November 10, 2021

Mr. Michael Connor
Assistant Secretary of the Army, Civil Works
U.S. Army Corps of Engineers
441 G Street NW
Washington, DC 20314-1000

Re: Call to Action on America's Flood Risk

Dear Mr. Connor,

Our groups are writing this letter as we believe there exist immense opportunities for the U.S. Army Corps of Engineers (USACE) to improve and evolve its approaches for addressing current and future flood risks facing residents, businesses and ecosystems in our country from a rapidly-changing climate. More people are at risk from flooding than ever before, and that risk is growing rapidly as climate change fuels more intense hurricanes and rainfall, and as sea level rise threatens coastal communities across the country. The recent IPCC AR6 Climate Change 2021 report clearly articulated how many of these flood impacts are "locked in" for the coming decades, demonstrating the urgency in moving beyond the status quo and ensuring holistic approaches to flood risk management.

In this letter and in the attached addendum, we outline specific actions that the USACE can take, under existing Congressional authorizations and policy guidance, to better address increasing and compounding flood threats impacting communities today and in the future.

We believe the USACE should advance the following principles to more adequately and equitably address our nation's flood risk over the long term:

1. **Advance holistic approaches to address comprehensive flood risks:** The USACE's current approach for coastal storm risk management studies that focuses solely on hurricane storm surge is short-sighted and leaves millions of Americans exposed to current and future chronic flood risk from sea level rise (tidal or nuisance) and extreme precipitation along riverine floodplains. There is a clear and urgent need for the USACE to expand its studies to provide solutions that tackle the complex issue of independent and compounding flood threats today and in the future. By integrating multiple flood threats, the USACE can better align with the needs of local sponsors as a collaborative partner, as well as ensure the agency is proactively addressing current and future risks. A holistic approach to flood resilience should integrate the social, economic and environmental systems that must all function and adapt together for improved outcomes. By holistically managing flood risks, the USACE will better serve its constituents, better invest resources and become a global leader in addressing flood threats through innovation.

2. **Prioritize natural solutions to address risks over time and deliver other benefits:** The USACE can pair natural and nature-based features (NNBF) with non-structural measures to account for the complexities of coastal and riverine systems and the shifting equilibriums associated with sea level rise and more intense rainfall. Natural infrastructure is not limited to ecosystem restoration, such as barrier island and marsh restoration, oyster reefs, mangroves and coastal forests, but can also include conservation practices such as open space preservation and natural landscaping. The USACE's "Engineering with Nature" initiative states that utilizing, "a strategy that combines NNBF with nonstructural….measures represents an integrated approach to flood risk management that can deliver a broad array of ecosystem goods and services to local communities." Not only can these natural solutions be implemented more quickly and often at lower costs than traditional grey infrastructure, they can also adapt to changing conditions over time and deliver a number of environmental, economic and societal benefits to help ecosystems and communities thrive in a changing climate.

3. **Incorporate the social and economic impacts and break systematic inequality:** The USACE must recognize that our nation has a flood risk gap that puts low wealth communities and communities of color at greater risk of flooding. These communities experience greater hardship in recovering after flood disasters, resulting in compounding personal and societal impacts to health, livelihoods and the environment. Going forward, the USACE must include these social and economic costs to show the full impact of these studies and proposed solutions, as well as clearly articulating the residual economic and social risks. These estimates should include the compounding and interdependent economic impacts to economic drivers of the region. In addition, the USACE should improve or modify its cost-benefit analysis and decision-making processes to address equity and environmental justice. In doing so, the USACE should also account for the multiple benefits of natural infrastructure, as well as the true costs of flood threats and disasters to a community. The USACE can address our nation's disproportionate flood risk gap and start to fix the systemic inequalities and systematic racism of the past by considering the cumulative impacts of flood disasters to communities and improve the cost-benefit methodologies to make better, more equitable investment decisions.

The economic, environmental and social costs of ignoring the multiple flood threats impacting our coastal and riverine communities is astronomical. We need to act now to take more holistic, equitable and long-term approaches to meet the very real and severe threats of a changing climate. All levels of government have a role in building flood resilience. Multiple directives from the Biden Administration focus on the whole of government approach to tackling the challenges of climate change and environmental justice. The USACE plays a key role in developing and prioritizing federal investments to address flooding for the betterment of the nation. The USACE has the technical expertise, the modeling and tools, and the capability to truly embrace a leadership role in building comprehensive, nationwide flood resilience.

Mr. Assistant Secretary, we believe it is in your power to lead the USACE into the future, as well as your duty to the residents of this nation. We hope the USACE will recognize this urgent need and step up to

fulfill that duty to build a more flood resilient nation today and for future generations.

If we can provide any further guidance, we would be happy to schedule a briefing to discuss our recommendations. In the attached addendum, we also provide additional details on the recommendations highlighted above with specific examples and references from across the country.

We look forward to hearing your response as we work toward our shared goal of protecting residents, businesses and natural resources from increased flood risk across our nation.

For further information, please contact Natalie Snider, Associate Vice President of Climate Resilience Coasts and Watersheds at Environmental Defense Fund at nsnider@edf.org.

Sincerely,

Anthropocene Alliance
Apalachee Regional Planning Council
Atchafalaya Basinkeeper
Berks Gas Truth
Bronx River Alliance
Catalyst Miami
Center for Biological Diversity
Chesapeake Bay Foundation
Chesapeake Climate Action Network
Clean Water Action
Coalition to Restore Coastal Louisiana
Coastal States Organization
College of Engineering, University of California Berkeley
Coney Island Beautification Project, Inc.
Conservation Trust for North Carolina
Environmental Defense Fund
Everglades Law Center, Inc.
Flood Mitigation Industry Association
FreshWater Accountability Project
Friends of Dyke Marsh
Greenbelt Alliance
Greenleaf Communities NFP
Groundwork Jacksonville, Inc.
Healthy Gulf
Hudson Riverkeeper
James River Association
Keep Virginia Beautiful
Kissimmee Waterkeeper
+LAB Architect PLLC
LEAD Agency, Inc.
Levees.org
Lower Raritan Watershed Partnership
Lynnhaven River NOW
Miami Waterkeeper
National Aquarium
National Audubon Society
National Marine Manufacturers Association
National Parks Conservation Association
National Wildlife Federation
NC Conservation Network
Neighborhood Housing Services of Brooklyn CDC, Inc.
New Jersey State Conference NAACP
New Jersey Voluntary Organizations Active in Disaster
New York League of Conservation Voters
Newtown Creek Alliance
North Brooklyn Neighbors
North Carolina Coastal Federation
North Sound Baykeeper
Orleans Audubon Society
Potomac Conservancy
Public Citizen
Puget Soundkeeper
Rachel Carson Council
Raritan Riverkeeper
Regional Plan Association
Regional Ready Rockaway
Resilience 21
RETI Center
RISE (Rockaway Initiative for Sustainability & Equity)
River Network
Rock Creek Conservancy
Rockbridge Area Conservation Council

Sanibel Captiva Conservation Foundation
Save the Bay, San Francisco
Save the Sound
SCAPE
SouthWings
St. Johns Riverkeeper
The CLEO Institute
The Living City Project
The New York State Floodplain and Stormwater Managers Association
Theodore Roosevelt Conservation Partnership
Three Rivers Waterkeeper
Virginia Conservation Network
Virginia Grassroots Coalition
Virginia Interfaith Power & Light
Virginia League of Conservation Voters
VOLKsHouse LLC
Washington Water Trust
WASHTENAW350
Waterfront Alliance
Waterkeepers Chesapeake
Wetlands Watch

Academics and policy experts signing in an individual capacity:

Lance Jay Brown (Consortium for Sustainable Urbanization)*
Bibi Calderaro (The Graduate Center CUNY/Newtown Creek Alliance)*
Alejandro E. Camacho (University of California, Irvine)*
Heather Fenyk (Rutgers University of New Jersey)*
Paul Gallay (Columbia University)*
Greg Guannel (University of the Virgin Islands)*
Jacqueline M. Klopp (The Climate School, Columbia University)*
Alexander S. Kolker (Louisiana Universities Marine Consortium)*
Ehab Meselhe (Tulane University)*
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**Institutions and affiliations included for identification purposes only.*

cc: Mr. Jamie Pinkham, Principal Deputy, Assistant Secretary of the Army for Civil Works
Mr. Al Lee, Director of Civil Works, USACE
Ms. Brenda Mallory, Chair, Council on Environmental Quality
Dr. Rick Spinrad, Administrator, National Oceanic and Atmospheric Administration
Mr. David Hayes, Special Assistant to the President for Climate Policy

Addendum:

Advance holistic approaches to address comprehensive flood risks

The problem: Current USACE studies do not include a holistic approach to flood risk. The USACE's current approach for coastal storm risk management studies that focuses solely on hurricane storm surge is short-sighted and leaves millions of Americans exposed to current and future chronic flood risk from sea level rise (tidal or nuisance) and extreme precipitation along riverine floodplains. There is a clear and urgent need for the USACE to expand its studies to provide solutions that tackle the complex issue of independent and compounding flood threats today and in the future.

Current USACE coastal storm risk management studies do not adequately address comprehensive flood risks. The USACE has completed or is in the process of completing studies in San Francisco, New York-New Jersey, Miami-Dade, Coastal Texas, and Norfolk. Several new studies, such as Virginia Beach and North Carolina, were recently authorized in the Water Resources Development Act (WRDA) of 2020. These and other regions contemplating coastal storm risk management studies are equally if not more vulnerable to sea level rise as they are to storm surge. However, the USACE continues to solely focus on flood and storm damage reduction related to natural hazards based on authorizing language from 1955 (Public Law [P.L.] 84-71) where the term "coastal storm" is defined exclusively as tropical events and nor'easters. Many of these studies, such as the studies stemming from the North Atlantic Coast Comprehensive Study, reference authorizing language from June 15, 1955 (Public Law [P.L.] 84-71) that authorizes an "examination and survey of the coastal and tidal areas of the eastern and southern United States, with particular reference to areas where severe damages have occurred from hurricane winds and tides." Funded through the Disaster Relief Appropriations Act of 2013 (Public Law [P.L.] 113-2), these studies continue to focus on flood and storm damage reduction related to episodic events. Utilizing a study authorization that is over 65 years old demonstrates how antiquated this approach is to flood risk today and in the future.

The recently completed Norfolk Coastal Storm Risk Management Study defined its tasks as addressing flood risk from coastal storms like nor'easters, tropical storms and hurricanes, as well as climate change and rising sea levels. However, this framing is misleading to the public as the Norfolk study, similar to all the other USACE studies, did not analyze impacts and develop effective solutions to sea level rise, but only examined how a combination of sea level rise and climate change will exacerbate coastal storm extreme events over the study period.

These studies are immensely important and urgent to identify and prioritize federal investments in large-scale solutions to address flood risk and build resilience, but taking a narrow approach to the multiple flood risks that face coastal regions is not an effective or efficient way to plan for our future, given the high costs of these studies. Rainfall events and relative sea level rise are viewed as residual risks, but the economic, social and environmental costs of these residual risks are far too great to ignore in these studies. By excluding sea level rise and precipitation changes due to climate change, these studies fail to analyze impacts and develop effective, holistic solutions that address the compounding flood risks facing coastal and riverine communities.

The solution: Provide agency guidance to all coastal risk management studies to fully incorporate the impacts and solutions to independent and compounding flooding. The study objectives and subsequent analysis of all USACE studies should be expanded to include sea level rise (king tides and nuisance flooding) and extreme precipitation events along coastal and riverine floodplains. Norfolk is one of the many highly vulnerable coastal regions from sea level, and the region is already experiencing significant impacts from this threat. While federal studies are ignoring these multiple flood threats, local planning efforts, such as Virginia Beach's Sea Level Wise comprehensive adaptation program, have integrated a combination of high tides/sea level rise, wind-driven, storm surge, rainfall and groundwater flooding. Other local sponsors have started to push back on this one-risk approach and solutions proposed by the USACE. We must take a holistic approach to planning and implementing coastal flood resilience projects now.

By integrating multiple flood threats, the USACE can better align with the needs of local sponsors as a collaborative partner, as well as ensure the agency is proactively addressing current and future risks. A holistic approach to flood resilience should integrate the social, economic and environmental systems that must all function and adapt together for improved outcomes. By holistically managing flood risks, the USACE will better serve its constituents, better invest resources and become a global leader in addressing flood threats through innovation.

We understand that the complexity of addressing multiple individual and compounding threats may not fit in the 3x3x3 and that waivers would be needed in most cases. However, we support the use of waivers to build comprehensive flood resilience plans as opposed to spending millions of dollars studying only part of the problem and leaving coastal communities exposed to flooding.

Prioritize natural solutions to address risks over time and deliver other benefits:

The problem: Grey infrastructure does not adequately address comprehensive flood risk. By only focusing on episodic, extreme events, the USACE has created an over-reliance on gates, levees and barrier systems that will only alleviate storm surge caused by hurricane and tropical storm events. These approaches will not effectively mitigate flood risk from sea level rise and extreme precipitation. Even more, there are clear examples around that country that solutions developed to solely address storm surge can actually exacerbate flood risk from sea level rise and along rivers daily and during a storm event.

During fair weather conditions, the gates are theoretically open and have no impact on rising seas and high tides that affect shoreline communities. During an extreme event, hard structures (levee, gates, locks, etc.) may reduce the surge coming in from the ocean, but they also have the potential to impede the draining of water from the interior during and after the event. Additionally, wind-driven surge can still impact areas within the barrier.

For example, the Coastal Texas Study failed to acknowledge that extreme precipitation events, either associated or not with a tropical event, also represent a great risk for the Galveston-Houston region, as witnessed during Hurricane Harvey. In fact, the study stated that the expensive project (estimated $26 billion) could potentially pay for itself with one storm using Harvey as an example. However, the majority of damages from Hurricane Harvey was due to rainfall and not storm surge. This overstatement of benefits

from this project is a detriment to the people of the region and can lead to a false sense of security. Other solutions, such as the Galveston Ring Levee, can reduce the flood risk from sea level rise, but could increase risk from heavy precipitation events. Storm surge barriers could increase the risk from both. Without a holistic approach, solutions that are proposed could increase flood risk worse over time.

Grey infrastructure also can induce flooding on communities outside of the barrier system, which includes a likely greater impact from sea level rise. Sea level rise is not linear and can vary depending on geography and structures. In the New York and New Jersey Harbor and Tributaries Study (NYNJHATS), barrier systems will induce flooding from storm surge on neighboring communities, such as Coney Island, but could also make the impacts from sea level rise worse. Without including the full impact of grey infrastructure in the analysis, communities and ecosystems are left vulnerable.

In addition, these studies do not analyze how sea level rise and frequent tidal flooding will increase water levels inside of the barrier systems that could result in the gates being closed more often than originally designed. A study of the NYNJHATS barrier system found that sea level rise causes an exponential increase of the gate closure frequency, a lengthening of the closure duration, and a rising probability of trapped river water flooding[1]. If the triggers are adjusted to close the gates more frequently and for longer periods to reduce this increased flood potential, it will cause economic impacts to ports and navigation. These studies should account for the growing and long-term environmental, social and economic impacts of any barrier system.

The over-reliance on grey infrastructure further highlights the need for the USACE to develop a holistic approach to manage flood risk over time. Grey infrastructure is very expensive and will take decades to complete engineering and design, secure funding and construct. Across America, USACE studies are recommending hundreds of billions of dollars in gates, structures and barrier systems, many of which will never receive the level of funding needed for construction, leaving millions of people and billions in economic assets at risk from a changing climate.

The New York-New Jersey Harbor and Tributaries Study (NYNJHATS) estimates project costs at $119 billion and will take 25 years to construct once funded. The Texas Coastal Study has a final price tag of $26.2 billion and will take 15 years to construct once funded. Funding is limited and highly competitive, which will result in a delay of years or decades to secure federal funding for large barrier systems. The Morganza to the Gulf levee system in Louisiana was first authorized for construction in 2000, and after 20 years, finally received its first $12 million in federal funding for a $3 billion project. By the time those funds are secured and the project is constructed, it will be too late for many communities.

Given the extremely long implementation time periods, these studies fail to acknowledge or evaluate how flood risk increases over time. For instance, in many of these studies, the proposed non-structural projects are limited and depend on the barrier system being in place; however, these analyses do not take into account the additional non-structural projects that may be needed to address long-term sea level rise or provide near-term flood mitigation before a barrier can be funded and constructed. For instance, if the barriers in New York and New Jersey will take 25 years to construct if fully funded today, what happens to exposed communities over the next 25 years and what are the costs of damages they will experience while

waiting for expensive grey infrastructure?

The solutions proposed and selected may differ if the study objectives were expanded to address the multiple flood threats experienced by the study communities and take a long-term planning approach to how flood risk will change over time.

The problem: Cascading impacts to the environment from grey infrastructure

A history of "flood control" projects, focused on grey infrastructure, should demonstrate that we cannot rely solely on hardened infrastructure to manage climate-induced flood risk. Grey infrastructure, while necessary in some cases, can also severely impact the environment. Impacts can include altering tidal flow, flushing and circulation, degrading water quality, restricting species movements and impacting ecology, habitat degradation and altering sediment movement and increased erosion.

All of these impacts affect the ecosystem's ability to provide essential services to society and come with real costs that are not included in the analyses. Some of these lost costs are permanent, while others have high replacement costs that are borne by the communities, such as replacing water filtration services.

Grey infrastructure is likely to lead to a loss of a wide variety of coastal habitats, from coastal forests to different marsh habitats to barrier islands and oyster reefs. If communities continue to rely on hardened shorelines and levees instead of wetlands and natural landscapes for protection, these losses will only continue. Hundreds of species - including many threatened and endangered species, species of concern and pollinators - rely on these coastal habitats, and the primary production of these systems fuels the food web. In addition, coastal wetlands are essential during some part of the lifecycle of most species of fish that are harvested for commercial or sustenance use. These coastal habitat losses will lead to a loss of species and species diversity.

Wetlands and oyster reefs are natural filters for nutrients and stormwater. There is not a coastal system today that does not have issues with nutrient loading or total maximum daily loads (TMDLs) that lead to degraded water quality. Poor water quality can lead to hypoxia and fish kills, harmful algal blooms and public health risks. A storm surge barrier in the Vasse-Wonnerup estuary in Australia suffers regular mass fish kills, even after fish gates were installed, due to poor water quality[2].

Existing storm surge barriers have been shown to establish a new hydrologic forcing regime that throws the system out of equilibrium. After 25 years, the Eastern Scheldt storm surge barrier in the Netherlands is still far from equilibrium and has decreased tidal amplitudes, tidal volumes and flow velocities and prevented any sediment transport through the barrier, leading to increased erosion[3]. This reduction in tidal flow will also restrict and disrupt species movements and migrations, further impacting recreational and commercial fish species, endangered species and marine mammals. In addition, as gate closure frequency and length are expected to increase exponentially over time with sea level rise, this will lead to an increase in impacts to the tidal regime and species.

The solution: Increase reliance on natural infrastructure solutions

Limiting these adverse impacts, as well as sustaining and restoring as much of the coastal landscape as possible, should be an objective of these studies. Natural solutions provide risk reduction and ecosystem benefits that improve the environment while simultaneously supporting social and economic systems.

Natural and nature-based features can not only provide multiple ecological and social benefits, including flood risk reduction, but can also address multiple flood risks, thereby increasing the effectiveness of investments into resilience. Rella and Miller (2014) found that, particularly in regions with rapid sea level rise, sites with ecologically enhanced features had lower long-term costs than those with hard armoring[4]. Boston's "Green Ribbon Commission" recently recommended that surge gates would not be an effective approach for that city, and that "shore-based solutions would provide flood management more quickly at a lower cost, offer several key advantages over a harbor-wide barrier, and provide more flexibility in adapting and responding to changing conditions, technological innovations, and new information about global sea level rise[5]."

Coastal wetlands in the U.S. were estimated to provide $23.2 billion per year in storm protection services alone based on a regression model of 34 major hurricanes to hit the U.S. since 1980; a loss of 1 hectare of wetland in the model corresponded with increased average storm damages of $33,000 from specific storms[6]. Mangroves averted $1.5 billion in damages during Hurricane Irma, including in developed areas with only thin strands of mangrove remaining, and protected 626,000 people[7] and can be two to five times less expensive than certain structural measures[8].

WRDA 2020 emphasized and prioritized the importance of natural- and nature-based solutions to build community and ecological resilience against natural hazards. Natural and nature-based solutions should be a key principle guiding the development of these studies and can provide flood risk reduction benefits in addition to ecosystem services like critical wildlife habitat, recreational and commercial opportunities and improved water quality. These ecosystem service benefits are not accounted for in the assessment of costs and benefits in USACE studies, however, these features can provide:

- **Species and Habitat Diversity**: Nature-based solutions can enhance fish foraging habitat, provide critical nursery, spawning or transition habitat for species, and serve as critical corridors for migratory species[9,10]. A diverse collection of finfish, shrimp, crabs, lobster and other shellfish rely on natural and nature-based features such as conserved and restored saltmarsh, mangroves, seagrass and oyster reef for essential habitat[11, 12, 13]. For example, the incorporation of oyster reefs to provide coastal protection has also been found to increase diversity of many important fish species and promote other habitat types such as seagrasses to thrive[6]. Natural infrastructure serves to enhance habitat value while providing a number of co-benefits including supporting natural coastal processes and providing added storm protection. Research has shown that hardened shorelines support 23% less biodiversity and 45% fewer organisms than more natural shorelines[14]. Understanding how diversity is impacted by hardened infrastructure is critical to effectively evaluating impacts to other ecosystem services like fisheries production. Natural infrastructure mimics the complexity of natural systems unlike seawalls which likely explains why biodiversity is greater in a system closely representing its natural form[15].

- **Improved Water Quality**: Water quality is one of the most important factors in a healthy ecosystem. It can support habitat diversity and species like mangroves that stabilize shorelines and in return filter water to maintain improved water quality and clarity[16]. In addition, suspension feeders used as NNBF like oyster reefs remove particulates out of the water column providing water quality benefits for the system. Research suggests an increase in wetland restoration across the US can lead to nitrogen and nutrient removal in coastal wetlands improving water quality in addition to other ecosystem services[17].
- **Carbon Sequestration**: Natural infrastructure dealing with vegetation or other organic materials have the ability to remove carbon from the atmosphere. Seagrasses and mangroves in an ecosystem can store carbon in soils depending on the density of vegetation and how long the system has been intact[18,19,, 20]. Wetlands are natural carbon sinks, but also have a positive feedback loop in that the loss of wetlands releases greenhouse gas (GHG) emissions. Reducing erosion and restoring and sustaining coastal forests and marshes can sequester carbon, thereby improving a wide range of environmental benefits which comes from maintaining a healthier carbon cycle.
- **Recreation and Tourism:** As billion-dollar industries in many coastal states of the US, recreation and tourism are greatly enhanced by the presence of natural and nature-based features. Because NNBF increases the quality of habitats available and therefore the diversity of species, people travel from all over the world to experience the recreational opportunities provided by the enhanced ecosystem. In return, these thriving systems have proven to benefit human health and wellbeing. Cracknell et al. 2015 found that watching and experiencing marine life reduced heart rate and blood pressure in viewers. By providing opportunities for recreation and tourism, NNBF protects not only the systems themselves, but also the communities that rely on them[21].
- **Prevent Saltwater Intrusion**: Saltwater intrusion, specifically into the groundwater, can affect inland habitats, agriculture and drinking water supplies. In addition, the rise in sea level in the groundwater can impact septic tanks, leading to additional pollution and water quality degradation. Exacerbated by sea level rise, the protection of these groundwater resources will reduce the loss of inland freshwater habitats and maintain healthy agriculture fields, while sustaining an important water resource for communities.
- **Restoring Natural Processes:** Most of the restoration projects we are working to implement are targeted at fixing problems that we have caused in the past, such as changes in hydrodynamics. By restoring and relying on natural processes, such as restoring tidal creeks and marshes, environmental outcomes will be more sustainable in the long-term in the face of climate change and provide essential ecosystem benefits into the future.

Incorporate the economic and social costs and break systematic inequality

The problem: The economic and social impacts of sea level rise

There is no question that the impacts of climate change on sea level rise, storm intensity and heavy precipitation will make episodic, extreme events more disastrous. However, sea level rise is causing chronic nuisance (or “blue sky”) tidal flooding now on an annual basis in many regions of the country and this is only going to worsen over time. A NOAA study found nuisance flooding has increased in coastal cities, such as San Francisco, Washington, DC, and Annapolis by 300% to nearly 1000% between 1963 and 2013[22]. Florida is facing an increase in tidal flooding from just a few days a year to 30 to 60 days in less

than a decade[23]. Similarly, Boston is facing between 43 to 87 flood events by 2030, which are predicted to increase to 213 to 743 events by 2050[24]. By 2035, nearly 170 coastal communities in the United States are projected to experience flooding more than 26 times per year[25].

Sea level rise is an existential threat to coastal communities, economies, livelihoods and ecosystems. Recent research has shown that the economic cumulative costs of nuisance flooding could exceed the costs of episodic, extreme events[26]. By 2050, more than $106 billion in existing coastal property will be below sea level[27]. Collectively, these flood threats will result in major economic impacts. Globally, the costs of rising seas could reach $14.2 trillion in lost or damaged assets by 2100, with 68% of costs attributed to tidal and storm flooding and 32% of those costs attributed to sea level rise[28]. In California, annual storms are predicted to cost $119 billion and affect 483,000 people, increasing to $150 billion and 600,000 people for 1% chance storm by 2100[29]. In smaller communities, like Virginia Beach, this loss could cost the city $50 million to $250 million annually depending on the sea level rise rates[30].

These estimates often do not include the compounding and interdependent economic impacts to economic drivers (ports, tourism, fisheries), ecosystem services, real estate values, wastewater treatment and subsequent water quality and public health impacts from increased leakages, saltwater intrusion impacts on groundwater supplies for drinking water and agriculture, replacement/relocation costs for all community infrastructure (housing including affordable housing, roads, utilities, critical and public infrastructure), loss of property taxes and jobs, and mental and physical health impacts to coastal residents.

Examples of these types of economic and public health impacts are clear from around the nation:

- On the East Coast, nuisance flooding will impact transportation networks increasing vehicle hours by 126% from 2010 to 2060. Some roadways in Connecticut, New Jersey, Maryland, District of Columbia, North Carolina and Florida will experience almost daily flooding under an intermediate sea level rise scenario[31].
- Property values have decreased by nearly $16 billion from 2005 to 2017 across 17 states, with the worst losses coming in Florida ($5.4 billion), New Jersey ($4.5 billion) and New York ($1.3 billion)[32].
- Local economic activity, such as tourism, is increasingly impacted by tidal flooding. In Annapolis, there has already been a decline in local economic activity that could reach up to 24% with a foot of sea level rise[33].
- Recurrent flooding increases the occurrence of mold leading to asthma and other public health issues. An increase in asthma-related hospital visits and fatalities, especially with children, has been documented in North Carolina since 2010[34]. These impacts are disproportionate to low-income and minority communities that are more likely to experience recurrent flooding and do not have the resources to properly clean up after a flood event.
- The mental health impacts of Hurricane Katrina far exceeded any other natural disaster in U.S. history[35,36]. However, there are growing studies focused on the impact of recurrent flooding. After the 2016 floods in Louisiana, hospital visits for mental health increased 14% over the previous year, specifically for adolescents[37]. A study in Prehospital and Disaster Medicine found a large negative impact of recurrent flood on mental health outcomes and psychological and physical function, likely related to an erosion of the social, environmental and material context[38]. In

addition, there is an increase in substance abuse use and hospitalizations following flood events, specifically with low-income and minority individuals[39]. All of these mental health issues induce costs on the health care system.

- Tampa Bay found that sea level rise could result in submerging over $15 billion in residential and commercial properties by 2060 resulting in the loss of over 17,000 jobs and $5.4 billion in tax revenue[40].

The problem: An approach to flood risk management that perpetuates systemic inequities The costs of ignoring sea level rise and low-frequency precipitation flood events are not just monetary, but will perpetuate the systematic inequalities in the way the nation manages flood risk. However, flood risk is not equally distributed. In this country, we have a flood risk gap that places low wealth communities and communities of color, particularly Black communities, at higher risk from flooding than wealthier, predominantly white communities. A recent study by Redfin found that it is more likely for flooding to impact areas designated undesirable for mortgage lending under the racist 1930s-era practice known as redlining. These historically redlined communities consist of 58.1% non-white residents[41]. In Sacramento, for instance, 21.6% of homes in redlined and yellow-lined areas face high risk of flooding today compared to 11.8% of other homes ($716.8 million worth) in green-lined and blue-lined neighborhoods[41].

Systemic inequities compound underlying risks and drive disproportionate impacts from climate change to these communities. This gap is visible in many coastal areas, where communities of extreme wealth and poverty exist within a few square miles, yet have unequal protections against flooding and unequal access to recovery funding. In Hurricane Katrina, of the seven zip codes with the costliest flood damage, four zip codes had at least 75% Black residents[42]. After Hurricane Harvey, Black and Latino Hispanic Americans were about twice as likely as white Americans to say that they had fallen behind on their mortgage payments in the wake of the storm[43]. These inequities are making it harder for low-income individuals and people of color, particularly Black Americans, to recover after a disaster. People with greater access to wealth and resources can more quickly bounce back or have the means to relocate out of harm's way, leaving those without resources at risk of experiencing repeat disasters. In fact, a 2018 study found that Black residents tend to lose wealth after natural disasters, while white residents tend to gain wealth, in part because federal disaster money favors wealthier Americans[44]. A recent study of FEMA expenditures, which uses a similar cost-benefit approach to USACE, found 85% of funding for buyouts went to white and non-Hispanic neighborhoods[45].

In addressing flood risk, federal and state agencies have turned to benefit-cost analyses to make decisions about where to invest resources, but the methodologies behind them actually increase inequities. The USACE bases their cost-benefit analysis on the value of avoided property losses, leading to the selection of projects that protect wealthier communities over low-income communities. Low-income communities are therefore exposed to higher flood risk and are more likely to lose their wealth and livelihoods following a flood event. Relying solely on this kind of cost-benefit analysis to make important decisions about investments in flood risk reduction perpetuates income, wealth and racial inequality. Low-income communities are therefore exposed to higher flood risk and are more likely to lose their wealth and livelihoods following a flood event. This emphasis on property values also fails to take into consideration the environmental, recreational and other community health and wellbeing benefits that may come along

with nature-based flood risk reduction projects.

In the Miami Dade Back Bay Study, the USACE states one of the desired future outcomes is to reduce coastal storm-related economic damage and improve economic resilience, particularly to low-income communities and vulnerable populations. However, high income areas like Golden Beach, where the average home value is in excess of $4 million, are identified for assistance with non-structural investment for over 184 residential properties.

The solution: Expand and modify the BCA methodology to capture full costs and benefits and eliminate inequities. The USACE must recognize that our nation has a flood risk gap that puts low-wealth communities and communities of color at greater risk of flooding. These communities experience greater hardship in recovering after flood disasters, resulting in compounding personal and societal impacts to health, livelihoods and the environment. Going forward, the USACE must include these social and economic costs to show the full impact of these studies and proposed solutions, as well as clearly articulate the residual economic and social risks. These estimates should include the compounding and interdependent economic impacts to economic drivers of the region.

In addition, the USACE should improve or modify its cost-benefit analysis and decision-making processes to address equity and environmental justice. Federal agencies should not be bound by strict benefit-cost tests, and that a good analysis also identifies important distributional consequences[46]. BCAs should not rely on property values alone to determine benefits. Simply aggregating discounted benefits in the form of property values across many subpopulations implicitly prioritizes those with higher incomes and wealth. Multiple approaches are being explored to improve the benefit-cost analysis (BCA) that should be explored and integrated, including:

- Calculate benefits using a weight for underserved communities to correct for property value bias or calculate separate benefit-cost ratios (BCRs) for underserved subpopulations in flood hazard areas and comparing benefits across alternatives prior to project selection.
- Waive a BCR requirement for underserved communities to avoid the bias from using property values and allow underserved communities in flood hazard zones to apply for and receive federal flood protection.
- Require consideration of natural infrastructure alternatives in BCA47 and revisit the 7% discount rate for natural infrastructure solutions[48]. The water planning discount rate is currently 2.5%, and there is theoretical justification in economics that to set a lower discount rate the longer the lifespan of a project[49,50].
- Provide scientifically sound, pre-calculated benefits for ecosystem services to include in BCA for BRIC and USACE flood control projects.
- Equity-weight a BCA using previously existing or recent advancements in economics (e.g. weights based on marginal utility of income or inverse optimum weights)[51,52].
- Rank flood exposure distributions generated by different portfolios of projects prior to inclusion in WRDA, or selection by FEMA in the BRIC context[53]. This approach, or one similar, would allow for policymakers to choose a portfolio utilizing both efficiency and equity criteria.

In modifying the methodology or use of the BCA, the USACE should be able to account for equity, the multiple benefits of natural infrastructure, as well as the true costs of flood threats and disasters to a community. The USACE can address our nation's disproportionate flood risk gap and start to fix the systemic inequalities and systematic racism of the past by considering the cumulative impacts of flood disasters to communities and improve the cost-benefit methodologies to make better, more equitable investment decisions.

The economic, environmental and social costs of ignoring the multiple flood threats impacting our coastal and riverine communities is astronomical. We need to act now to take more holistic, equitable and long-term approaches to meet the very real and severe threats of a changing climate.

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