Managing U.S. Coastal Hazards

Position Statement. Storms, tsunamis, and rising sea levels threaten U.S. coastal communities and their economies. Much of the nation's existing coastal infrastructure must be adapted to expected future conditions or relocated. New coastal development and post-storm reconstruction should be planned, sited, and maintained with coastal geologic hazards clearly in mind.

Purpose. This position statement summarizes the main geologic hazards along the marine coasts of the United States—Atlantic, Gulf, Pacific, and Arctic—and urges scientists and policy makers to collaborate toward integrating geoscience information into policy and management actions in order to reduce the nation's future vulnerability to these hazards.

Rationale

The United States is vulnerable to coastal hazards. In 2010, more than half of the U.S. population resided in coastal watershed counties (NOAA, 2013a). The U.S. coastal zone supports 66 million jobs and contributes US$8.3 trillion to the U.S. economy, or 58% of the nation's economic output (NOAA, 2013a). The high population density in coastal regions and continued pressure for residential, commercial, and industrial growth persist despite a range of natural hazards and an increasing number of disasters. Hurricanes and coastal storms, such as Katrina (2005), Ike (2008), Sandy (2012), Harvey (2017), Maria (2017), Florence (2018), and Michael (2018) underscore the nation's vulnerability to coastal hazards and the risks and costs of rebuilding in disaster-prone areas.

The type and severity of coastal geologic hazards—and the potential harm they can inflict on existing or future development—vary because of differences in geology, tectonic setting, topography, climate, and oceanographic conditions. The scientific community has made considerable progress in improving our understanding of these hazards and the risks they pose. Resource managers and decision makers in all sectors (government, business, and non-profit) must be willing and able to access and apply geoscience information to inform their decisions in order to avoid catastrophic losses from the following hazards.

Coastal Storms

Some of the costliest natural disasters in U.S. history have resulted from tropical and extra-tropical storms. The nature of these storms varies, but development along all U.S. coastlines is exposed to significant risks. Some examples:

- Low-lying areas along the Gulf and Atlantic coasts are routinely battered by hurricanes and other tropical systems. Barrier islands are particularly vulnerable due to their low elevations. The combination of storm surge and large waves can wash over islands, undermining structures built on the shoreline or dunes, and destroying roads and bridges connecting the islands to the mainland. Coastal wetlands, which act as sponges to absorb some of the water and energy associated with tropical storms and hurricanes, are being lost at alarming rates due to human activities (dredging, construction of flood control infrastructure, etc.), leaving coastlines even more vulnerable to damage from tropical storms and hurricanes.
- Nor'easters (extra-tropical storms) produce heavy rain or snow, high winds, tornadoes, storm surges, and very large waves that can flood low-lying areas and overwash and erode beaches and dunes of the Atlantic barrier

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islands and coast (Hyndman and Hyndman, 2017). Human-made alterations or constrictions to natural drainage systems can trap salt water from storm surges, which can contaminate shallow aquifers that provide drinking water to many coastal communities. Several powerful nor'easters in early 2018 caused more than US$3.3 billion in damages resulting from heavy snow, coastal erosion, and high winds in multiple northeastern states (NOAA, 2018b).

- El Niño events and Pacific Atmospheric Rivers can have significant impacts on storms, coastal erosion, and regional flooding along the western margin of North America. High tides and storm waves associated with these events can flood low-lying coastal communities and can damage infrastructure and natural resources including along cliffs, bluffs, dunes, and beaches (Barnard et al., 2017; Hamlington et al., 2015; NRC, 2012; Russell and Griggs, 2012).

The number of hurricane-related deaths has decreased over the past century due in large part to our improved ability to both predict landfall location and evacuate at-risk populations. Unfortunately, the cost of damages has dramatically increased, reflecting rapidly growing coastal populations, more construction in hazardous locations, more expensive buildings, and the high costs of post-storm solid waste disposal from damaged infrastructure. During 2017, the U.S. experienced its costliest year due to 16 extreme weather events each exceeding US$1 billion, totaling US$306 billion, driven largely by hurricane Harvey, US$125 billion, and hurricane Maria, US$90 billion (NOAA, 2017a). The five most costly hurricanes in U.S. history occurred between 2005 and 2017 (NOAA, 2018a), with Katrina as the costliest, followed by Harvey, Maria, Sandy, and Irma. This assessment does not include Hurricane Florence, which early estimates of economic losses are between US$38 and US$50 billion (Scism and Ailwork, 2018).

Tsunamis

The 2004 Indian Ocean disaster spurred worldwide progress toward reducing loss of life from future tsunamis. Major advances include official early warnings for tsunamis generated by earthquakes in distant locations (Bernard et al., 2006). Such warning systems, formerly limited to the Pacific Ocean, now have the potential to help reduce loss of life on Atlantic and Caribbean shores as well. There remains, however, the greater hazard posed by tsunamis from nearby earthquakes. Near-field waves triggered by seafloor displacement and/or co-seismic submarine landsliding may arrive before official warnings are delivered (Yulianto et al., 2010). Nearly all the loss of life from the 2011 Japanese tsunami occurred in the near-field. The flooding began as soon as 25 minutes after the start of the earthquake. The enormity of the disaster was difficult to anticipate from the geologic records of a comparable tsunami in A.D. 869 (Sawal et al., 2012; Sugawara et al., 2012). The September 2018 Sulawesi Earthquake (M7.5), which triggered a near-field tsunami and other co-seismic geological hazards, is yet another example of coastal vulnerability to complex disaster.

The coasts of the United States are subject to far-field and near-field tsunami hazards (Barth and Titus, 1984). The greatest near-field hazards are associated with subduction zones in Alaska, Cascadia, and the Caribbean. The subsidence that would accompany a repeat of the giant 1700 Cascadia earthquake would cause a relative sea-level rise of as much as one meter along parts of coastal Washington, Oregon, and northern California (Atwater et al., 2005). The National Tsunami Hazard Mitigation Program has taken steps to address these hazards with measures that include inundation modeling, evacuation signage, and public education, although the program continues to face challenges.

Climate Change and Sea Level Changes

Global sea-level rise is perhaps the most obvious manifestation of climate change in the oceans. The rate of sea-level rise has increased globally from about 1.4 mm per year over most of the last century to about 3.4 mm per year since 1993 (NOAA, 2017b), and this rate is projected to increase in the future (Vitousek et al., 2017). Global mean sea-level is projected to rise by 0.3 to 2.5 m from 2000 levels by 2100 (NOAA, 2017b). As sea-levels rise, the impacts of storm surges worsen (NOAA, 2017b). Sea-level rise varies along U.S. coasts, due in large part to regional differences in land uplift or subsidence (a result of melting of land-based ice) and to changes in ocean currents (Sallenger et al., 2012; NOAA, 2017b). The wide range in future sea-level rise trajectories presents challenges to sustainable coastal zone management.

The long-term impacts of an increasing rate of sea-level rise along the U.S. coast are becoming increasingly clear (NOAA, 2013b). Sea-level rise will affect coastal communities and infrastructure through more frequent flooding and gradual inundation, as well as increased cliff, bluff, dune, and beach erosion. Coastal aquifers that provide water for drinking, industry, and irrigation will be affected, as well as the ecosystems supporting coastal fisheries. Coastal transportation corridors, coastal power and wastewater treatment plants, transfer and discharge systems, ports and harbors, other municipal infrastructure, and private development, including homes and businesses, will be affected (Russell and Griggs, 2012; Burkett and Davidson, 2012). Adaptation to sea-level rise must take place in the context of regional and local, as well as global, sea-level changes.

OTHER CONSIDERATIONS

Implications for Coastal Management

Losses from long-term, chronic events, such as progressive sea-level rise and large storms, as well as larger-scale natural disasters, continue to increase over time, due to increasing development in coastal communities (Hyndman and Hyndman, 2017). Recognizing, delineating and mapping, and identifying and publicizing the risks that they pose can enable coastal management or land-use decisions that will reduce future losses for public infrastructure and private development, as well as government funds spent on repetitive losses (Burkett and Davidson, 2012). Political, institutional, and public recognition of the risks posed by coastal hazards is necessary for advancing a sustainable approach to coastal management. Storms such as Katrina, Ike, Sandy, Harvey, Maria, Florence, and Michael emphasize the severity and reality of such hazards and present an opportunity to reassess and reduce the exposure of coastal communities to storm surges and inundation. The densely populated shorelines of New York and New Jersey and the low-lying areas of the southeastern Atlantic and Gulf coastal plains are among the most vulnerable to sea-level rise and storm surge and will only become more vulnerable with time (NOAA, 2013a).

RECOMMENDATIONS

- Geoscientists should communicate information and concerns about coastal hazards and the risks they pose to government agencies and the public, thereby encouraging and supporting responsible and sustainable policies, actions, and decisions. This could be accomplished through a state and federal partnership to systematically map areas vulnerable to coastal hazards over the next century, especially by incorporating high-resolution LiDAR.
- Coastal property damaged in past events or that are at risk from future events should be delineated and the risks determined and documented. Local governments should develop relocation or adaptation plans for existing at-risk development and infrastructure, whether public or private. Future sea-level rise and the exposure to coastal hazards, as well as the cost and lifetime of any proposed facility, should be factored into decisions about construction or reconstruction.
- Government agencies should accept their responsibility for using the best information and recommendations that the geosciences community can provide in land-use decisions, including regulation of coastal construction and reconstruction, in order to develop resilient coastal communities and infrastructure in high-risk coastal areas and to reduce losses from recurring natural events.

- The U.S. must develop a vision for the future that accepts the natural processes of a high-energy, rapidly evolving coastal system, and that seeks to live with the dynamics of change. This is essential in order to maintain sustainable coastal economies and preserve the natural resources upon which these economies are critically dependent.

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