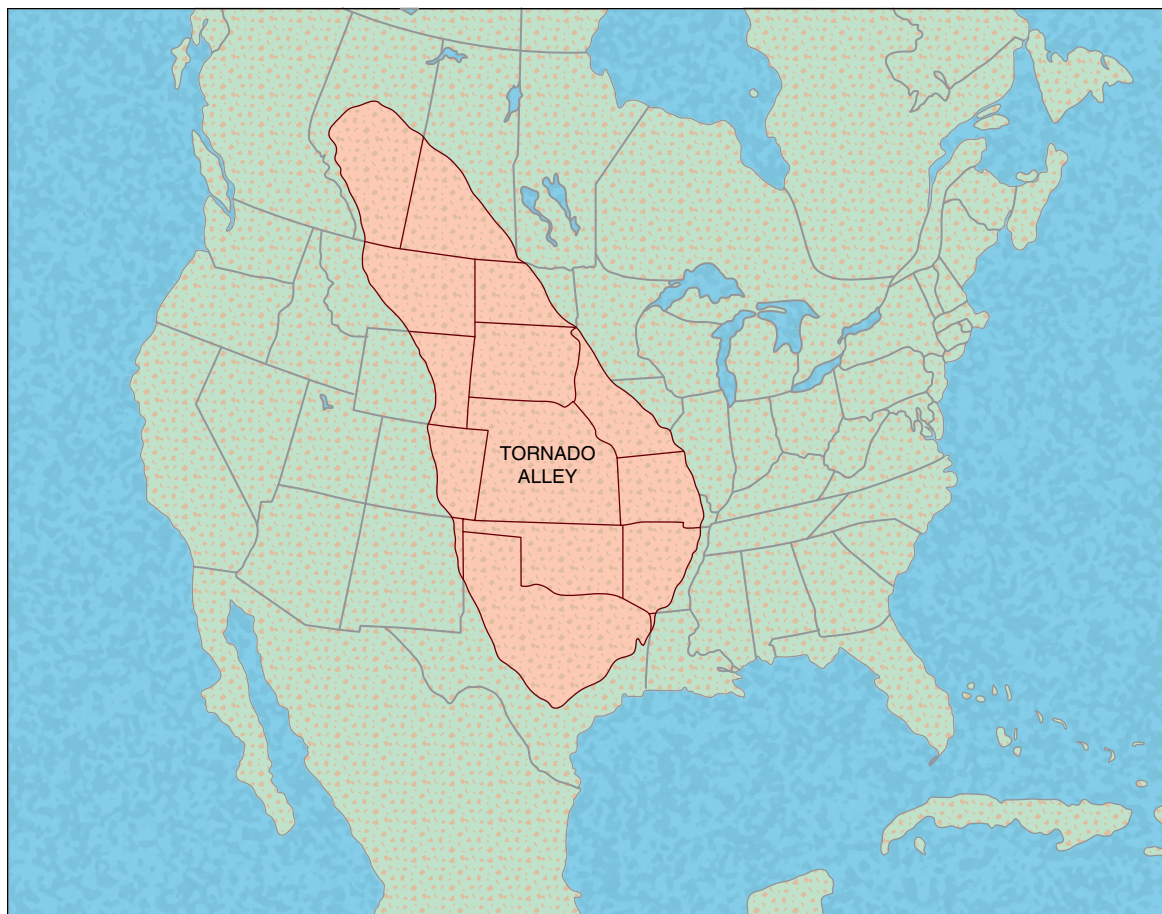


FIGURE 1.3 The approximate location of Tornado Alley in North America.



FIGURE 1.4 Night satellite image of the Mount Vesuvius area in Naples in Italy including the ancient towns of Pompeii and Herculaneum. The lighted lines, areas, and spots show human habitation. The entire human population of the area is under threat by an eruption of the Mount Vesuvius active volcano. *Source:* Photograph courtesy of NASA.

The other reason that people are tending to live in areas that are more prone to natural disasters is psychological. Humans have attempted to control nature with ever-increasing efforts and have done so in very significant ways. If a natural disaster has not occurred in a prone area for several decades, residents quickly become complacent and assume safety. They overdevelop areas that may not be safe and occupy them with an attitude of impunity and entitlement. Miami, Florida has grown dramatically in recent years with extensive development right on the beaches (Figure 1.5). In 1926, less than 100 years ago, the city was destroyed by a major hurricane. It is estimated that if a similar storm strikes today, it will cause damages of more than \$235 billion, making it, by far, the costliest natural disaster in the history of the United States. In 1928, the much more powerful Okeechobee hurricane just missed the Miami area. The potential for damage and loss of life in Miami from a major hurricane is very high, yet fear does not appear to be a limiting factor.

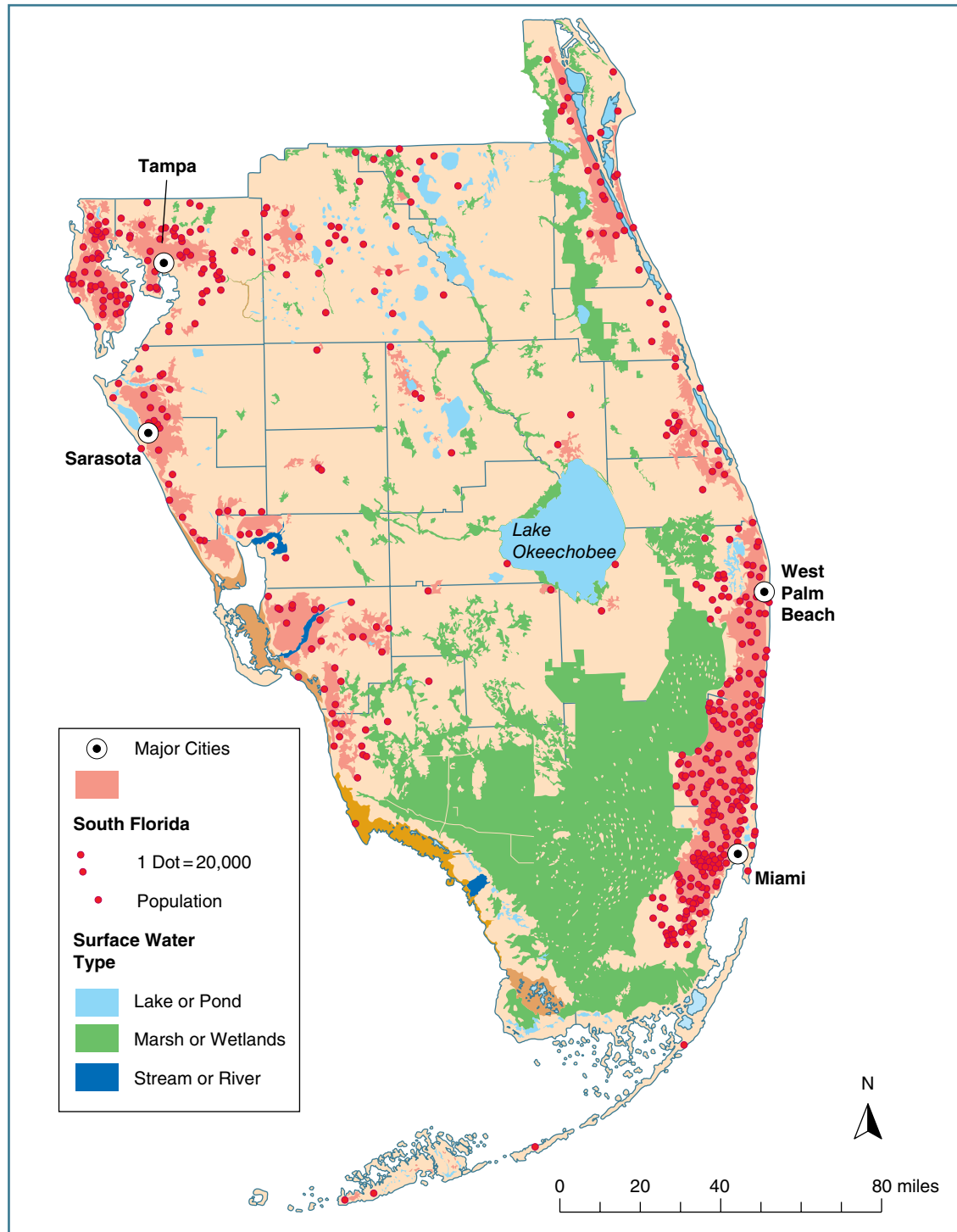


FIGURE 1.5 Population distribution map of South Florida showing the high population density in the Miami area.

Source: Adapted from Hickford (2015), <http://alanhickford.blogspot.com/2015/03/module-10-dot-density-mapping.html>.

CASE STUDY 1.2 Death Tolls

Horrifying death tolls have been reported for many natural disasters. If the numbers are low, typically, the death toll can be considered relatively accurate. Large events tend to be less accurate because multiple sources of casualties must be tallied, which leaves multiple sources for error. In ancient events, survival was such a concern that there wasn't time to count all of the bodies, so the death toll could be in error by as much as ten-fold or more. Death tolls for recent events tend to be more accurate. However, even with recent events, some disasters are subject to more counting errors. In inland earthquakes where rescue and relief efforts are done properly, the numbers are more accurate. In floods and coastal events such as hurricanes, typhoons, and tsunamis, there can be large errors even today. In case of an earthquake, the collapsed houses remain in place as do the bodies, so counting is easier. With many floods and flooding events, the bodies get displaced along with the houses and even whole neighborhoods. Even the town hall may be washed

away, removing the residency and birth records. In these cases, numbers tend to be very inaccurate. Volcanic eruptions can be equally inaccurate with the severe destruction caused by the explosions and lava flows. Translations from other languages may also lead to errors which can then disseminate throughout the literature. For example, one of the worst earthquake disasters on record occurred in China in the 1920s. Most literature report a death toll of 200 000. A recently released more reliable source states that 200 000 livestock perished in this event, but only 35 000 people died. Death tolls may be purposefully exaggerated by officials for political reasons. The Tangshan earthquake of China has an official death toll of 249 000 people. However, recent studies show that it was likely closer to 655 000. The communist government at the time did not want to look weakened to its enemies, so it reported a deflated death toll. On the other hand, if there is international relief aid available, some governments inflate the death tolls to get more aid.

1.3 What Can We Do to Stay Safe?

There are many ways for humans to be safe from natural disasters. The most reasonable of these solutions is not to inhabit locations that are subject to frequent natural disasters. That would eliminate many inhabited areas and still not guarantee full safety because events can still occur outside of expected areas. The next best solutions are to plan for them by engineering solutions or warning and evacuation systems or some combination of these.

The simplest of these is an early warning system. These traditionally have consisted of multiple far-reaching sirens, television and radio announcements, and cell phone alerts. In some areas, there are marked escape routes for evacuation, and in others, emergency drills are conducted, such as in middle and high schools. The more challenging aspect of warning is the detection of the impending dangerous events far enough in advance for residents to take action. Volcanoes are so destructive that those in populated areas are well monitored using advanced technology, and warnings are typically issued well ahead of the eruptions. Hurricane movement is typically slow enough that they can be accurately tracked by national weather services and, in most cases, residents can be safely evacuated ahead of the danger. Tsunamis can also be tracked and the systems provide ample warning in many cases (Figure 1.6).

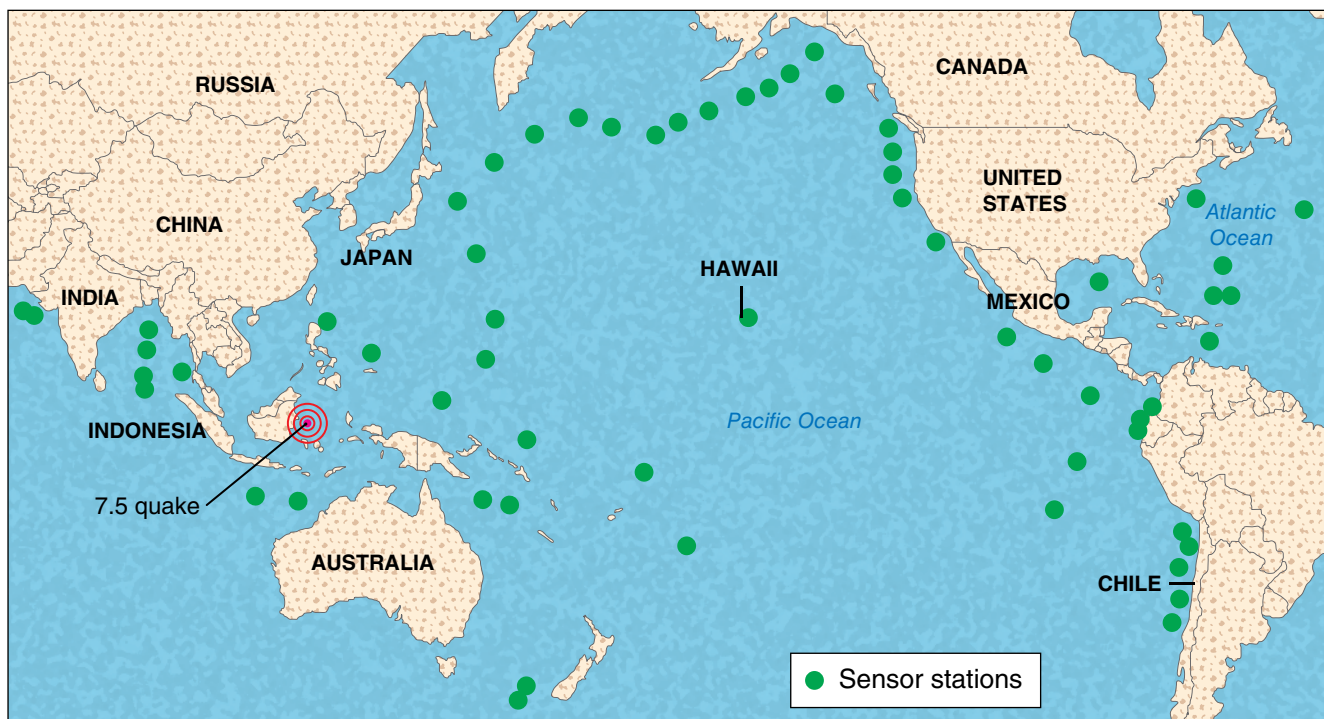


FIGURE 1.6 Location of tsunami sensors in the Pacific Ocean and surrounding areas.



FIGURE 1.7 Sharp contrast of earthquake engineered Transamerica building (left structure) with a surviving older building (right structure). Source: Courtesy US Library of Congress.

included earthquake reduction techniques in its construction. In Sicily, towns and residents built rock walls along the slopes of the Mount Etna volcano to hold back lava flows from reaching inhabited areas. In many disaster-prone areas, public buildings are constructed with extra reinforcement so that they can act as emergency shelters during a natural disaster. Residents are informed and alerted to be evacuated to them in case of an emergency. In the Midwestern United States, many people build tornado shelters or cellars in their homes. Even local building codes may include some provisions for disaster reduction in home construction.

1.4 Societal Response to Natural Disasters

In ancient civilizations, natural disasters could mean the downfall of cities and empires. If two groups were battling or even competitive, a natural disaster weakened one of the groups, making it susceptible to being overthrown. Large earthquakes, tsunamis, storms, and volcanic eruptions have been responsible for several of the great and enigmatic historical catastrophes. This is especially true for the Eastern Mediterranean region where tectonic activity tends to be episodic. Large earthquakes, for example, tend to occur over a 50–100-year interval followed by a period of quiet that may last hundreds of years. The active periods are termed *seismic crises*. Because ancient cities were commonly protected by walls, a large earthquake could breach them making the city vulnerable. Such attacks might be from: (i) external enemies during active conflicts such as Joshua at Jericho and the Arab attack on Jerusalem in 31 BCE, (ii) neighbors in long-term conflict like Mycenae's fall in 1200 BCE and Saul's battle around 1020 BCE, and (iii) uprisings of enslaved people like Sparta and the Helots in 464 BCE, Hattusas around 1200 BCE, and Teotihuacan around 700 AD. If a small earthquake occurred during a modest conflict, damage would take a few tens of years to repair with minor if any shift of power. However, if a large earthquake occurred during a major military conflict, it would take hundreds of years to rebuild the damage and the city would be plunged into a dark age with all efforts centered on pure survival. It is during these incidents that the outcomes of conflicts could be decided by earthquakes and radical shifts of power possible.

For that reason, afflicted regions downplayed the impact of the damage and casualties from natural disasters. This practice existed throughout most of history and is not completely gone today. As late as 1976, communist China was struck by two major earthquakes of the Tangshan event in a few hours and in a highly populated area. The official number of casualties listed by the government was 252 000 and that remains the official total today. This was the height of the Cold War and showing weakness could have been deadly. Later studies, after the Cold War subsided, estimated the death toll from the Tangshan event at 655 000, making it potentially the worst natural disaster ever.

The sensing systems, however, are more complex and difficult to effectively install. Systems were installed in the Pacific Ocean after a major earthquake in 1964 and in the Indian Ocean after a major earthquake in 2004, but few other ocean basins contain them. Tornadoes, on the other hand, strike so quickly that they may not be as easy to identify or predict by national or local weather services. In most cases, there is little forewarning and, consequently, people must take refuge in a home tornado shelter or in a reinforced, safer part of a house.

The other main way people can protect themselves from natural disasters is through engineering. This involves different solutions that depend on the specific threat. In general, construction practices have improved with time in advanced countries as the result of updated building codes. California updates its building codes after each large earthquake, which is a great example of a proactive policy against one type of natural disaster. The Transamerica building in San Francisco has a recognizable shape that was constructed to be earthquake resistant (Figure 1.7). Japan also has excellent earthquake engineering including the installation of walls and gates in critical coastal locations to protect against tsunamis. If a tsunami is sensed in time, the gates slide shut preventing the wave from penetrating inland. The Netherlands has developed one of the most advanced technologies to protect against flooding to which they are so prone. Even large skyscrapers along the East Coast of the United States are typically designed to flex in response to strong winds.

These may be big-scale engineering examples, but there are many smaller and simpler methods as well. The ancient complex of Machu Picchu in the mountains of Peru actually

CASE STUDY 1.3 1949 Khait Earthquake, USSR

Downplaying Casualties Not to Show Weakness

On 10 July 1949 at 9:45 a.m., a powerful earthquake struck the Garm Oblast region of Tajikistan (USSR at the time). The magnitude was 7.4–7.5, and the maximum shaking intensity was IX (out of XII) on the Modified Mercalli Scale. It had two foreshock earthquakes on 8 July that were 12 minutes apart and had magnitudes of 5.1 and 5.6. The main shock was powerful enough to be destructive on its own, but the real damage was caused by the massive landslides it generated (Figure 1.8).

Eastern Tajikistan contains the Pamir Mountains, known as the “Roof of the World,” and the high Pamir Plateau. This rugged terrain generates numerous rockfalls, landslides, floods, and avalanches even without earthquakes. The reason the terrain is rugged is that it is in a very complex plate tectonic zone which also produces the strong earthquakes. The Khait earthquake occurred at the southern margin of the Tian Shan belt which extends westward from China. The belt is being generated by the ongoing collision between the Indian and Eurasian continents forming the Himalayan orogeny to the south. This area is marked by a combination of dextral strike-slip faults which move the land laterally and thrust faults which move it vertically. There are a series of north-south to northeast-oriented thrust faults that overlap the Tian Shan faults. The Khait earthquake appears to be the result of movement on the Vakhsh fault.

This part of the Pamir is known for seismic activity and mass movement. In 1911, an earthquake generated a landslide that blocked and flooded a river valley creating earthquake Lake Sarez, 36 mi (60 km) long and more than 1625 ft (500 m) deep. This activity led American seismologists to take an interest in the area. Through an unprecedented cooperative study with Soviet seismologists, they established a seismic network across the region and a research center in the town of Garm on the Surkhab River.

July 1949 had heavy rains that soaked the soils, loess deposits, and sediments that mantled the slopes. Loess is fine dust blown by wind from deserts and deposited on some slopes. Earthquake activity then increased causing minor landslides and contributing to the instability on many of the slopes. When the Khait earthquake struck on 10 July, the area was primed for massive landslides, especially on the loess slopes. Hundreds of small loess slides coalesced into a huge flow with a volume of 320.4 million cubic yards (245 million m³) that traveled 12.4 mi (20 km) in the Yasman Valley on a shallow slope of 2°. In the adjacent Yarhich and Obidara-Khauz Valleys, the Khait landslide began as a rockslide that entrained water-saturated loess deposits (Figure 1.8A). It traveled 4.6 mi (7.41 km) and descended 4662 ft (1421 m) at an average velocity of 97.5 ft (30 m) per second. In some sections, it achieved a velocity of 325 ft (100 m) per second. The estimates of the volume of this slide range from 327 million m³ (250 million m³) to as little as 98.1 million cubic yards (75 million m³). While moving, these landslides and avalanches made a deafening noise and were accompanied by strong winds and huge dust clouds.

All of the buildings in an area 37–41 mi (60–65 km) long by 4–5 mi (6–8 km) wide were destroyed by the earthquake and landslides. The town of Khait and around 20 neighboring towns from the two valleys were buried in soil and debris to a depth of 100 ft (30 m) in some places (Figure 1.8A). Overall, about 150 towns and villages were impacted. With the complete burial of so many towns, it was difficult to determine the death toll of the disaster. The minimum count is about 7200 people, but other estimates are 12 000–28 000 deaths.

In addition to the burial, another factor that complicated the death toll was the secrecy that surrounded the disaster. The Khait earthquake occurred at the beginning of the Cold War during the rule of Joseph Stalin. The USSR viewed disasters as a sign of weakness that could encourage enemies to attack. The government attempted to cover up and disavow the Khait disaster, not admitting to any fatalities

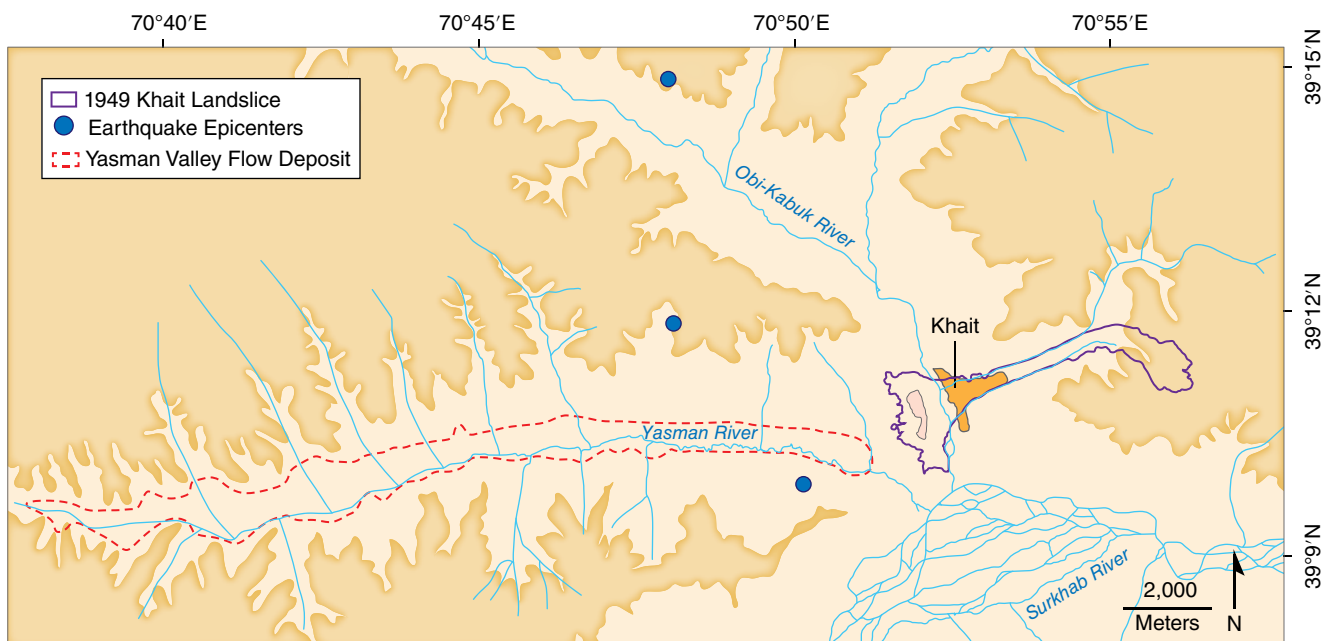


FIGURE 1.8 Map showing the locations of the 1949 earthquake epicenters, landslides and former town of Khait in the Garm Oblast region of Tajikistan. Adapted from Evans et al. (2009), DOI:10.1016/j.enggeo.2009.08.007.

at all for many years. The true extent of the disaster was not revealed until the past decade.

Today, between the towns of Gharm and Jirgital, there is a monument of white marble that commemorates the tragedy. A statue of a woman with her head down in grief overlooks the Yarhich River

Valley where the largest mass burial remains unexcavated. This is where the thriving towns of Khait, Badimlog, Turatal, Deplan, Karakol, Mazar, Aitalob, and many others once stood. It is now a grim reminder of the power of mass movements and the danger inherent to life in the Pamir.



FIGURE 1.8A Photo of a major 1949 Khait landslide. *Source:* Courtesy of the USGS.

Recent world politics has changed the response to natural disasters among many nations. In recent history, many of the larger and richer countries began to provide aid to countries that had been impacted by natural disasters. Even private groups developed ways to generate significant aid. In 1970, ex-Beatle George Harrison organized the first benefit concert to help the people of Bangladesh after they had been devastated by the Bhola typhoon. It generated an enormous amount of aid and many other benefit concerts followed. This new attitude led countries to more accurately report casualties or even to exaggerate them in hopes of receiving more aid. In 2010, a major earthquake struck Port-au-Prince, Haiti. It did extensive damage and caused an enormous number of casualties. Aid poured into the poor island from around the world. The official government estimate of casualties remains at 316 000, making it one of the worst natural disasters ever. However, independent studies conducted after the event estimate the casualties at 100 000–160 000, which is devastating but far less than the government claim.

CASE STUDY 1.4 2010 Port-au-Prince, Haiti Earthquake

Poor Construction and Possible Exaggerated Death Tolls

California updates their building codes after every strong earthquake, and it is reflected in the outcomes. In 1989, the Loma Prieta earthquake struck California at a magnitude of 6.9 located a mere 44 mi (70 km) from San Francisco and at a depth of 12 mi (19 km) producing a strong shaking intensity of IX (Modified Mercalli Scale) in the city. Yet, only 63 people lost their lives, 42 of whom perished because of a single highway collapse. This result stands in stark contrast to the 2010 Port-au-Prince earthquake in Haiti and illustrates the striking impact that construction practices play in preventing the loss of life. The faults that generated the two earthquakes are similar, both being marked by lateral movement. However, California, and especially San Francisco,

is among the most affluent areas in the world and can afford to prepare for earthquakes, whereas Haiti is among the poorest and cannot.

After a decade of some of the worst natural disasters ever, the second decade of the twenty-first century began with more devastation. On Tuesday, 12 January 2010 at 04:53 p.m., a major earthquake struck near Port-au-Prince, Haiti. The magnitude was 7.0 with a shallow focus of 8.1 mi (13 km), a mere 15 mi (25 km) west-southwest of the city. Even though Hispaniola is seismically active having experienced earthquakes that destroyed Port-au-Prince in 1751 and 1842 and an earthquake of magnitude 6.8 in the Dominican Republic as recently as 1985, the city was ill-prepared for the event.

The source of the earthquake was the Enriquillo–Plantain Garden fault system which has produced several large historical earthquakes in 1860, 1770, and 1751. The east-west fault system is one of

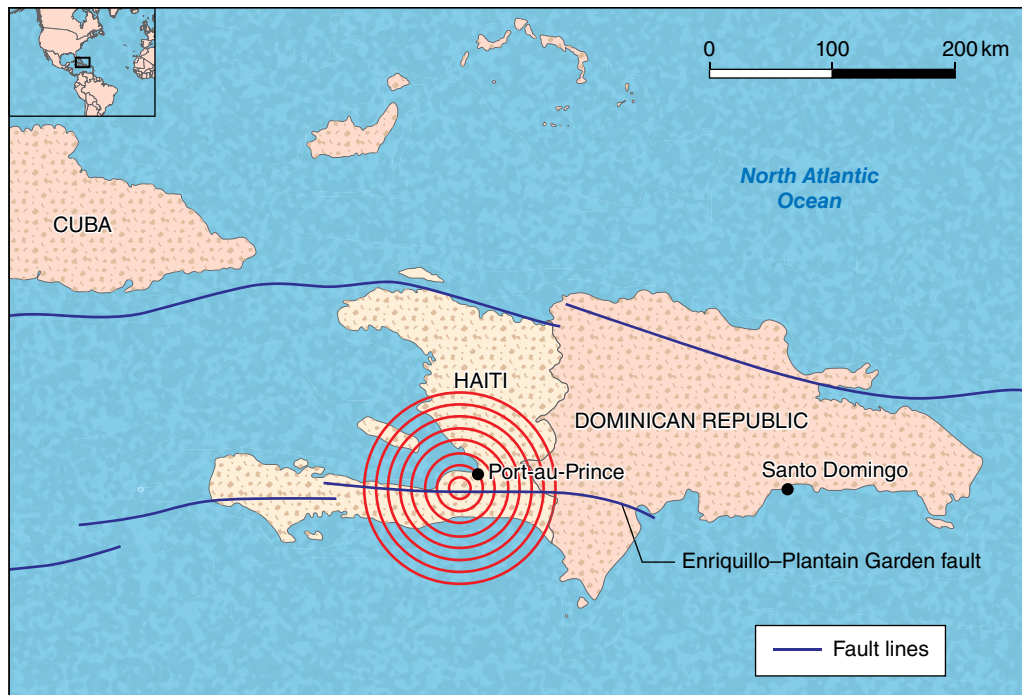


FIGURE 1.9 Map of the location of the 2010 Port-au-Prince, Haiti earthquake in Hispaniola, and the generating Enriquillo–Plantain Garden fault.

two that cross the island (Figure 1.9). These systems are part of the boundary region that separates the Caribbean tectonic plate from the North America tectonic plate. This transform plate boundary connects the Caribbean arc and the Central American arc and experiences left-lateral strike-slip or lateral motion and uplift. The movement on the boundary is about 0.8 in. (2.0 cm) per year. This boundary has produced numerous earthquakes including the 1692 Port Royal and 1907 Kingston earthquakes in Jamaica and the 1972 Motagua earthquake in Guatemala that killed 23 000 people.

Surface waves from the main shock produced ground shaking with a Modified Mercalli Intensity of IX (of a maximum of XII) in Port-au-Prince and its suburbs (Figure 1.9A). Shaking was felt throughout the region in Cuba at intensity III, in Jamaica at intensity II, in Venezuela at intensity II, in Puerto Rico at intensity II–III, and in the bordering Dominican Republic at intensity III. It also produced a local tsunami that killed at least four people.

The reason this earthquake was so devastating is that it was the worst in more than 200 years and Haiti is not prepared for earthquakes.



FIGURE 1.9A Collapsed buildings and crushed cars in Port-au-Prince, Haiti after the 2010 earthquake. Source: Courtesy of the USGS.



FIGURE 1.9B Aerial view of the destruction in downtown Port au Prince, Haiti as the result of the 2010 earthquake. *Source:* Courtesy of the USGS.

The country is the poorest in the Western Hemisphere, with four of five people living in poverty and more than 50% in abject poverty. Haiti has substandard building codes, and few builders follow them anyway. Most buildings can barely survive under normal conditions, much less the shaking from a strong earthquake. It was these collapsing buildings that caused the most loss of life. The United Nations estimates were 105 000 homes destroyed and 208 000 damaged, mostly in Port-au-Prince (Figure 1.9B).

Estimates are that upwards of 3 000 000 people were directly affected by the earthquake. The Haitian government estimates that 316 000 people were killed, 300 000 injured, and 1 000 000 made homeless. If the 316 000 deaths are correct, officially, it would be the worst earthquake disaster in modern times and the second worst ever. The death toll, however, was estimated by other international organizations to be much lower, between 92 000 and 160 000. The Inter-American Development Bank estimated that the total cost of the disaster was between \$7.8 billion and \$8.5 billion, based on a death toll of 200 000–250 000.

The international response to the disaster was immediate. On 13 January 2010, Secretary-General Ban Ki-moon of the United Nations released a statement of the humanitarian disaster in Haiti. President Barack Obama immediately pledged \$1.15 billion toward the rescue and relief efforts. After that, aid poured in from around the world. Venezuela pledged \$1.32 billion, and the International Monetary Fund canceled Haiti's \$268 million debt. Other countries made similarly large pledges and sent troops, rescue personnel, and supplies.

Former president Bill Clinton and the Haitian prime minister headed up a 26-person team that oversaw the \$5.3 billion raised in the first two years. Many countries and benefit fund raising efforts continued to generate relief funding for many years.

Although the world leaders pledged generous aid, delivering on the promises was a logistical nightmare. In the days following the earthquake, aid arrived in a trickle, electric power was unavailable, and telecommunications were spotty. Ships could not bring their cargos of supplies and were forced to remain offshore because of Haiti's damaged port (Figure 1.9C). The airport was functional but with severe limitations on flights both in and out of the country. All main roads and even most secondary roads were blocked by debris and throngs of survivors.

The Haitian government developed an aggressive plan to begin the reconstruction phase of the recovery process. They used the plan at a March 2010 donor conference to solicit almost \$10 billion in pledges. The rebuilding began in a very disorganized manner and was slow and inefficient with accusations of misuse of funds. The only bright spot in this disaster is that the government intends to inspect all new construction to be sure that it meets building codes. Permits are now required for those who want to repair damaged houses deemed as salvageable by the Haitian Ministry of Public Works, Transport and Communications. Building inspectors have even suspended reconstruction projects that they deemed questionable. There is at least the appearance of action to avoid such a terrible tragedy in the future.

Another consideration in the study of natural disasters is that ancient and modern events are not always comparable. There are differences in hazards such as fires which could be responsible for the majority of the damage in older events. Fires did the majority of the damage in the 1906 San Francisco earthquake and the 1923 Great Kantō earthquake in Japan. This was because fire was used for heating and cooking in the past, but typically is not anymore. The other problem is that there can be significant errors in reporting and recording of the details of events. As described, some details are misreported on purpose. However, in other cases, the misreporting can be by mistake.



FIGURE 1.9C Collapse of cliff face in Haiti as the result of the 2010 earthquake. *Source:* Courtesy of the USGS.

CASE STUDY 1.5 The 1737 Calcutta Earthquake

The Earthquake that Wasn't: Reliability of Ancient Accounts

The 1737 Calcutta, India earthquake is included in a number of lists of the world's greatest natural disasters. It was estimated to have had a death toll of 300 000, placing it among the top three or four of all time. Recent analyses of the event, however, not only cast doubt on the number of deaths but also suspect whether there was an earthquake at all. The problem is that on 11 October 1737, the day of the earthquake, a major cyclone struck the Calcutta area. It was such an intense storm that it sunk eight of the nine British ships and virtually all of the boats operated by the natives that were moored in the Ganges River. Many deaths were attributed to this storm.

However, the British East India Company did not compile a report of the disaster until survivors reached the headquarters in London six months later. Their report listed 3000 fatalities with no mention of an earthquake at all. However, the following year, stories in *The Gentleman's Magazine* and *The London Magazine* claimed 300 000 deaths as the result of an earthquake. This caused the confusion about the event. Historical records indicate that the urban population of Calcutta was less than 20 000 in 1737. There were other settlements outside of Calcutta, but it is doubtful that there were 300 000 people in the entire area much less than many killed. Although there are small to moderate earthquakes in the Calcutta area, they are not the large events that strike the Himalayan region to the north. For this reason, it is unlikely that such a huge earthquake could strike Calcutta. It is most likely that the 1737 Calcutta earthquake is the earthquake that wasn't.

1.5 How This Book Is Organized

There is science controlling natural disasters that must be understood to fully appreciate these catastrophic events. Several of the chapters are the pure science of the controlling processes in order to set the stage for understanding the natural disasters. However, most of the processes of the disaster itself are conveyed through case studies of individual exemplary events. These case studies include much of the science of the event itself that provide the specific background. As case studies, however, the human aspect is included.