GSA Position Statement

MANAGING U.S. COASTAL HAZARDS

Flooded coastal streets, houses, and fields after Hurricane Ike passes through Texas. Photo by Karen L. M. Morgan/U.S. Geological Survey, Public Domain.

Position Summary. 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.

This position statement provides a communications tool that (1) summarizes the main geologic hazards along the marine coasts of the United States—Atlantic, Gulf of Mexico, Pacific, and Arctic—and (2) urges scientists and policy makers to collaborate toward integrating geoscience information into policy and management actions in order to reduce the nation's current and future vulnerability to these hazards.

Conclusions and 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 state and federal partnerships to systematically map areas vulnerable to coastal hazards over the next century, especially by incorporating high-resolution LiDAR.
- Local governments should develop relocation or adaptation plans for existing at-risk development and infrastructure, whether public or private. Coastal property damaged in past events, or that are at risk from future events, should be delineated and the risks determined and documented. 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 use 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 accounts for the natural processes of a high-energy, rapidly evolving coastal system. This is essential in order to maintain sustainable coastal economies, preserve the natural resources upon which these economies are critically dependent, and protect national security.

Rationale

The United States is vulnerable to coastal hazards. In 2018, more than half of the U.S. population resided in coastal watershed counties (NOAA Office for Coastal Management, 2022). The U.S. coastal zone supports over 58 million jobs and contributes over US$10 trillion to the U.S. economy (NOAA Office for Coastal Management, 2022). 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), Michael (2018), and Ian (2022) underscore the nation's vulnerability to coastal hazards and the risks and costs of rebuilding in disaster-prone areas. Frequency and intensity of these events are expected to increase.

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The type and severity of coastal geologic hazards—and the potential harm they can inflict on existing or future development—vary based on factors including 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 nonprofit) must be willing and able to access and apply geoscience information to inform their decisions in order to avoid catastrophic losses from hazards including coastal storms, tsunamis, and climate change and sea level changes.

Coastal Storms

Some of the costliest natural disasters in U.S. history have resulted from tropical and extratropical (mid-latitude) storms damaging U.S. coastal communities and infrastructure, including:

- Low-lying coastal areas along the Gulf of Mexico and Atlantic Ocean 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 the alarming rate of 80,000 acres/year (for the lower 48 states) due to human activities (dredging, construction of flood control infrastructure, etc.). The loss of coastal wetlands leaves coastlines even more vulnerable to damage from tropical storms and hurricanes (Dahl and Stedman, 2013).
- Nor'easters (extratropical storms) produce heavy rain or snow, high winds, tornadoes, storm surges, and very large waves, which can flood low-lying areas and overwash and erode beaches and dunes of the Atlantic barrier 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 (Smith, 2023).
- El Niño events and Pacific Atmospheric Rivers (airborne streams of water vapor leading to increased rainfall) 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).

Our improved ability to predict landfall location and evacuate at-risk populations has helped to reduce the number of hurricane associated deaths, though it is now more recognized that secondary and tertiary causes, including carbon monoxide poisoning, electrocution, infections and parasitic disease are increasingly behind hurricane-related deaths (Henson, 2022; Parks, et al., 2022). 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 (Philbrick and Wu, 2022).

During 2022, the U.S. experienced its third costliest year due to 18 weather/climate disaster events, each exceeding US$1 billion and totaling US$160 billion—driven largely by Hurricane Ian, US$112.9 billion (Smith, 2023). The five most costly hurricanes in U.S. history occurred between 2005 and 2022 (Smith, 2023), with Katrina as the costliest, followed by Harvey, Ian, Maria, and Sandy. US$1 billion dollar disasters are tracked by NOAA (https://www.ncei.noaa.gov/access/billions/).

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. However, accurately and quickly issuing official warnings that precede the arrival of locally triggered (near-field) tsunamis remains a challenge (Papadopoulos, 2016). 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 (Goda et al., 2019).

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 (https://www.tsunami.noaa.gov).

Climate Change and Sea Level Changes

Global sea-level rise is perhaps the most obvious manifestation of climate change in the oceans. The average rate of global sea-level rise between 1901 and 1971 was 1.3 mm per year. The rate has continued to increase since then to 1.9 mm per year between 1971 and 2006 and 3.7 mm per year between 2006 and 2018, and this rate is projected to increase in the future (IPCC, 2021). Global mean sea-level is projected to rise by 0.28 to 1.88 m relative to 1995–2014 across all emissions scenarios by 2100 (IPCC, 2021). As sea levels rise, the impacts of storm surges worsen (Sweet et al., 2022). 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, pumping, and variations in sedimentation due to infrastructure) and to changes in ocean currents (Sweet et al., 2022; Sallenger et al., 2012). The wide range in future sea-level rise trajectories presents challenges to sustainable coastal zone management.

Sea-level rise is already affecting coastal communities and infrastructure through more frequent flooding and gradual inundation, as well as increased cliff, bluff, dune, and beach erosion. Increasingly, coastal aquifers that provide water for drinking, industry, and irrigation will be affected, as well as the ecosystems supporting coastal fisheries. Flooding and sea-level rise will increasingly affect coastal transportation corridors, military installations, coastal power and wastewater treatment plants, ports and harbors, other municipal infrastructure, and private development, including homes and businesses (Burkett and Davidson, 2012; Department of Defense, 2021; Russell and Griggs, 2012). Flooding from heavy rainfall and/or sea-level rise can also remobilize toxic chemicals in industrial areas, contaminating drinking water, particularly for low-income and disadvantaged communities (Johnson 2021). Adaptation to sea-level rise must take place in the context of regional and local, as well as global, sea-level changes.

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 coastal hazardous events pose can enable coastal management or land-use decisions that will reduce future losses for public infrastructure, private development, and 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. Hurricanes impacting the U.S. over the past several decades 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 (Allen et al., 2021; Reidmiller et al., 2018).

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