

CLIMATE CHANGE AND COASTAL WATERSHEDS



Adaptation to Attain Clean Water Goals and Sustainable Coasts

Sustainable means: to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations.

—Executive Order 13514 of October 5, 2009

Sustainability and Climate Change

Healthy and resilient ocean and coastal ecosystems are directly linked to environmental quality, human well-being, and national prosperity. Protecting, restoring, and maintaining these ecosystems and national resources are essential for ensuring a sustainable future.

Current environmental challenges in coastal watersheds loom large. Yet, the climate changes that are anticipated (such as warmer temperatures, sea level rise, or intensification of the hydrologic cycle) are going to increase existing pressures on estuaries as well as give rise to new problems. Management strategies and practices will need to evolve as climate changes. It may not be sufficient to restore or maintain historical conditions; sustainability might require creating and maintaining new environments as well.

Sustainability planning in estuaries encompasses nearly every sector, including human health, natural resource management, and disaster response. EPA's Climate Ready Estuaries (CRE) program focuses on the aspects of climate change that affect the chemical, physical, and biological integrity of coastal watersheds. Climate Ready Estuaries works to ensure that the goals of the Clean Water Act will continue to be achievable.

Adaptation for Sustainability

Clean Water Act legislation that specifically addresses estuaries ^{*}[†], contains a mandate to control pollution, to improve estuary habitat, to ensure healthy plant and animal communities, and to

^{*} 33 USC 1330. National estuary program. (Section 320 of the Clean Water Act)

[†] 33 USC Chapter 42—Estuary Restoration. (The Estuaries and Clean Waters Act of 2000)

maintain human uses. Efforts to incorporate sustainability principles into how the country tries to reach those goals will be complicated in many ways by the impacts of future changes.

Coastal managers will be faced with climate changes that will affect their systems. Warmer summers and winters, and warmer water temperatures will have a variety of effects on native plants and animals. More intense drought and heavy precipitation will complicate efforts to control point and nonpoint sources of pollution. Estuary habitats, especially coastal marshes, are increasingly at risk of shoreline erosion, rising sea level, and ecological transition. Sea level rise also poses a threat to water and wastewater infrastructure, as well as to drinking water in our rivers and aquifers. Adaptation will be necessary to avoid, resist, or absorb those impacts and to help society achieve clean water goals under changing environmental conditions.

Many of the strategies that have value for today's situation will also help to adapt to climate impacts. Preserving healthy watersheds and restoring coastal environments are thought to be important ways of maintaining robust fish, plant, and animal communities that can more easily transition with changing climate conditions. Options for stormwater and pollution management, such as using green infrastructure techniques or adopting low-impact development, can be no-regrets strategies as well.

Adapting to climate change will not simply be a matter of adjusting to a new stable state. Sustainability will be elusive as climate will be continually evolving. The challenge will be to optimize needed environmental, economic, and social benefits, while being aware that climate changes in the decades to come may mean our work is never done.

Being Climate Ready

Climate Ready Estuaries works to raise the capacity of the National Estuary Programs (NEPs) and other coastal managers to anticipate and respond to climate change impacts. By choosing wisely, the necessity of adapting to climate change can be leveraged so that present and future generations of Americans can exist in productive harmony with nature. Prepared and alert coastal managers will recognize needs and opportunities to avoid losses and to guide their systems to sustainability in a constantly changing climate.

This progress report highlights some of the ways that NEPs have used CRE projects to continue reaching for a sustainable future where the aspirations of the Clean Water Act can be achieved.

Pollution Control

Effectively controlling point and nonpoint sources of pollution and pollution cleanup are important aspects of the Clean Water Act. Legislation also calls for improving and maintaining water quality and cleaning up pollution for the benefit of estuary habitat. Pollution control activities will be affected by climate change impacts, including changes in air and water temperature; changes in amounts, frequency and distribution of rain and snowfall; sea level rise; and ocean acidification.

Point sources of pollution

In regions experiencing more frequent drought, critical-low-flow criteria for discharging may not be met and pollutant concentrations would increase if sources stay the same as flow diminishes.

Warmer winters with less snow accumulation could affect point sources of pollution by reducing spring or summer flow volume which would affect pollution concentrations in receiving waters. Increased water temperature can make it harder to meet water quality criteria, and could increase the toxicity of pollutants. Floods may cause treatment plants to go offline. More intense precipitation events can cause combined sewer overflow events to increase and sea level rise may also produce seawater backflows into combined sewer systems. Sea level rise might require operational changes at sewage treatment plants. Additionally, sea level rise could lead to flooding or shoreline erosion at contaminated sites.

Water quality problems and nonpoint sources of pollution

Climate change will also affect the ability to effectively manage nonpoint sources of pollution. Warmer water temperature could cause increased algal growth; and parasites and bacteria can have greater abundance, survival, and transmission. Higher surface temperatures may lead to stratification within the water column and warmer waters will hold less dissolved oxygen. Warmer summers may increase the frequency of wildfires and lead to soil erosion. In regions experiencing more intense precipitation, streams might also have greater erosive force. Where drought is more frequent, nonpoint sources of pollution could increase from the buildup of pollutants on land, followed by high intensity runoff when rain does come. Urban areas may be subject to more floods and flood control facilities might be inadequate. Excessive rainfall can also cause septic systems to fail. Sea level rise will cause tides to reach higher and flood new areas. Finally, acidification could be exacerbated in coastal waters when decomposing organic matter interacts with pH changes in the oceans.



Climate Ready Estuaries partners are working to identify how particular climate change impacts will affect their ability to manage point and nonpoint sources of pollution and pollution cleanup activities. The **Piscataqua Region Estuaries Program** conducted a study of how increases in the frequency and intensity of rainfall events are likely to impact hydrology and the drainage infrastructure within the Oyster River watershed. The analysis demonstrated that implementing low-impact development techniques in the watershed would allow for better management of stormwater runoff. The **Albemarle-Pamlico National Estuary Program** held a series of listening sessions to discuss residents' concerns about sea level rise and population growth. Residents spoke about nonpoint source runoff from development, issues of poor drainage of water on the landscape, and other results of population growth, such as the increase in green lawns and the resulting chemical runoff from these residential areas. The **Sarasota Bay Estuary Program** developed a sea level rise viewer to show a range of sea level rise and storm surge scenario impacts to coastal development and infrastructure, including stormwater drainage systems. The viewer is online to facilitate education of officials and the public. The **Indian River Lagoon National Estuary Program** completed a sea level rise vulnerability assessment for the City of Satellite Beach, FL to aid city planning. They are working with the city's Comprehensive Planning Authority Board to include climate considerations into its comprehensive plan. The **Lower Columbia River Estuary Partnership** is incorporating climate change into their Comprehensive Conservation and Management Plan. This will ensure consideration of climate change in future management of conventional and toxic water pollutants.

Estuary Habitat

Establishing chemical, physical, and biological qualities of estuaries which will support a balanced population of living resources, is a goal of the Clean Water Act. Coastal and near-shore marine ecology and the ecosystems services they provide are vulnerable to a host of climate change-related effects including increasing air and water temperatures, sea level rise, changes in runoff from the land, and altered currents.

Aquatic environments

Surface water and ground water resources in coastal watersheds may be affected by a greater rate of evaporation. Where temperatures are warmer or drought is more frequent, ground water tables will be affected and base flow in streams could decrease. A change to ground water and surface water resources can force municipalities to switch between drinking water sources, which may have effects in estuaries. Managers at hydropower dams might react to greater electricity demand in the summertime by changing how much water they release from reservoirs. The amount of water in streams would also be affected by stronger storms that lead to more intense flooding and runoff. This in turn can lead to less infiltration and also increase turbidity of surface waters. Changes in the proportion of rain and snowfall might also change the runoff/infiltration balance, causing the base flow in streams to change. Additionally, warmer winters may prevent rivers from freezing, eliminating the spring thaw and a spring runoff pulse. Sea level rise will push tidal influence and saline water farther upstream, and freshwater habitat would become more brackish.

Terrestrial environments

Stronger coastal storms can lead to greater shoreline erosion, and also cause coastal overwash or island breaching. Even what are now routine storms would have enhanced effects because of sea level rise. Intertidal environments are at risk of erosion and also to progressive drowning from rising water. People may increasingly turn to bulkheads, sea walls, and revetments in an effort to preserve the existing shoreline. In places where salt marshes will not be able to keep up with sea level rise there is likely to be large wetland losses. Marshes and beaches can also be exposed to erosion in the winter storm season by the loss of protective ice.



Climate Ready Estuaries partners are considering how changing climate conditions affect the integrity of estuarine habitats and the shellfish, fish, and wildlife populations they support. Implications of sea level rise and changing precipitation patterns to estuaries have been of particular interest to NEPs. The **Narragansett Bay Estuary Program** is analyzing dams and other in-stream structures in the Pawtuxet River watershed to assess their vulnerability to climate change and flooding and resulting impacts on watershed restoration efforts. The **Partnership for the Delaware Estuary** and the **Indian River Lagoon National Estuary Program** used the Sea Level Affecting Marshes Model (SLAMM) to conduct an analysis of sea level rise impacts on coastal wetlands. The **Santa Monica Bay Restoration Commission** is conducting a vulnerability assessment of the Ballona Wetlands to changes in temperature, precipitation, and sea level rise. Study results and recommendations are being applied to wetland restoration planning and water quality management. The **Partnership for the Delaware Estuary** is designing a living shoreline approach for maintaining

ecological quality in tidal wetlands. The **Tampa Bay Estuary Program** is likewise leading the creation of a “Gulf Coast Community Handbook” which will identify best practices and lessons learned for incorporating climate change resiliency into habitat restoration and protection plans. The **Puget Sound Partnership**, the **Charlotte Harbor National Estuary Program**, and the **Long Island Sound Study** have all developed climate change indicators which will allow them to track climate-driven changes and identify vulnerabilities or ecological thresholds.

Animals and Plants

Protection and propagation of fish, shellfish, and wildlife is another focus of the Clean Water Act. This includes the control of nonnative and invasive species and the reintroduction of native species to maintain the biological integrity of an ecosystem. Animals and plants are sensitive to changes in climate such as warmer air and water temperatures or changes in the frequency and intensity of precipitation. Threatened and endangered species that are already stressed may be particularly susceptible to climate change.

Temperature impacts

Species that cannot tolerate warmer temperatures may die or migrate and biota at the southern edge of their range could disappear from ecosystems. Warmer winters can raise pest survival, increase invasive species’ ranges, and alter food sources and supplies. Changes in water temperature will affect aquatic animals and plants. Habitats might become unsuitably warm for particular species or for the food on which they depend; the dissolved oxygen capacity of water would decline; coral bleaching episodes may occur more frequently; and some fish reproduction can be affected if they require specific water temperatures.

Process impacts

During droughts, freshwater flow in streams will diminish and changing freshwater inputs might affect salinity distribution in estuaries, particularly affecting shellfish habitat. Additionally, sensitive species may not tolerate prolonged dry spells. Conversely, increases in frequency and intensity of precipitation, will lead to greater soil erosion and can increase turbidity, decrease water clarity, and increase sediment deposition in estuaries. This has particular consequences for the survival of benthic species. Sea level rise would cause salinity to change, pushing saltier water farther upstream. Sea level rise may also prevent sunlight from penetrating through the full depth of deeper water. Animals that are dependent on coastal marshes might find that wetland losses will accelerate under increasing rates of sea level rise. Ocean acidification brings into question the long term sustainability of shellfish and changing pH could cause adverse affects to fish during particular development stages. Furthermore, the effect of ocean acidification on calcifying plankton might lead to cascading effects in the food chain.



Climate Ready Estuaries partners are working to document and monitor climate change impacts on animals and plants in their watersheds and to determine how changing management techniques will help improve the resilience of the biological integrity of estuarine systems. In partnership with EPA’s Office of Research and Development, the **Massachusetts Bays Program** and the **San Francisco**

Estuary Program used expert elicitation to conduct vulnerability assessments of birds that use the mudflats and salt marshes in their estuaries. The expert elicitation process was demonstrated to be a useful methodology for adaptation cases with similar parameters. The **Partnership for the Delaware Estuary** conducted a vulnerability assessment and developed a detailed case study of impacts and adaptation options for bivalve shellfish. The **Barnegat Bay Partnership** held a series of stakeholder workshops to advise its Climate Change Work Group and inform its adaptation activities. Participants identified species loss, and migratory bird flyways among their concerns. The **Tillamook Estuary Partnership** is updating their management plan to incorporate climate change impacts. Areas of concern include pathogen contamination affects on shellfish, sedimentation affects on habitat for bay shellfish and fish, and changes in living resources due to the loss of spawning habitat for anadromous fish.

Human Uses

The Clean Water Act calls for managing and protecting water resources for human uses. In estuarine areas, this includes allowing recreational activities in and on the water and protecting public water supplies. The ways people use natural resources developed in conjunction with past climate conditions, thus any changes to the generally prevailing climate will have impacts on human systems.

Public water supplies

Warmer summers and winters may lead to changes in water supply and demand. Water supply can be affected by increased evaporation from reservoirs and ground water; summer water supplies that are derived from snow pack might be threatened. Ground water may also become salinized due to insufficient freshwater input or higher demand on aquifers. Also, with more frequent drought, ground water tables would drop. Saltwater intrusion into ground water could be more likely and sea level rise may also push salt fronts upstream past water diversion points. Sea level rise and increases in precipitation will also cause water plants or pumps to be more vulnerable to flooding, inundation, or erosion.

Where surface water is warmer, it can lead to increased growth of algae and microbes. Water treatment processes might need to change in response to health threats and changes in water quality (for example, warmer water can hold more dissolved material). Flood waters may increase downstream turbidity, negatively affecting the quality of the waters. Finally, in cold places, warming temperatures could induce more freeze/thaw cycles that can affect water infrastructure.

Recreation

Recreational activities in and on the water, such as swimming, fishing, or boating will also be impacted due to climate change. Increases in water temperature can make harmful algal blooms (HABs) more likely, and jellyfish might become more common in some regions. Decreased freshwater flows in streams may impede recreational uses. More frequent or more intense bad weather would reduce recreational opportunities. Increased precipitation will cause greater nonpoint source pollution, which may also impede recreation. Sea level rise might cause beaches and public access sites to be threatened by coastal erosion. Boaters could have to contend with decreased clearance under bridges or invasive plants that might clog creeks and waterways. With more frequent drought,

increased estuary salinity may drive away targeted recreational fish and salinity or temperature changes can cause fish habitat ranges to shift. Desired fish might no longer be around, or they may be present at different times of the year. Finally, ocean acidification could lead to the loss of shellfish harvests, as well as to the degradation of eco-tourism resources and attractions, such as diving or fishing.



Climate Ready Estuaries partners are considering how climate change impacts in their watersheds will affect sustainability, and they are identifying potential adaptation options. Through consultation with stakeholders and local decision makers, the **Casco Bay Estuary Partnership** identified the water resource infrastructure community as a critical audience for adaptation related outreach, and then developed a strategy to target this audience. The **Charlotte Harbor Estuary Program** completed a vulnerability assessment for the City of Punta Gorda, FL. The assessment found that seventeen public water supply facilities and fourteen wastewater treatment facilities are likely to be impacted by sea level rise by 2100. The **Albemarle-Pamlico National Estuary Program** is working with CRE and EPA's Climate Ready Water Utilities program to develop its capacity to use CRWU's Climate Resilience Evaluation and Awareness Tool (CREAT) with North Carolina municipalities to identify and assess climate impacts on public utilities. The **Morro Bay National Estuary Program** is working with local water suppliers to identify the environmental impacts from sea level rise and climate-driven changes in water availability. The **New York–New Jersey Harbor and Estuary Program** worked with the North Hudson (N.J.) Sewerage Authority to look at climate change impacts and identify adaptation options for consideration. The **New York–New Jersey Harbor and Estuary Program** is also assessing how climate change will affect public access sites and the human uses of the estuary that are dependent on getting to the water.

The above descriptions of the National Estuary Programs' achievements through their Climate Ready Estuaries projects are highly abbreviated. Please see their respective websites for more information.

Learn more about climate impacts in coastal watersheds

Climate Ready Estuaries *Synthesis of Adaptation Options for Coastal Areas*
water.epa.gov/type/oceb/cre/upload/CRE_Synthesis_1-09.pdf

[U.S. Climate Change Science Program Synthesis and Assessment Products](#)

- SAP 4.1. *Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region.*
 - SAP 4.4. *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources.*
- library.globalchange.gov/products/assessments/

Coastal Areas Impacts and Adaptation

www.epa.gov/climatechange/impacts-adaptation/coasts.html

Climate Ready Water Utilities

water.epa.gov/infrastructure/watersecurity/climate/index.cfm

Climate Ready Estuaries Partners, 2008–2012



Pacific

- Puget Sound Partnership (WA)
- Lower Columbia River Est. Partnership (WA/OR)
- Tillamook Estuaries Partnership (OR)
- San Francisco Estuary Partnership (CA)
- Morro Bay National Estuary Program (CA)
- Santa Monica Bay Restoration Commission (CA)

Gulf of Mexico

- Mobile Bay National Estuary Program (AL)
- Tampa Bay Estuary Program (FL)
- Sarasota Bay Estuary Program (FL)
- Charlotte Harbor National Estuary Program (FL)

Atlantic

- Casco Bay Estuary Partnership (ME)
- Piscataqua Region Estuaries Partnership (NH)
- Massachusetts Bays Program (MA)
- Buzzards Bay National Estuary Program (MA)
- Narragansett Bay Estuary Program (RI)
- Long Island Sound Study (CT/NY)
- Peconic Estuary Program (NY)
- NY–NJ Harbor and Estuary Program (NY/NJ)
- Barnegat Bay Partnership (NJ)
- Partnership for the Delaware Estuary (NJ/PA/DE)
- Albemarle-Pamlico NEP (NC)
- Indian River Lagoon NEP (FL)
- San Juan Bay Estuary Program (PR)