

Floods

Originating from the Middle English *flood* meaning “to flow,” the term flood refers to the overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Flooding can occur along any body of water when normal capacity is exceeded and water overflows its natural or artificial boundaries. Although the spatial and temporal characteristics of floods are quite complex, all floods are characterized by excess precipitation around the flood site. Some floods are slow-moving, inundating large regions for months while other flood types may be highly localized and of short duration. Floods are of greatest concern when rising water threatens life and property, likely given approximately half the global population lives within a few kilometers to a water source. Floods are low-probability, high-impact events and, in many parts of the world, the costliest natural disaster both in terms of human life loss and socioeconomic damage. Some evidence suggests hydroclimatic extremes are becoming more commonplace in recent decades as a result of anthropogenic induced climate change.

Floods are characterized by their duration, intensity and frequency, cause, and subsequent impact. Duration is the length of time an area is inundated and/or a stream is above flood stage (i.e., the height of the water surface above an established local elevation at which overflow of the streambanks begins). The intensity or magnitude of a flood is usually measured as the volume of water passing a point per unit time (e.g., cubic feet per second) known as discharge. Alternately, flood magnitudes along streams are often expressed as the height above flood stage. Annual flood magnitudes are compared with the historical record using return periods, the average time interval between floods of a given size. Return periods are the reciprocal of the flood frequency or the *probability* of a flood level being equaled or surpassed in any given year. For example, a flood with a return period (or recurrence interval) of 50 years has a 1 in 50 probability or 2% chance of occurring in any given year. Flood probabilities are statistically independent events, meaning a 50-year flood has the same 2% chance of occurring each year and successive 50-year flood events are possible. The definitive cause of floods is excess precipitation, but the timing, persistence and atmospheric circulation type determine the flood size and damage extent.

Flash Floods

Highly localized flooding that occurs extremely quickly with rapid runoff is known as flash flooding. This type of flooding usually occurs within minutes to a few hours after a heavy rainfall event, such as a thunderstorm. Flash floods also occur when a man-made structure such as a dam or levee breaks, or when water behind an ice jam on a frozen river is quickly released during a spring thaw. As such, they can be extremely hazardous events, both to lives and property. Rainfall intensity (the rate of rainfall) and duration (how long the rain lasts) are two of the most important factors that determine the likelihood of flash flooding. When the atmosphere supports the development of slow-moving (long-duration) thunderstorms, rainfall quickly saturates the upper-most layer of soil. Once the soil reaches its holding capacity, any excess rain that falls will not be absorbed by the ground and either evaporates or becomes runoff. It is this runoff that leads to flash floods. Thunderstorms that produce heavy (high-intensity) rainfall, upwards of one to two inches or more per hour can produce flash flooding. Organized, long-lasting multicellular thunderstorms, such as mesoscale convective systems (MCSs), are often responsible for flash flooding conditions, especially in areas of highly variable terrain.

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Topography, the features and surface shape of an area, is also a significant factor in the development of flash floods. Streams, creeks, and other low-lying areas are extremely vulnerable to flash floods. Steep, mountainous terrain causes runoff to move downslope, quickly filling valley streams. The soil type and condition influences the capacity and runoff potential of a given area during a flash flood. Permeability, or the measure of a fluid (usually water) movement through soil, changes with different types of sediment. Low permeability soils such as clay will not allow water to infiltrate into the subsurface at a fast rate, resulting in large amounts of runoff and increased flash flooding potential when compared to high permeability soils (e.g., sand). Additionally, as storms develop over areas that have had recent rainfall, the likelihood of flash flooding is increased due to the higher moisture content of soil.

Soil ground cover also makes a difference in the development of flash floods. Locations which have little to no vegetation or plant life are at a higher risk of flash flooding. Grasses, trees, and shrubs help absorb rainfall through their leaves and roots, as well as help hold soil in place, preventing a mudslide or debris flow. In arid regions, ordinarily dry stream beds or water-carved gullies known as arroyos can quickly fill with fast moving water that originally occurred from a thunderstorm several kilometers upstream. Even well-developed urban regions are at risk for flash flooding as concrete and asphalt increase the runoff potential of rainfall two to six times over that of natural terrain. With heavy downpours, urban storm drains quickly become overwhelmed and can turn normal streets into swift moving rivers. Since the latter half of the 20th century, global atmospheric moisture content has increased with increasing global temperatures, a trend that is expected to continue throughout the 21st century. Higher moisture contents and a more convectively stable atmosphere may increase the likelihood of intense thunderstorm formation and ensuing flash flooding.

Long-Term and Widespread Floods

The most recognized type of flooding can occur over several days and even weeks usually due to a prolonged meteorological event, such as a monsoon, stalled mid-latitude frontal system or tropical storm. Locations along main river tributaries frequently see flooding during spring snowpack thaws and after upstream areas have had considerable rain. As with flash floods, soil type, ground cover, and topography all affect the extent and duration of floods. Locations with soils that have a low permeability are likely to see ongoing flooding for a longer period of time when compared to areas with soils of higher permeability. Vegetation reduces the extent of flooding by absorbing water. However, unlike with flash floods, areas with flatter terrain are more prone to flooding as runoff accumulates and subsequently has no other outlet. Coastal regions and estuaries are prone to flooding during land-falling tropical storms and mid-latitude cyclones. Strong winds from these weather systems can produce large storm surges which drive ocean water inland, resulting in devastating flooding, especially in low-elevation areas. Tsunamis harbor yet another threat for serious flooding and loss of life, whereby displacement of large volumes of water is generated by earthquakes, volcanic eruptions, landslides, and other disturbances above or below water level. For example, a magnitude 9.1 Indian Ocean earthquake in 2004 produced several tsunamis that killed over 230,000 people across the ocean basin as water inundated low-lying coastal plains and many islands. Humans can also cause flood events, usually on a more local scale by accidental damage to pipes and

tunnels during construction projects. The deterioration of pipes, especially water mains, increases the risk for flooding in urban areas as well.

Flood Impacts

Depending on severity and spatial coverage, floods can have devastating effects on both the environment and society. Floods can cause severe physical damage to homes and businesses. One cubic meter of water weighs 1,000 kg (or 1 ft³ equals 62.4 lb); the applied force of such a mass of flowing water is enormous enough to undermine the structural integrity of most buildings. In urban areas, flooding can cause waste water treatment systems to backup and fail, resulting in the release of raw sewage and contaminating drinking water supplies; water-borne diseases, such as cholera become more widespread after a flood event. Standing water also provides an excellent breeding ground for mosquitos which can spread malaria and other vector-borne diseases. Above or below-ground power transmission lines which become inundated can cause electrocution to those who tread through flood waters. Roads and other transport links can be destroyed or impaired, making it difficult, if not impossible, for emergency aid to reach affected areas. Automobiles can become death traps as motorists try and cross flooded roadways; approximately 0.6 m (2 ft) of water is enough to float the average car. Bridges and/or their support structures can become compromised and motorists or pedestrians can drown as weight is applied and the bridge fails. Food supplies can be destroyed and entire crop harvests become inundated by flood waters. Trees and shrubs unaccustomed to flooding can die from oxygen deprivation.

In the long-term, the socioeconomic loss from flooding can be especially hard. Flooded homes and businesses become uninhabitable, forcing residents to rely on aid and temporary shelters provided by relief organizations. Economic loss from major floods can be astronomical and costs further rising from reconstruction projects. For example, the 2011 floods in northeastern Australia cost upward of \$ billion dollars, making the flood event the costliest natural disaster in the nation. Tourism to flooded regions can plummet, resulting in further economic hardship. With food shortages, yet high demand, the cost of basic supplies increases and price gouging becomes more prevalent.

Although there are numerous disadvantages to floods, the positive aspects are very important as well. Natural floods bring nutrient-rich sediment and silt to downstream crops, increasing harvest yield and regenerating leached soil. The seasonal flooding cycle was a vital process for early civilization development along the Nile, Tigris-Euphrates Rivers, Yellow, Ganges, and Indus Rivers. Floods also remove debris, thus improving water flow. Flood water can also create habitats for new ecological communities and deposit seedlings for new growth. Only when floods threaten local communities and population centers do the negative effects increase and as such, many flood prevention methods have been devised.

Flood Control

Flood control and management measures such as dams, levees, and reservoirs construction, as well as reforestation, are found throughout the world and have shown varying degrees of success over the centuries. During the Middle Ages, Germanic tribes developed levees along the Rhine and Danube rivers in present day Germany and eastern Europe. In North

America, French settlers in the 18th century built levees to protect the city of New Orleans, USA from floods along the Mississippi River; the levees have since been extended to include over 1,000 km (620 mi) of shoreline upstream. The Chinese have long used a system of levees to raise the banks of the Yellow River (Huang He); however, devastating floods, such as those in 1887, 1931, and 1938, have still killed millions. Despite flood disasters, China is presently one of the largest builders of new dams and levees for flood control and hydroelectric power production; the largest dam in the world, the Three Gorges Dam on the Yangtze River, was completed by China in 2008.

Originally built for water storage and irrigation, dams and reservoir in the modern era are largely constructed for flood control. During heavy rain events, dams help mitigate flooding downstream by retaining water behind the structure; during droughts, the water is used to irrigate cropland. On the other hand, the construction of dams and reservoirs also requires locations upstream behind the structure eventually become inundated as water begins to fill the reservoir to capacity, resulting in social and environmental damage. Along major streams and rivers, floodways divert water so a controlled area of land is flooded, sparing locations which otherwise would have been flooded. They are usually located upstream from a highly populated area, and although flooded areas are controlled and predetermined, residents of those areas become affected. Coastal areas may use sea walls, beach nourishments, and barrier islands to defend against inland flooding from storm surges. Additionally, tide gates placed strategically along the mouths of streams and rivers help to prevent the high tides from moving inland and inundating coastal areas.

Floods and Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC), a high (>90%) confidence exists that there will be an increase in global temperatures and heavy rainfall through the 21st century. Average global temperatures could rise between 1.1 and 6.4 °C (2.0 and 11.5 °F) by the year 2100. Somewhat lower (>66%) confidence exists that droughts, high tides, and tropical cyclones will increase over the next century. Global average sea level has increased by 1.7 mm (0.07 in) per year between 1870 and 2000, raising mean sea level by 221 mm (8.7 in). Increasing global temperatures are expected to melt portions of the Greenland and Antarctic ice sheets, small ice caps and mountain glaciers, as well as expand ocean water volume. The IPCC estimates this would result in a global average sea level rise between 0.18 and 0.59 m (0.6 and 2 ft) or more, especially if warmer temperatures accelerate the polar ice cap melt. Low-lying coastal areas, especially wetlands, would be flooded and residential areas would become uninhabitable as sea levels rise. An increase in sea surface temperatures (SSTs) mean would expand the Tropics, thus increasing the likelihood for more frequent and intense tropical cyclones over the course of a longer formation season. Locations with insufficient mitigation infrastructure and high coastal population densities, such as Latin America and Southeast Asia, would be particularly impacted by an increase in land-falling storms.

Interior continental locations would also be affected by flooding from climate change. With increasing temperatures, mid-latitude cyclones and convective thunderstorms could become more frequent and/or produce more precipitation. Warmer air temperatures have greater moisture content, thus these systems would have the potential for producing wide-scale flooding for extended periods along major inland rivers and their tributaries. Localized thunderstorms could become more numerous, possibly resulting in additional flash flooding; locations in steep terrain

would be especially threatened. Storm sewers in urban areas may not be sufficient for additional storm runoff, especially if the storm systems are both slow-moving and producing more intense precipitation. An increase in droughts could cause an increase in flash flood conditions when storms eventually develop over such areas. The melting of high-elevation glaciers coupled with a greater winter snow pack may increase the severity of spring floods in mountainous locations and those areas downstream.

As global temperatures continue to increase through the 21st century, flooding is expected to become more frequent and deadly. Low elevation coastal regions will be most impacted by rising sea level heights and storm surge from tropical or midlatitude cyclones. Thunderstorms will likely become more widespread with greater precipitation intensities, leading to a possible increase in flash flooding, especially in rugged terrain and drought-stricken areas. However, much uncertainty still exists to the extent of these changes and if current flood episodes are a product of short or long-term climate variability.

SEE ALSO: Intergovernmental Panel on Climate Change (IPCC); Oceanic Changes; Rain; Rising Sea Level; Sea Ice; Soils.

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