Coastal Flood Resilience Project

WHITE PAPER

Proposal for National Plans to Prepare Critical Infrastructure on the American Coast for More Severe Storms and Rising Seas

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The ***Coastal Flood Resilience Project*** is a coalition of organizations working for stronger programs to prepare for coastal storm flooding and rising sea level in the United States. This *White Paper* proposes that the federal government lead the development of national plans to prepare critical, major infrastructure along the American coast for more severe storms and rising seas.

I. Introduction

A changing climate is driving more severe storms and rising sea levels along the American coast. Storm surge flooding, and the permanent inundation that will come with rising seas, poses a significant risk to critical infrastructure, including major transportation, energy, and water treatment facilities. **Building the long-term resilience of these critical, major infrastructure assets to risks posed by storm surges and rising seas is essential to sustaining the services that support the normal operation of society.**

Today, there are no national plans to prepare critical coastal infrastructure for the impacts of storm surge flooding and rising sea levels. Information about the vulnerability of critical assets is incomplete, and vulnerability assessment methods are not standardized from one infrastructure sector to another. New national assessments pointing to more severe storms and accelerating sea level rise have not been used to comprehensively identify risks to existing major infrastructure assets or to set priorities for response actions to assure their sustainable operation.

> "…coastal infrastructure, such as roads, bridges, tunnels, and pipelines, provides important lifelines between coastal and inland communities, meaning that damage to this infrastructure results in cascading costs and national impacts."
>
> *Fourth National Climate Assessment;* Chapter 8, Coastal Effects; 2018

In addition, because there is no national consensus about the geographic areas of the coast at risk of storm surge flooding and rising seas, governments and private parties continue to site major new infrastructure projects in places that may expose these investments and the communities that rely on them to flood risk. The new Federal Flood Risk Management Standard will help to steer some, but not all, new federal investments away from risky areas, and new non-federal and private infrastructure projects are still being sited in risky coastal areas.

Another key concern is that there are no commonly recognized procedures for addressing the social justice implications of critical major infrastructure management decisions. Decisions about managing coastal infrastructure assets and siting new facilities have important implications for communities. Past decisions have often imposed disproportionate burdens on disadvantaged communities. Assuring that social justice is a guiding element of adapting critical infrastructure to more severe storms and rising seas will require cross-sector coordination on tools and decision frameworks and a shared commitment to avoid the mistakes of the past.

Finally, there is no effort underway by the federal government to address cascading infrastructure failures, where coastal storms or sea level rise contribute to the failure of one system which then causes other systems to fail (e.g., to ensure that electric power will be available to airports during a major storm). And there is no mechanism in place to coordinate response measures, including relocation of large-footprint infrastructure assets, with plans for protecting coastal communities and coastal ecosystems (e.g., avoiding relocating an interstate highway at a site that might be better used for relocation of a coastal community).

This *White Paper* proposes that federal agencies lead the development of sector-specific national plans to build the long-term resilience of critical, major coastal infrastructure assets to more severe coastal storm surge flooding and rising sea level. This new effort should be initiated immediately and be coordinated by the White House. As a first step, the White House should develop planning guidance to agencies that addresses consistent assessment of the vulnerability of infrastructure assets, attention to both existing facilities and siting of new facilities, consideration of social justice, and coordination among infrastructure sectors and with work to develop related coastal flood resilience plans for communities and ecosystems.

This *White Paper* includes:

- a brief summary of the science predicting more severe storms and rising seas;
- an overview of flood and inundation risks to critical, major coastal infrastructure;
- a description of the shortcomings of existing plans to manage critical infrastructure as storms become more severe and seas rise; and
- a proposal for federal agencies to lead development of sector-specific national plans to prepare critical, major infrastructure sectors for more severe storms and rising seas based on planning guidance developed on an interagency basis.

II. Problem Statement: Coastal Inundation Due to Storms and Rising Seas

The Atlantic, Gulf of Mexico, and Pacific coasts are home to over 100 million Americans. The population living right along the coast (i.e., at elevations of 33 feet and lower) is expected to double by 2060 to about 44 million. Climate change poses a significant risk to coastal communities through the combined impacts of more severe storms bringing temporary flooding, and permanent inundation by rising seas. More severe storms and rising seas bring flood waters to homes and businesses and threaten the operation of major, critical infrastructure assets that provide essential services such as transportation, energy, and water.

A. More Severe Coastal Storms

Coastal storms are a major risk to life and property and major storms can deliver storm surges of over fifteen feet. A warming climate is causing an increase in the number of the strongest storms. These storms bring more extensive coastal flooding, higher storm surges, and increased rainfall. Research indicates that the speed of intense storms is slowing down and storms are thus raining on a given place for longer, generating more flooding. Even as storms move more slowly, they intensify more rapidly, making their landfall harder to predict and more likely to result in major damage and loss of life.

B. Steadily Rising Sea Level

The National Oceanic and Atmospheric Administration (NOAA) recently issued new estimates of future sea level rise concluding that the rate of sea level rise along the U.S coasts is accelerating and is likely to rise as much over the next 30 years as it has over the last 100 years (i.e., about 1.3 feet by 2050 in the "Intermediate" scenario). Sea level rise averaging as high as 1.7 feet around the coastline is possible over this period (i.e., in the "High" scenario) and could reach as much as 2.2 feet in some places (e.g., in the Western Gulf of Mexico).

> "Sea level rise driven by global climate change is a clear and present risk to the United States, now and for the foreseeable future."
>
> *Global and Regional Sea Level Rise Scenarios for the United States*; NOAA, 2022

By the year 2100, NOAA projects sea level rise along the U.S. coasts to average about 4 feet (in the "Intermediate" scenario), while an average increase of over 7.2 feet is possible. Sea level rise in some regions likely could be higher. By 2150, NOAA forecasts average sea level rise of over 7 feet in the "Intermediate" scenario with the possibility of average increases as high as 12.8 feet, with increases in the Western Gulf of Mexico of 14.7 feet.

NOAA explains in its report that the rate of increase of sea level rise depends on increases in global air temperature driven by the release of greenhouse gasses. Additionally, the rapid deterioration of ice sheets in Antarctica and Greenland, due to both air and ocean temperatures, could result in higher projected increases occurring sooner than previously

expected. These changes in ice sheets are difficult to model but are thought to pose the greatest risk in the decades after 2050. Finally, sea level will continue to rise for centuries after 2150.

III. Overview of Flood and Sea Level Rise Risks to Major, Critical Coastal Infrastructure

This section provides an overview of the risks that more severe storms and rising seas pose to critical, major infrastructure assets located along the coast in three key sectors:

- transportation;
- energy production and distribution; and
- wastewater treatment and drinking water.

It is important to note that information about the vulnerability of infrastructure in these sectors along the coast varies in terms of assessment methods, geographic completeness, and age. In addition, some studies of flood risks to coastal infrastructure address storm surge flooding but not sea level rise, or vice versa. **Even these glimpses, however, are enough to suggest significant risk of damages and the potential for wider costs to society, including disruption of daily life, when this infrastructure is out of operation or operating below par.**

This *White Paper* focuses on transportation, energy, and water infrastructure because they are the most critical economically and are essential to maintaining services that support daily life. Within these sectors, the overviews focus on major infrastructure assets that have regional or national significance (e.g., interstate highways rather than every roadway, power plants rather than every power line).

In the years ahead, however, the country will also need to plan for impacts of severe storms and rising seas in other infrastructure sectors, including emergency service facilities, hospitals and other health care facilities, tourism and recreational infrastructure, and general government buildings.

Note that coastal infrastructure assets supporting national defense, including major military bases, are not addressed in this *White Paper.* Although there is substantial evidence of flood and sea level rise risk to major defense assets, these facilities do not directly provide services that support the regular operation of society. In addition, concern within Congress and the Department of Defense for impacts of storm flooding and sea level rise on military infrastructure has prompted a series of risk assessments and related studies. Despite this work, there is no national plan for protecting or relocating key defense infrastructure, and the case for such a plan will be made in a separate white paper addressing the unique circumstance, of these assets.

A. Transportation Sector

The transportation sector includes highways, railways, bridges, airports, and ports. More severe storms and rising seas pose a risk to facilities in each of these categories. A report by the National Research Council looking at all climate change-related threats to the transportation system found that sea level rise was a top concern among climate impacts:

> Potentially, the greatest impact of climate change for North America's transportation systems will be flooding of coastal roads, railways, transit systems, and runways because of global rising sea levels, coupled with storm surges and exacerbated in some locations by land subsidence.

Highways and Roads: The 2018 *National Climate Assessment* reported that coastal flooding poses a significant risk to highways and roads:

> Sea level rise (SLR) is progressively making coastal roads and bridges more vulnerable and less reliable. The more than 60,000 miles of U.S. roads and bridges in coastal floodplains are clearly already vulnerable to extreme storms and hurricanes that cost billions in repairs. Higher sea levels will cause more severe flooding and more damage during coastal storms and hurricanes.

Authors of a 2018 study of coastal roads in states along the Eastern Seaboard found that tidal nuisance flooding "threatens 7508 miles (12,083 km) of roadways including over 400 miles (644 km) of interstate roadways….With sea level rise, nuisance-flood frequency is projected to grow at all locations assessed."

A 2020 study of road networks in northern California points out that storm flooding and rising seas cause employee absences and commuter delays on both the roads actually flooded and roads further inland:

> Our analysis quantifies one of the cascading, indirect consequences of present-day and near-future sea level rise: the disruption of urban traffic flows. We find a spectrum of indirect impacts of coastal flooding on traffic systems, from impassable commutes for communities in the areas of inundation to travel time delays that propagate region-wide.

Railways: No national-scale assessment of coastal flood risks to railroads is available, but it is clear that storm surges and rising seas are especially serious risks to rail lines on the Eastern Seaboard. In 2018, Bloomberg News reported on an internal Amtrak study that found that coastal storms and rising seas threaten to erode track, signals, power poles, and power substations and that parts of the corridor are at risk of "continual inundation."

A ten-mile stretch of track around Wilmington, Delaware, is of special concern, but track along the Connecticut coast and at other locations faces flood risks and, because some of these sections lack alternative routes, this flooding could result in disruption along the larger corridor. On the other side of the country, officials are considering relocating rail lines in southern California to avoid rising seas in both San Diego and Orange County.

Commuter rail systems in major U.S. coastal cities are also at risk from storms and rising seas. For example, a study of Boston's commuter train system found that the system "could be operating at 40 percent less capacity within a decade because of increased flooding."

Ports: The 2018 *National Climate Assessment* states that:

> Ports, which serve as a gateway for 99% of U.S. overseas trade, are particularly vulnerable to climate impacts from extreme weather events associated with rising sea levels and tropical storm activity.

The 2014 *National Climate Assessment* noted:

> most ocean-going ports are in low-lying coastal areas, including three of the most important for imports and exports: Los Angeles/Long Beach (which handles 31% of the U.S. port container movements) and the Port of South Louisiana and the Port of Galveston/Houston (which combined handle 25% of the tonnage handled by U.S. ports).

The Environmental Defense Fund reported that "Ports in the United States have experienced significant downtimes because of hurricanes," and estimated that, on a global scale:

> …the combination of projected sea level rise and more severe storms by 2050 is likely to impose billions of dollars in additional storm-related port damages and disruption costs each year unless significant mitigation/adaptation steps are taken. Moreover, these added costs in 2050 are likely to double by the end of the 21st century.

Airports: In the case of airports, the 2014 *National Climate Assessment* reports that "thirteen of the nation's 47 largest airports have at least one runway with an elevation within 12 feet of current sea levels…," which is "within the reach of moderate to high storm surge." Airports in the New York City area (JFK, LaGuardia, and Newark), Florida (Fort Lauderdale, Tampa, and Miami), and San Francisco Bay area (Oakland and San Francisco) are on this list.

A recent study of coastal flood and sea level rise risk to airports globally found that the United States ranked first in the number of airports in the Low Elevation Coastal Zone (LECZ) (the land area less than 10 meters above sea level), and several major U.S. airports ranked in the top twenty globally for flood and sea level rise risk, including airports serving New Orleans, New

York, Newark, Key West and Oakland. In addition, the main airport in Puerto Rico upon which the island is dependent (along with the primary port) for basic supply chains, is within 12 feet of the current sea level.

This study found that coastal airports handle more air traffic routes than other airports and are a critical part of commercial aviation:

> airports at risk of flooding by 2100 provide significant connectivity with each other, and inland airports. Even for low sea level rise scenarios the number of airport routes at-risk is a notable proportion of the global network…and disproportionately higher than the number of airports at risk…Over two-fifths of all routes involve an airport in the LECZ, which are responsible for a significant proportion of global passenger and freight movement.

B. Energy Production and Distribution Sector

One of the "key messages" in the Energy chapter of the 2014 *National Climate Assessment* is:

> sea level rise, extreme storm surge events, and high tides will affect coastal facilities and infrastructure on which many energy systems, markets, and consumers depend.

The report goes on to note special risks in the Gulf of Mexico region:

> in particular, sea level rise and coastal storms pose a danger to the dense network of Outer Continental Shelf marine and coastal facilities in the central Gulf Coast region. Many of California's power plants are at risk from rising sea levels, which result in more extensive coastal storm flooding, especially in the low-lying San Francisco Bay area. Power plants and energy infrastructure in coastal areas throughout the United States face similar risks.

In 2015, a Department of Energy report offered a more detailed risk assessment, looking at different elements of energy infrastructure and the combined impacts of storm surge and sea level rise:

> As recent hurricane events have demonstrated, this study found that an extensive amount of U.S. energy infrastructure is currently exposed to damage from hurricane storm surge. Furthermore, between 1992 and 2060, the number of energy facilities exposed to storm surge from a weak (Category 1) hurricane could increase by 15 to 67 percent under a high sea-level rise scenario from the recent *National Climate Assessment.*

The nonprofit organization Climate Central evaluated coastal flood risk to energy facilities and identified 287 facilities less than 4 feet above the high tide line, spread throughout the 22 coastal states of the lower 48. More than half of these are in Louisiana, mainly natural gas facilities. Florida, California, New York, Texas, New Jersey each have 10 to 30 exposed sites, mainly electricity in the first three states and or oil and gas in the last two. All told, Climate Central found 130 natural gas, 9 electric, and 56 oil and gas facilities built on land below the 4 foot line. Below the 5 foot line, the total jumps to 328 facilities with similar geographic and type distribution.

Power Generation: Looking at the local implications of sea level rise impacts on electric power generation, a 2015 study found that the share of power produced by facilities at risk from a 100-year storm, assuming sea level rise by 2100, varied strongly by state: "For Delaware it is 80% of the mean generated power load. For New York this number is 63% and for Florida 43%." Nearly all nuclear plants were constructed without the consideration of sea level rise.

Data generated by Climate Central indicate that 7 nuclear plants are at risk of flooding due to sea level rise under a 2-degree Celsius scenario, and an additional 6 nuclear plants under a 4 degree Celsius scenario. Sea level rise risks at some plants, such as the Turkey Point power station in southern Florida, are the subject of long-running debates.

Petroleum Production: Petroleum production and refining is the element of the energy sector where assets are most likely to be privately held. The Department of Energy reviewed the exposure of oil refineries to coastal storms and rising seas and found that thirty-four refineries, constituting 4.9 percent of United States refining capacity, are currently exposed to storm surge inundation from a Category 3 hurricane. With sea level rise of twenty-three and thirty-two inches, the number of facilities at risk of a Category 3 storm increases to thirty-six and thirty-nine, respectively.

Refineries along the Gulf of Mexico are most at risk. Ten of the sixteen oil refineries that are exposed to storm surge from Category 1 hurricanes are located in the Gulf Coast region, and most of the refineries that are not currently exposed to a Category 1 storm surge, but would become exposed as a result of sea level rise, are located in Louisiana and east Texas (Galveston Bay and Port Arthur).

In a 2015 evaluation of storm and sea level rise risks to refineries, the Union of Concerned Scientists noted that coastal storm damage to refineries can have consequences for the American economy, finding:

> In 2005, for example, Hurricanes Katrina and Rita devastated the Gulf coast, shutting down 23% of the U.S. refining capacity, causing a significant drop in gasoline production and resulting in a 50% jump in the weekly average spot price of conventional gasoline.

C. Water Sector

Drinking water treatment plants and sewage treatment plants provide essential services, and the interruption of service due to flooding of either type of water facility can cause immediate hardship for communities, undercut the local economy, and present serious public health and water pollution issues including both direct and cascading. For instance, releases of raw or undertreated sewage can contribute to harmful algal blooms, which can cause severe economic and public health hardships for nearby communities and threaten important drinking water sources.

Sewage Treatment Plants: Major sewage treatment facilities are especially vulnerable to storm surge and sea level rise because they are commonly located at a low elevation and next to a waterbody receiving a discharge of treated water. Flooding of a treatment plant interrupts treatment and results in discharge of untreated sewage, sometimes for extended periods.

Although the greatest risks to these facilities lie in the future, damage is already occurring. Hurricane Florence, for example, caused releases of sewage from the Wilmington, North Carolina, wastewater treatment plant, and its storm surge flooded the Onslow County wastewater treatment plant. More recently, Hurricane Ian caused release of raw sewage from several Florida treatment plants, including a 7.2 million gallon sewage spill into Indian River Lagoon and a release of 13 million gallons of sewage into Manatee River.

In the San Francisco area, most of the region's sewage treatment plants are vulnerable to rising seas. An investigation by NBC News found:

> 30 out of 39 sewage treatment plants located around San Francisco Bay Area are at risk of flooding as sea levels rise due to climate change. Four of those plants could flood with as little as 9.84 inches of sea level rise.

Unfortunately, the national picture of water treatment system risk to storm surge and sea level rise is still hazy. In early 2018, researchers at the University of California at Berkeley, led by Michelle Hummel, published the first national study of sea level rise risk to sewage treatment plants, concluding:

> Across the United States, 60 wastewater treatment plants, serving over 4 million people, are exposed to flooding with 1 ft of SLR [sea level rise]. The largest increases in exposure occur from 3 to 4 ft of SLR, when an additional 83 plants serving 5.9 million people become exposed, and 4 to 5 ft of SLR, when an additional 91 plants serving 9.9 million people become exposed. By 6 ft of SLR, a total of 394 plants is exposed, and over 31 million people could be impacted by loss of wastewater services.

Drinking Water Treatment Plants: In the case of drinking water systems, a study focusing on just the Atlantic and Gulf Coasts, and on systems drawing water from surface water influenced by the tide, found twenty public water systems serving over one million people at risk of saltwater intrusion to freshwater supplies due to sea level rise, with five of these systems serving over 100,000 people "highly vulnerable." Drinking water for the City of Philadelphia is drawn from the Delaware River, and rising sea levels have pushed salt water to a point just eight miles from a key intake pipe. A USGS study of sea level rise impacts on groundwater in California found critical infrastructure at risk in low lying areas including in San Francisco Bay, Santa Barbara, Ventura, Port of L.A., Long Beach, Seal Beach, San Diego Bay and San Francisco and San Diego Airports. Saltwater intrusion due to rising sea levels also poses a threat to small water systems and private drinking water wells.

Coastal storms can result in failure of drinking water treatment plants due to both inundation by storm surges and loss of the electric power needed to run the plant. For example, in Lee County, Florida, Hurricane Ian shut down the water system serving 760,000 people. Hurricane Harvey in 2017 shut down 45 water systems in south Texas and resulted in 171 boil water orders.

There is no national assessment of the loss of safe drinking water due to coastal storms, but many storms cause at least temporary service disruptions. These disruptions can lead to human health impacts when people drink unsafe water and to significant economic losses as businesses close. These risks often fall on disadvantaged communities where water systems may lack storm protection and where resources for repairs or alternative supplies are fewer.

Finally, it is important to note that widespread flooding commonly associated with major storm surges poses a risk of damage to hazardous waste facilities in coastal areas, and flooding of these facilities can jeopardize health and disrupt supplies of safe drinking water for extended periods of time. The Environmental Protection Agency recently released a new mapping tool describing 55 sites managing 1.6 million tons of hazardous waste that are at risk of rising sea levels. Unfortunately, these sites are not cross-mapped to major drinking water supplies. National plans to protect major drinking water infrastructure should also account for risks of flooding of these facilities.

IV. Existing Plans for Coastal Flood Resilience of Major, Critical Infrastructure

Despite the lack of comprehensive and consistent estimates of risks to assets in these three major infrastructure sectors, the risk data now available points to significant potential for losses now and growing risk of more significant losses and social disruption in the decades ahead. Unfortunately, today there is very limited planning to build resilience of major, critical infrastructure as coastal storms become more severe and sea level rises. Several recent studies,

however, point to the need for improved flood resilience planning for these infrastructure assets. For example:

- A 2023 report from the Brookings Institution on climate change and flood risks at U.S. airports noted:

  There is no requirement that airport authorities draft resilience plans focused on adaptation, which limits their understanding of both individual climate risks and the potential costs to address those risks.

- A 2020 Technical Paper evaluating sea level rise impacts on ports published by the American Society of Civil Engineers found:

  Only 29% of respondents indicated that their organization had an internal SLC [sea level change] policy, design, or planning document. Furthermore, results show that the lack of regulatory design standards in this area leads to engineers and their clients disregarding SLC more frequently. There is a clear need for collaboration among stakeholders to develop practical design methods for designing resilient port infrastructure.

A. Existing Coastal Infrastructure Planning Frameworks for Coastal Flood Resilience

There are several existing planning frameworks that partially address preparedness of coastal infrastructure for more severe storms and rising seas, including:

- Facility-specific plans;
- Federal agency climate adaptation plans;
- State or Local Hazard Mitigation Plans; and
- State Coastal Zone Management Plans.

In addition, in the case of *new* facilities, plans are evaluated under the National Environmental Policy Act (NEPA) and the Federal Flood Risk Management Standard (FFRMS), and these evaluations consider coastal flood risk on a facility-specific basis.

Facility-Specific Plans: Some transportation, water, and energy infrastructure facilities along the coast have independently developed plans that address coastal flood risk, but many have not. A key problem is that a model that relies on facilities to self-identify the need for a coastal flood resilience plan may result in some of the most critical major facilities not having plans.

In addition, existing plans vary in terms of the currency of sea level rise data, their degree of focus on both storm surge and sea level rise (as opposed to just storm surge), consideration of

implementation of response measures (as opposed to just assessment of vulnerability), attention to social justice, and coordination with other facilities in the sector or with other infrastructure assets of different types. Some examples of flood resilience plans developed by major infrastructure facilities include:

- the Port of San Diego;
- major infrastructure assets generally in San Francisco; and
- the sewage treatment serving Ogunquit, Maine.

Federal Agency Climate Adaptation Plans: Agencies updated agency climate change adaptation plans in 2021 in response to Executive Order 14008. In general, these plans look broadly at climate change impacts with a focus on agency operations and facilities. In some cases, these plans address risks to agency facilities on the coast but do not generally describe risks to infrastructure or needed response actions. For example:

- the Department of Transportation plan calls for adding consideration of climate resilience to grants and project planning and developing a workplan describing needed changes to regulations, but does not address coastal flood or sea level rise risks or identify existing infrastructure at risk;

- the Department of Energy plan addresses department facilities, rather than energy sector facilities more generally, although it does call on each facility to update its vulnerability assessment by the fall of 2022; and

- the Environmental Protection Agency plan provides that the Agency will add climate change considerations to regulations and grant programs, including clean water and drinking water revolving fund programs, but does not address coastal resilience, identify water treatment facilities most at risk, or identify measures to reduce coastal flood vulnerability of water systems more generally.

State or Local Hazard Mitigation Plans: Hazard mitigation plans are commonly focused on disaster risks, such as more severe storms, rather than long-term risks related to rising sea levels. State-level plans generally address state-owned assets (e.g., transportation facilities) while local plans may address risks to sewage treatment or drinking water facilities. Oftentimes, these plans rely on traditional coastal armoring rather than long term solutions such as relocation and nature-based solutions.

New guidance from the Federal Emergency Management Agency for state hazard mitigation plans taking effect in April 2023 speaks to the benefits of considering a range of climate change impacts, including rising sea levels, in a hazard mitigation plan and encourages, but does not

specifically require, states to account for climate-related changes. Local hazard mitigation plan guidance tracks the state-level plan guidance.

State Coastal Zone Management Plans: State plans funded and approved under the Coastal Zone Management Act (CZMA) address coastal flood resilience to different degrees but mostly focus on reducing impacts on communities and ecosystems (e.g., wetlands, public access, marine debris) rather than major infrastructure sectors.

CZMA allows states some discretion to select the topic areas they want to be the focus of coastal planning.

- Some states, such as Massachusetts, have a "ports" element of their program, but that element does not reach to port flood resiliency planning.
- The State of California CZMA program published *Critical Infrastructure at Risk: Sea Level Rise Planning Guidance for California's Coastal Zone*, describing optional approaches for managing sea level rise impacts on transportation and water infrastructure.
- The State of New Jersey used CZMA funds to develop a *Climate Change Resilience Strategy* that includes general actions to "reduce flood risk to buildings and infrastructure."

Water Sector Coastal Flood Resilience Planning: It is important to note that water sector infrastructure is commonly owned and operated by local governments. Some larger water systems, including systems serving New York, San Francisco, and Seattle, have developed plans specifically focused on storm surge and sea level rise inundation risks. Large municipal water systems have organized a Water Utility Climate Alliance to share information and practices for dealing with climate change risks, including a 2022 report describing practices systems can use to address sea level rise.

In addition, the Environmental Protection Agency operates a Creating Resilient Water Utilities (CRWU) Program and offers water utilities a "Climate Resilience Evaluation and Awareness Tool" (CREAT). Although not focused specifically on coastal water facilities or coastal flood risks, the program supports water systems that voluntarily decide to understand and address system risks.

New Infrastructure Siting — NEPA and FFRMS: In the case of *new* infrastructure projects, storm surge and sea level rise risks will likely be considered as part of the assessment under NEPA, and in the case of federally funded projects, the FFRMS.

NEPA reviews are now guided by new guidance on climate change published by the Council on Environmental Quality in January of 2023 that addresses the need to consider future climate conditions, including more severe storms and rising seas.

The FFRMS requires federal agencies that support infrastructure projects to avoid siting the project in a flood risk area and, if a location outside a flood risk area is not feasible, to elevate new facilities two feet above the base flood elevation, or by three feet in the case of critical projects.

B. Assessment of Existing Coastal Infrastructure Flood Planning

Steps to date to build resilience of major critical infrastructure to storm surges and rising seas are commendable and provide benefits in selected places and sectors. Taken together, however, the existing planning and project review mechanisms do not squarely address coastal flood risks to major facilities in critical infrastructure sectors.

In general, coastal flood resilience adaptation planning for major, critical infrastructure has some significant shortfalls, including a lack of:

- **national-scale** plans for an infrastructure sector, looking comprehensively at the entire coast and setting national priorities for developing resilience plans where most needed;
- **national consistency** in terms of defining which facilities are critical and evaluating risks (e.g., use of NOAA sea level rise scenarios);
- plans focused specifically on risks from **both more severe storms and rising seas** (i.e., as opposed to just storm surge flooding);
- **long-term time horizons** for plans that adequately account for sea level rise (i.e., time horizons that include sea level rise projections for 2100 or 2150, rather than just twenty years out);
- **attention to strategies such as relocation and using nature-based solutions** where feasible, rather than relying on outdated, traditional coastal armoring practices;
- **consistent recognition of the social and environmental justice** implications of infrastructure damage and consideration of these impacts in response plans; and
- **implementation funding and schedules** (i.e., some plans assess vulnerabilities but do not make choices concerning response actions or describe how and when actions will be implemented).

Perhaps most importantly, the coastal infrastructure flood resilience work to date lacks leadership from the federal government to define the challenge and coordinate the needed resources across the federal, state, and local governments and private sector.

V. Proposed Guidance for National Plans to Prepare Critical Infrastructure for More Severe Storms and Rising Seas

This mixed bag of plans and implementation actions to build resilience to storm surges and rising seas at major, critical infrastructure facilities requires that the country adopt a new, more effective strategy.

A new strategy for building resilience of major, critical coastal infrastructure should be based on four key elements:

- **Goal:** The goal of a coastal infrastructure flood resilience strategy should be to reduce storm surge and sea level rise damage to major, critical infrastructure assets as needed to avoid disruptions of services that are essential to the normal operation of society.

- **National Plans for Priority Infrastructure Sectors:** An initial strategy should provide for development of national-scale coastal flood resilience plans for at least three key infrastructure sectors:
    - transportation;
    - energy; and
    - water.

- **Federal Leadership:** The federal government should lead the work needed to develop a coastal flood resilience strategy for major, critical infrastructure, and work with state and local governments and the private sector to develop and implement a strategy.

- **Long-term Plans:** Infrastructure plans should identify solutions that address long-term risks, such as relocation of vulnerable assets and the effective use of nature-based solutions and natural infrastructure.

In operational terms, the Administration should issue a Memorandum from the President to the Secretary of Transportation, Secretary of Energy, the Administrator of the Environmental Protection Agency, and other appropriate officials to:

- establish an interagency task force on building coastal infrastructure flood resilience;
- call for development of sector-specific national plans based on a guidance document providing a framework for such plans for the transportation, energy, and water sectors; and
- establish a process and schedule for the development of initial, national scale plans.

A. Establish Interagency Task Force

An initial step in developing a new strategy for building resilience of major, critical coastal infrastructure is to establish an interagency task force and charge it with providing leadership and oversight of efforts by federal agencies and others to develop and implement the strategy.

An Interagency Task Force on Coastal Infrastructure Flood Resilience (Task Force) should be co-chaired by the Office of Management and Budget and the Council on Environmental Quality and include senior leaders from the Departments of Transportation and Energy and the Environmental Protection Agency. Other key federal agencies on the Task Force should include the Office of Science and Technology Policy, National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, the Army Corps of Engineers, and the Department of Housing and Urban Development.

A key function of the Task Force should be to draft guidance for the development of sector-specific resilience plans (see part B below), support federal agencies in developing plans, and promote coordination among sector plans as well as with coastal adaptation plans developed by others (e.g., plans to build flood resilience of coastal communities and ecosystems.)

B. Guidance on Key Elements of Infrastructure Sector National Coastal Flood Resilience Plans

To provide an overall framework for coastal flood resilience plans for infrastructure sectors, the Administration should develop guidance addressing the key elements of the sector-specific plans and the plan development process. Note that the State of California published guidance for sea level rise planning for critical infrastructure in transportation and water sectors, and this guidance is a useful point of reference for development of similar guidance on a national scale.

National guidance should call for each of the infrastructure sector plans to address the key topics described below.

1. **Apply Common Definition of Critical Infrastructure:** Within the major critical infrastructure sectors, there are a wide range of facilities and assets with differing significance for the effective provision of services to society. Guidance should provide for a consistent approach across all three plans to defining the scale of facility or asset that should be covered by a plan. For example, the Department of Homeland Security has defined critical infrastructure sectors.

2. **Use Most Current Science:** Guidance should provide for use of the most current science related to coastal storms and sea level rise, including the 2022 NOAA Sea Level Rise Scenarios report or most current subsequent iterations.

3. **Adopt Common Planning Horizons and Risk Assumptions:** Guidance should also provide for a common planning horizon among the infrastructure plans, including attention to impacts and actions in the near term (i.e., by 2050), the mid-term (i.e., by 2100), and the long-term (i.e., by 2150). Because each national infrastructure plan will be focused on major facilities that are critical to the normal operation of society, plans should adopt risk assumptions that are conservative (e.g., use the "Intermediate High" sea level rise scenario in the NOAA sea level rise scenarios report).

4. **Coordination with IIJA and IRA:** The Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) both include substantial new funding for diverse coastal flood resilience-related projects at multiple federal agencies. Guidance should call on agencies to describe how IIJA and IRA funds can most effectively be used to support development and implementation of national, sector-specific plans for critical, major coastal infrastructure. As noted in items #6 and &7 below, guidance should focus federal investments on solutions that address long term risks, such as use of relocation strategies and nature-based solutions when possible.

5. **Discourage Siting of New Facilities in Coastal Flood Risk Areas:** Infrastructure sector plans should discourage siting of new facilities in areas at risk of storm surge flooding and rising seas and adopt policies to limit federal investment in new or substantially renovated facilities in these areas. Plans should also identify policies to limit private sector investment in critical new facilities in risky coastal areas.

   Plans should provide for agency implementation of the Federal Flood Risk Management Standard, including the climate-informed science approach that requires avoiding the siting new facilities in risky areas.

   Plans for new facilities should also provide for consideration of decommissioning any new structure built in a sea level rise risk area, including safe removal of debris (see #10 for discussion of decommissioning of existing facilities).

6. **Define Policies for Building Coastal Flood Resilience at All Major, Critical Facilities:** Each sector infrastructure plan should identify policies and programs to build resilience to storm surge and sea level rise at all the existing major, critical infrastructure facilities along the coast. These policies should be designed to provide a common foundation for subsequent development of facility-specific resilience plans, and might include:

   - measures to communicate with sector-specific national organizations and educate leaders and managers in the sector about coastal flood resilience risks, including sharing of facility-specific response plans as they are developed;

- basic best practices for facility operations to improve flood resilience that can be implemented at little or no cost (e.g., elevation of electrical and computer hardware, storm surge warning check lists, community outreach generally as well as to social justice communities);
- discussion of prioritizing opportunities to implement longer-term solutions such as relocation and nature based solutions at or nearby infrastructure facilities, to provide storm surge buffers and buy time for implementation of longer-term solutions;
- identification of geographic clusters of major, critical facilities in the infrastructure sector and mechanisms to foster coordination among facility operators to share information and provide mutual support;
- a format for, and commitment to completing, incident reports to document flooding events at major, critical facilities in the sector to develop a record to inform future planning; and
- identification of sources of federal funding to implement both basic best practices and more detailed resilience plans, including identifying needed new national statutory authority to build infrastructure resilience.

Federal Aviation Administration

In 2021 the Federal Aviation Administration and the Volpe Center at the Department of Transportation initiated a five-year initiative to close the climate "resilience gap" including:

- Develop a Resilience Analysis Framework that will assist airports with conducting repeatable and effective resilience assessments;
- Address framework criteria – over varying timescales and scenarios – for projected impacts on pavement, drainage, and electrical systems performance; and
- Assist FAA with prioritizing resiliency investments.

7. **Set Priorities for Building Coastal Flood Resilience at the Highest-Priority Existing, Major, Critical Facilities**: A key element of infrastructure sector plans is development of policies for managing existing facilities that are at risk of storm surge flooding and sea level rise, including identifying specific facilities in each sector that are top priorities for initiatives to build flood resilience, including implementing an existing resilience plan or developing a new plan where needed. Key considerations that the guidance should address include:

    - identification of facilities expected to be at risk in the near/mid-/long-term;
    - assessment of consequences of disruption of the facility (e.g., number of people subject to service disruption);
    - consideration of social justice implications of potential disruptions of operations or damage to the facility, and recognition that disadvantaged communities often face disproportionate impacts of disasters and are less able to recover after a flood; and

- setting of facility-specific priorities for planning and response measures based on consideration of immediacy of the risks and scale of disruption impacts, and social justice considerations.

Each sector plan should identify the top ten facilities (or geographic groups of facilities) for which development of a local plan to sustain the facility or facilities in the face of more storms and rising seas is most urgent. Each sector plan should outline a preliminary process for developing local plans for these facilities, including schedules and funding sources.

8. **Define Facility-Specific Resilience Plan Options Selection Criteria:** The success of an infrastructure sector-specific coastal flood resilience plan will depend largely on the effectiveness of project designs developed to build resilience at specific, high-priority facilities. The guidance for the sector-specific plans should address criteria for selecting a project design, including:

   - consideration of a range of resilience measures and project designs, including construction of protective measures, elevation of structures and other assets; preservation or development of natural infrastructure, and relocation of a facility to higher, safer ground;
   - the relative cost of response measures, including multiple iterations of response measures up to and including relocation (e.g., if a seawall with a life of 50 years is proposed, the cost of a replacement or eventual relocation should be considered) as well as negative environmental and social impacts;
   - the benefits of the design option, including monetized and qualitative benefits over the life of the infrastructure asset;
   - the social justice consequences of a project design option; and
   - a process for decommissioning of structures once a facility is relocated to higher ground, including safe disposal of debris.

   Although every specific infrastructure facility has unique characteristics and flood and sea level rise risks, sea level will continue to rise for decades and plans should recognize that most major, critical infrastructure facilities along the coast will need to relocate to high ground eventually. Plans should not avoid consideration of a relocation option by setting a planning horizon that is so short (e.g., 50 years) that storm surge and sea level rise risk mostly occur at a date beyond the planning horizon.

   There may be cases where the timing of future flood risks and other circumstances make investment in interim measures to protect a major, critical infrastructure asset at its current site an element of a larger, long-range plan. In these cases, plans should fully evaluate preservation or development of natural infrastructure as alternatives to

structural protection approaches. Natural infrastructure measures offer multiple benefits while avoiding harms associated with structural measures, such as increases in the rate of erosion and sediment loss, causing coastal access issues and elevated public safety hazards. Natural infrastructure also provides a more effective transition to relocation than does armoring or related structural protection.

9. **Encourage Coordination Across Sectors and with Related Plans**: The guidance should encourage agencies to consider interdependencies among the three major infrastructure sector plans, with special attention to coordination for sharing of preferred sites for potential relocation. Planners should explore opportunities for operational and economic efficiencies that may arise from coordinated relocation of infrastructure across sectors.

   Guidance should also address coordination of infrastructure plans with planning for the flood resilience of coastal communities and ecosystems. This should be accomplished through cooperation with other federal agencies as well as state and local government. Note also that investments in nearby natural infrastructure can provide flood resilience benefits to a larger area and help protect both communities and ecosystems neighboring the facility.

10. **Address Decommissioning of Infrastructure Sites Abandoned to Rising Seas:** As storm surges reach higher and further inland due to rising seas, protection of major infrastructure assets on existing sites will become increasingly untenable. Plans to relocate these assets to higher ground will need to include appropriate steps to decommission existing sites. Guidance should speak to decommissioning standards including removal of hazardous material, appropriate disposal of debris, public access and safety, and timing of decommissioning (i.e., prior to inundation of the site by rising seas).

C. Guidance for Process for Developing Coastal Flood Resilience Infrastructure Plans

The Administration should describe a process for agencies to follow in developing infrastructure sector-specific coastal flood resilience plans.

- **Stakeholder and Public Engagement:** Federal agencies (i.e., DOT, DOE, and EPA) should consult with state and local governments, stakeholders (e.g., industry associations, environmental organizations, professional societies), and the public in developing plans. Agencies should publish draft plans for public comment. Special attention should be given to engaging disadvantaged communities.

Development of coastal flood resilience for major energy facilities is a special case, because most of these facilities are owned and operated by a small number of large corporations. The private ownership of facilities limits the extent to which the federal government can influence the siting of new facilities or the management of existing facilities. At the same time, the comparatively small number of facility owners makes engagement simpler than in the case of other infrastructure sectors.

- **Plan Development Schedules:** The Interagency Task Force should be established over the course of the Summer of 2023 and guidance should be published by the end of 2023. Agency plans should be finalized by the end of 2024. Guidance should also describe a process for periodic review and updating of sector plans. Plans for specific, high-priority infrastructure facilities should be initiated in 2025, and developed as resources allow on a priority basis in the following years.

The *Coastal Flood Resilience Project* is a coalition of organizations working for stronger programs to prepare for coastal storm flooding and rising sea level in the United States. The views expressed in this *White Paper* are those of the supporters listed below and do not represent the views or endorsements of their organizations.

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