GSA Position Statement

U.S. FLOOD RISK MANAGEMENT

Photo by Joe Flood on NOAA's Photo Library.

Position Summary. Across the U.S. and worldwide, flooding is the deadliest and most costly natural disaster. The rising costs of flooding result from continued development of flood-prone land and modifications to river and coastal systems, amplified by climate change. By most metrics, the U.S. is losing the fight to manage the nation's flood risk. Science provides tools for quantifying flood risk, estimating future conditions, balancing human uses of floodplains with ecosystem services, and identifying effective mitigation strategies. The Geological Society of America recommends policies that move the U.S. toward long-term resilience, focusing on pathways toward sustainable floodplain management and flood-risk reduction.

Conclusions and Recommendations

The U.S. has experienced more than 250 weather- and climate-related disasters since 1980 with damages of $1 billion or more (adjusted for inflation), with flooding contributing to nearly 70% of these events [1]. By most metrics, the U.S. is losing, not winning, the fight to manage the nation's flood risk. But tools are available to chart a more sustainable path for the future. Science provides the best possible basis for estimating future conditions, informing hazard assessment, balancing human uses of floodplains with ecosystem services, and identifying effective mitigation strategies against future damages. Key recommendations are outlined below.

- **Move U.S. flood policy toward long-term sustainability, focusing on pathways to flood-risk reduction and resilience**—Every disaster provides a window of opportunity to rebuild better. In the face of spiraling losses from flood damages—driven by development, climate change, and other factors—communities across the U.S. and worldwide seek solutions to increase their resilience. Resilience can be defined as the ability to withstand a shock with minimal degradation and restore function in a reasonable amount of time. Specific policies, programs, and resources are needed that move away from rebuilding "just in time for the next disaster" and toward mitigating, protecting, and adapting to reduce losses long-term, improve ecosystem services, and foster community safety and resilience.
- **Invest in basic river and flood data and research**—Flood-risk management and investment decisions, involving billions and ultimately trillions of dollars, should be based on more detailed and better hydrologic and climatological data and science. Great strides in flood assessment have been made, including high-resolution topography (e.g., Lidar) and related modeling, but basic areas like hydrologic instrumentation lag. Investment today in continuing hydrogeoscience data collection and analysis translates into flood losses avoided, communities spared, and lives saved in the future.
- **Incorporate uncertainty and changing conditions in flood planning and flood-risk communication**—Flood hydrology and climate are understood by scientists to be both stochastic and non-stationary systems—meaning subject to uncertainty and changing over time. But most assessments of flood risk in the U.S. are communicated as fixed and certain values and lines on maps. Given evidence of shifting flood hazard in many locations, risk analyses that assume static conditions may underestimate present-day and future flood risk, sometimes significantly. Policy and risk management associated with flooding must recognize both uncertainty and past trends, while predicting for future conditions.
- **Provide the public with actionable flood-risk information, including for present and future conditions**—Communities need a clearer and more complete picture of their flood risk and what they can do about it. Comprehensive flood-risk

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information is essential to supporting planning, mitigation, and funding and policy priorities. Tools now exist to put such information into the hands of individual homeowners, renters, and business owners. Existing flood maps should be supplemented with data on residual risks behind levees and downstream of dams, areas with repeated pluvial flooding, and projections of future conditions resulting from development and climate change. Comprehensive flood risk information should drive communications, planning, mitigation actions, policies, and funding priorities among all stakeholders.

- **Maximize use of natural systems and processes to mitigate flooding**—Wherever possible, development and infrastructure projects should incorporate non-structural and nature-based approaches to flood-risk management, including strategies to retain water and sediment in uplands and floodplains and to attenuate storm surge and wave energy in coastal areas. Projects that use natural features or otherwise mimic natural processes can also provide significant co-benefits (e.g., water quality, habitat, cultural and recreation opportunities). Wherever possible, infrastructure and development that degrade these natural protective systems should be avoided.

Rationale

Flooding—including the inundation of inland waterways, coasts, and urban areas—ranks among the costliest and most frequent type of natural disaster in the U.S. and worldwide. The economic consequences of flooding are growing rapidly, with floods causing hundreds of billions of dollars in losses in the last decade alone [2], displacing communities, and damaging livelihoods. The rising economic and humanitarian costs of flooding are largely the result of continued development in watersheds and floodplains and other modifications to river and coastal systems, amplified by climate change [3].

Responsibility for managing flood risks across the U.S. spans every level of government (federal, state, local, tribal, territorial) and involves individuals, businesses, and other community stakeholders. Under the National Flood Insurance Program (NFIP), the federal government underwrites insurance for more than 22,000 participating communities in exchange for community adoption and enforcement of baseline land-use and construction requirements intended to mitigate losses associated with the base flood (1%-annual-chance or 100-year flood). Many NFIP participating communities have recognized the need to go beyond the NFIP minimum standards, adopting more stringent requirements. Building codes and standards (e.g., [4]) require most buildings to be elevated above the NFIP minimum. While individual federal agencies have adopted higher standards for planning and projects (e.g., [5]) or as conditions for financial assistance (e.g., [6]), the base flood currently remains the minimum federal flood standard nationwide.

Most current assessments of flood hazard assume that recent conditions are representative of the future (i.e., flooding is “stationary”), but geoscientists have repeatedly demonstrated that flood hazard is highly sensitive to climatic, geomorphic, and human-driven change and thus non-stationary [7–8]. In the United States, climate change is already altering the frequency, intensity, type, and seasonality of intense precipitation events, and is contributing to sea-level rise. Combined with increases in impervious cover, modifications to river floodways and shorelines, and development of flood-prone land, many communities are experiencing flood damages and risk greater than current assessments.

Not all flood risks are shown on flood maps. In urban areas, for example, intense rainfall combined with inadequate stormwater drainage can cause widespread damage [9]. Behind levees, there exists the “residual risk” of failure or levee overtopping even in communities with protection adequate for removal from FEMA’s regulatory floodplain. Many residents in leveed areas are unaware of their residual risk [10]. Similarly, downstream of dams, residual risk is not universally mapped or widely publicized.

River and flood science are fundamentally geological sciences. Geoscientists collect data on the characteristics and causes of flooding using field-based methods, modeling, and remote sensing. More broadly, geoscientists bring unique perspectives critical to understanding, predicting, and mitigating flood hazards, including how nature functions over long time scales and the variability and dynamics of natural systems. For example, paleoflood and paleoclimate records supplement short instrumental records, better predict extreme events, and help to parse out natural and human-caused shifts in flood hazard [11–13].

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About the Geological Society of America

The Geological Society of America (https://www.geosociety.org) is a scientific society with members from academia, government, and industry in more than 100 countries. Through its meetings, publications, and programs, GSA enhances the professional growth of its members and promotes the geosciences in the service of humankind. GSA encourages cooperative research among earth, life, planetary, and social scientists, fosters public dialogue on geoscience issues, and supports all levels of earth science education. Inquiries about GSA or this position statement should be directed to GSA’s Director for Geoscience Policy, Kasey S. White, at +1-202-669-0466 or kwhite@geosociety.org.

OPPORTUNITIES FOR GSA AND ITS MEMBERS TO HELP IMPLEMENT RECOMMENDATIONS

To facilitate implementation of the goals of this position statement, the Geological Society of America recommends that its members take the following actions:

- **Educate the next generation of flood-aware scholars and citizens**—Dealing with the challenges of flooding requires a multidisciplinary understanding of Earth systems, hydrology, climate, and engineering, with an appreciation of social sciences and policy. From large introductory classes to specialized graduate seminars, geoscience educators have a role in broadening our students' awareness of flood risk and training them in managing, mitigating, and adapting to this risk. At the broadest level, students who come from floodprone areas—or may move to at-risk areas in the future—should be aware of flood hazards and ways to address that risk. Among advanced students, flooding should be recognized as a geological hazard alongside earthquakes and slope failures, with specific skill sets and tool kits that can be applied to flood management. Key concepts, including hydrology, statistics, GIS, and modeling, should be taught in the context of flood hazards and management, and broader study of infrastructure, finance, planning, emergency management, and disaster- and preparedness-related policy should be encouraged. Geoscience students should recognize flood-risk and floodplain management as career paths.
- **Communicate flood risk and mitigation and resilience strategies with the broader public**—Geoscientists can lead in helping the public understand the spectrum of threats from flooding, now and looking into the future. The stochastic nature of flooding, with recurrence times of decades or centuries between major events, requires a long-term perspective. Geoscientists are trained to communicate this perspective to others. A sunny parcel of riverside land may be attractive for a new house or shopping mall, but the sediments underfoot may include numerous layers of overbank alluvium documenting a history of extreme floods. Similarly, historical precipitation data, gage records, and/or downscaled climate models may show long-term trends in flood magnitudes and frequencies. However slow the trends, planners would be remiss in calculating future flood risk assuming static conditions. Tools for managing flood risk in the future include avoiding flood-prone locations [14], mitigating existing exposure, and adapting to future changes. The key to implementing these strategies is a broad public understanding of the nature of the hazard and a public willing to use the best available science to guide society towards a sustainable and resilient future.
- **Translate flood data and science into actionable policy recommendations**—The Geological Society of America, its membership, and other scientific voices encourage the implementation of balanced, non-partisan, flood-risk management policies. Geoscientists are poised to be leaders in collaborative efforts with policy makers, planners, and engineers to improve flood-hazard management and mitigation. Geoscience offers unique perspectives on a broad range of topics relevant to flooding, founded on an appreciation of "deep time" and hydrologic and atmospheric processes that interact with Earth's surface in complex ways over many scales. Geoscience professionals should help bring the best available science to the challenges of flooding, communicating and translating their findings into tangible products for use by planners, engineers, and decision-makers. GSA and its members should take opportunities to reach out to local, state, tribal, and federal leaders to communicate the relevant science and offer expertise to help improve U.S. flood-risk management.

REFERENCES

1. U.S. National Oceanic and Atmospheric Administration, 2020. Billion-dollar weather and climate disasters: Overview. Available at https://www.ncdc.noaa.gov/billions/.
2. NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2020). Available at: https://www.ncdc.noaa.gov/billions/.
3. Winsemius, H.C., Aerts, J.C., Van Beek, L.P., Bierkens, M.F., Bouwman, A., Jongman, B., J. Kwadijk, W. Ligtvoet, P.L. Lucas, D.P. Van Vuuren, and Ward, P.J., 2016. Global drivers of future river flood risk: Nature Climate Change, v. 6,p. 381–385.
4. American Society of Civil Engineers, 2014. Flood Resistant Design and Construction. ASCE/SEI 24-14. Available at https://ascelibrary.org/doi/book/10.1061/asce24.
5. Public Law 115-232, John S. McCain National Defense Authorization Act for Fiscal Year 2019. Available at https://www.govinfo.gov/app/details/PLAW-115publ232.

6. U.S. Dept. of Housing and Urban Development, 2019. Allocations, common applications, waivers, and alternative requirements for Community Development Block Grant mitigation grantees, RIN: FR-6109-N-02. Available at https://www.hudexchange.info/news/hud-publishes-cdbg-mitigation-notice/.

7. Milly, P.C., Betancourt, J., Falkenmark, M., Hirsch, R.M., Kundzewicz, Z.W., Lettenmaier, D. P., and Stouffer, R.J., 2008. Stationarity is dead: Whither water management?: Science, v. 319, p. 573–574.

8. Salas, J.D., and Obeysekera, J., 2014. Revisiting the concepts of return period and risk for nonstationary hydrologic extreme events: Journal of Hydrologic Engineering, v. 19, p. 554–568. Available at https://doi.org/10.1061/(ASCE)HE.1943-5584.0000820.

9. University of Maryland and Texas A&M University, 2018. The Growing Threat of Urban Flooding: A National Challenge. Available at https://cdr.umd.edu/urban-flooding-report.

10. National Research Council, 2013. Levees and the National Flood Insurance Program: Improving Policies and Practices: The National Academies Press, Washington, D.C. Available at https://www.nap.edu/catalog/18309/levees-and-the-national-flood-insurance-program-improving-policies-and.

11. Munoz, S.E., Giosan, L., Therrell, M.D., Remo, J.W., Shen, Z., Sullivan, R.M., ... & Donnelly, J.P., 2018. Climatic control of Mississippi River flood hazard amplified by river engineering: Nature, v. 556, p. 95–98;

12. Wilhelm, B., Ballesteros Cánovas, J.A., Macdonald, N., Toonen, W.H., Baker, V., Barriendos, M., ... and Glaser, R., 2019. Interpreting historical, botanical, and geological evidence to aid preparations for future floods: Wiley Interdisciplinary Reviews: Water, v. 6, e1318.

13. Kochel, R.C., and Baker, V.R., 1982. Paleoflood hydrology: Science, v. 215: 353-361.

14. Geological Society of America, 2019 (Latest update). GSA Position Statement: Integrating geoscience with sustainable land-use management. Available at: https://www.geosociety.org/GSA/Science_Policy/Position_Statements/Current_Statements/GSA/Positions/home.aspx.