Chapter 2

Hazard Summary

INTRODUCTION

During the late 1980s and early 1990s several major disasters occurred in North America as well as other areas of the world. Hurricanes Hugo in South Carolina, Andrew in Florida, and Iniki in Hawaii severely disrupted water service in those areas. The Loma Prieta earthquake damaged many water systems in the San Francisco Bay area. The 1992 Chicago flood of utility tunnels shut down the business district for several days. And countless smaller and less-publicized disasters occurred.

This chapter provides general and specific information on natural and human-caused disasters that create major emergencies. Each type of disaster causes hazards that can damage water system components and disrupt normal service. The hazards associated with each type of disaster are described and specific examples given. A hazard summary table is constructed for water systems to use when developing an emergency response plan.

Definition

Hazard. A hazard is a source of potential damage associated with a disaster. Examples are the high winds of a hurricane and the ground shaking of an earthquake.

NATURAL-DISASTER HAZARDS

The following paragraphs describe the most common natural disasters and the hazards associated with those disasters.

Earthquakes

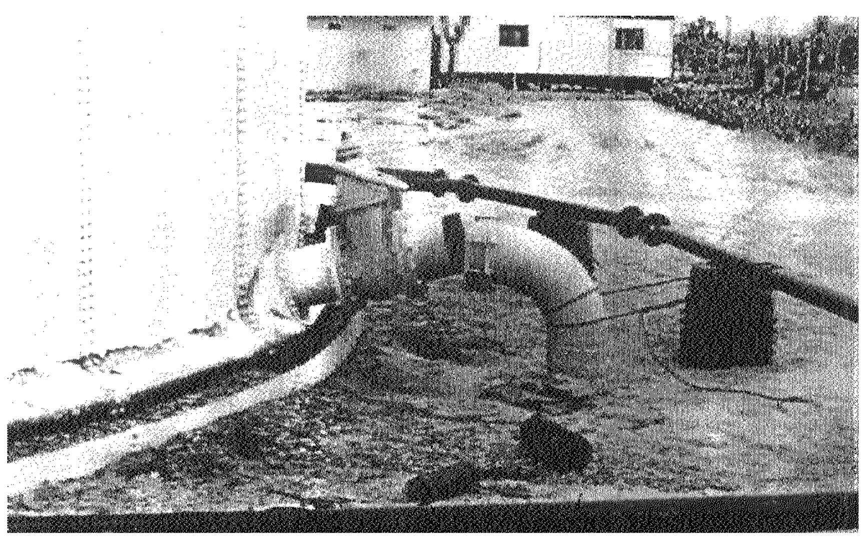
Damage from an earthquake can be extensive. The energy released by earthquakes can be equivalent to the explosion of millions of tons of dynamite. The degree of damage suffered is related to the magnitude of the earthquake, the distance from the epicenter (the part of the earth's surface directly above the focus of an earthquake), the soil types in the area, and the resulting mode of earth failure.

The San Fernando earthquake, which occurred in February 1971 in Southern California, demonstrated how destructive an earthquake can be to a water utility. A local power-converter station and two dams and outlet works were heavily damaged, two aqueducts were damaged, and a partially completed water treatment plant was nearly destroyed. The list of broken mains and valves, damaged pumping stations and distribution storage systems, disrupted communications and power supplies, and the resulting water shortages seemed endless.

In January 1994 another severe earthquake centered in the San Fernando Valley damaged aqueducts, trunk and service lines, and left pumping stations without power. By the second day after the quake, 100,000 people were without water. Due to the loss of water from major treatment plants, supplies came from backup groundwater sources and were imported through the Colorado River Aqueduct. The Los Angeles Department of Water and Power drew down finished-water reservoirs while repairing the system.

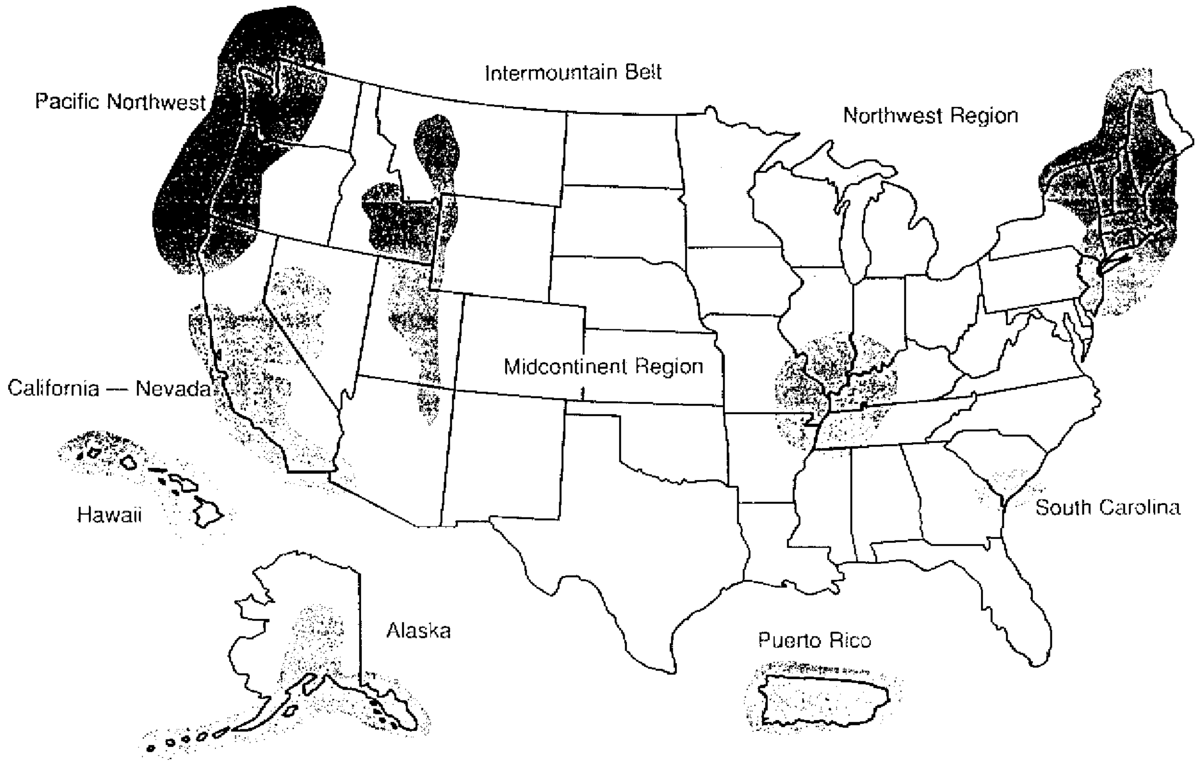
Likewise, the 1989 San Francisco Bay-area Loma Prieta earthquake and the 1992 Landers/Big Bear, Calif., earthquake caused pipe breaks, concrete-storage-tank cracks, steel-tank bursts, power and pump losses, and structural damage (Figure 2-1). Sixty-two people were killed in the Loma Prieta earthquake, and the damage is estimated at $6 billion

From a practical standpoint, earthquake risk for areas of North America has been defined with relatively high precision by experts using geological and historical information. Figure 2-2 indicates the risk of seismic damage in the United States. Portions of the Pacific coast have the highest risk, but other areas also indicate significant risk. To determine a more precise probability of an earthquake occurring and the potential magnitude, a water system should review the local geological and seismological data available from such sources as the US Geological Survey, state or provincial geological agencies, or universities, or employ a consultant experienced in earthquake hazard analysis.



Source: M J O'Rourke

Figure 2-1 A 400,000-gal (1.5 million-L) steel tank was uplifted and underwent "elephant's-foot" buckling on impact during the Landers, Calif., earthquake in 1992



Source: US Geological Survey.

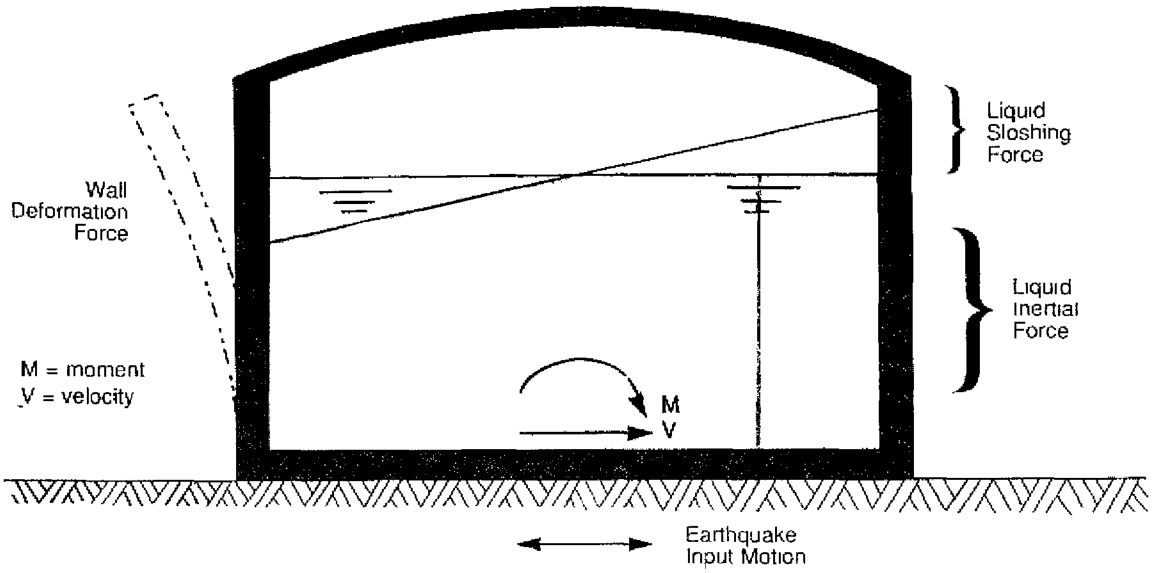
Figure 2-2 Major earthquake source regions of the United States

Earthquakes are complex phenomena that create equally complex hazards. A great amount of research is available on this subject; some of the important references are included in the bibliography of this manual. The following paragraphs provide summaries of the main earthquake hazards that can damage water system components.

Fault rupture. A fault rupture is the differential movement of two land masses along a fault. The 1992 Landers/Big Bear earthquake created a 21-ft (7-m) offset in some areas. If a pipeline crosses a fault that ruptures, the pipeline will experience forces that can deform or split the pipe or separate sections at the joints. Figure 2-3 illustrates those forces. Known faults are identified on geological and seismic maps, and can often be seen on aerial photographs or even on the ground. Crossing faults with pipelines should be avoided if possible. Pipeline design should allow for fault movement when crossings are required.

Ground shaking. The energy created by an earthquake radiates in waves from the epicenter like ripples caused by a stone thrown into a pond. The propagating waves cause the ground to shake. The closer to the epicenter, the more violent and vertical the ground shaking; the farther from the epicenter, the less severe and more rolling the ground shaking. Soil ground types affect the intensity of the ground shaking. The energy causes both vertical and horizontal accelerations that can damage water system components. For example, pipe entering a concrete structure without flexible joints is subject to shear failure. Another example is the seismic forces on water storage tanks (Figure 2-4).

Liquefaction. Pore water is the water located in the spaces between soil particles. The energy of an earthquake generates high pore water pressure that can



Source Epstein (1976)

Figure 2-4 Seismic forces on water storage tanks

vibratory roller to compact fill, or shaking loose sand in a tray to make it more compact. Ground subsidence can occur as the soil densifies. In Valdiva, Chile, the subsidence due to densification during the 1960 earthquake amounted to more than 3 ft (1 m) (Lambe and Whitman 1969)

Landslide. A landslide occurs when slopes lose shear strength because of a disturbance such as ground shaking. The major portion of the damage caused by the Alaskan earthquake of 1964 resulted from landslides. Landslides can cause earth dams to fail. In some earthquake-prone areas, landslide-hazard maps have been developed.

Tsunami and seiche. A tsunami is a tidal wave caused by an earthquake or volcanic explosion. A seiche is an oscillation of the surface of a lake, reservoir, or landlocked sea due to an earthquake. Tsunami and seiche can also be caused by earthquake-induced landslides. The wall of water from a tsunami can be many feet above normal high tide and contains tremendous energy. The tsunami from the 1883 Krakatau volcanic explosion was 100 ft (33 m) high and killed 36,000 people. The tsunami of the 1964 Alaskan earthquake destroyed coastal Alaskan communities and generated high tides as far south as La Jolla, Calif. A tsunami that hit Hilo, Hawaii, in 1960, caused damage in excess of $20 million and killed more than 80 people. In 1992 and 1993, tsunami in Nicaragua and Indonesia caused many deaths. In 1993, a 16-ft- (5-m-) high tsunami killed over 100 people in Japan.

A seiche can overtop dams, cause erosion of earthen dams, and result in dam failure. Seiche can damage dam inlet and outlet structures.

Hurricanes

The costliest disasters in recent years have been hurricanes. Approximately 44 million people in the United States live in areas that have been hit by hurricanes. Damages have been in the billions of dollars as the result of Hugo in South Carolina, Gloria in New York, Andrew in Florida, and Iniki in Kauai, Hawaii. The damage from Andrew alone was $25 billion. The main hazards associated with hurricanes are high winds, the storm surge, and flooding. Hurricane Andrew knocked down or damaged 60 percent of the power poles in its path. Though the water treatment plant in the path of Andrew remained in operation, the damage to residential and commercial structures resulted in multiple water leaks that effectively created an inoperable water distribution system (Tavano 1993).

Hurricane winds approaching 200 mph (320 km/h) have been recorded. A storm surge is a wall of water created by the extremely low atmospheric pressure in the eye of the hurricane. The surge can be higher than 20 ft (6 m) above mean sea level. Flooding is caused by the heavy rainfall from a hurricane, which can be as much as 36 in. (900 cm) as occurred in the Corpus Christi, Texas, area during the 1967 Hurricane Beulah (Cunningham 1973)

The high winds of a hurricane together with high tides and the storm surge can devastate shoreline areas, and water systems can be vulnerable Surface structures can suffer wind damage, and flooding can destroy plant facilities and contaminate water supplies. Structural damage (Figure 2-5) and the roots of trees toppled in a hurricane can break pipelines and result in tremendous flow demands due to numerous leaks. Power outages are also widespread.

Tornados

Tornados most commonly occur in the middle United States; however, they may occur in other sections of North America. The main hazard caused by tornados is extremely high winds. Exact speeds have not been measured because wind gauges rarely survive a tornado, but estimates are as high as 300 mph (480 km/h). Tornados can be tracked by radar and warnings can be issued; however, the generation of a tornado can occur with little warning. Because of this, tornados can cause high mortality rates. Structural damage from tornados can be very extensive as aboveground facilities are rarely designed to withstand tornado-force winds. The case study on page 11 outlines a water utility's response to a tornado.

Source: Ray Sato.

Figure 2-5 Structural damage from Hurricane Iniki in Kauai, Hawaii