II. Introduction: The Evolving Context

A. *2008 Strategy* vs. *2012 Strategy*

THE *National Water Program Strategy: Response to Climate Change*, published in 2008 (*2008 Strategy*), describes the likely effects that climate change will have on water resources and their implications for the EPA's NWP.[1] The *2008 Strategy* laid out 44 "key actions" that the NWP intended to take during 2008–2009, and an update extended the period of action to 2010–2011 (EPA, 2008a).

The *2012 Strategy* builds on the momentum achieved through the implementation of the 44 key actions in the *2008 Strategy*. Further, this *2012 Strategy* describes a longer term vision for the management of sustainable water resources in light of climate change and identifies the key "building blocks" or strategic actions that need to be taken to achieve the long-term goals. It also reflects the wider context of climate change-related activity that is underway throughout the nation. This *2012 Strategy* is a roadmap that reflects directional intention. While it describes an array of important actions consistent with creating a "climate-ready" national water program, it does not outline commitments to act within a specific timeframe. All proposed activities are contingent upon availability of resources and subject to change as new information develops to inform adaptive responses.

B. Relationship of the *2012 Strategy* to Other Planning Activities

The **Interagency Climate Change Adaptation Task Force** (the Task Force) was established under Executive Order 13514 (CEQ, 2009) to develop recommendations for climate change adaptation. On October 5, 2010, the Task Force delivered its initial report to the President with a first set of recommendations (CEQ, 2010a).

Two recommendations in the October 2010 Task Force Report inform the development of the *2012 Strategy*. First, the Task Force's **Freshwater Workgroup**[2] was asked to develop a National Action Plan (NAP) in coordination with similar action plans under development; one by ICCATF's **Fish, Wildlife and Plants Climate Adaptation Workgroup** (FWP Workgroup) and the other by the **National Ocean Council** (NOC) addressing ocean, coastal, and Great Lakes resources. An ICCATF coordinating team has worked together to ensure that the three national adaptation strategies produced by these three workgroups are complementary.

[1] The term "National Water Program" refers to the Office of Water (OW) plus the water programs in the 10 EPA Regions, and recognizes that many of our programs are implemented by state and tribal water authorities.

[2] Since 2009, Michael Shapiro, EPA Deputy Assistant Administrator for Water, has served as co-chair of the Task Force's Water Workgroup along with Matthew Larsen, U.S. Geological Survey (USGS) Associate Director for Climate and Land Use Change, and Jeffrey Peterson, White House Council on Environmental Quality Deputy Associate Director for Water Policy.

Subsequently, the Freshwater Workgroup published the National Action Plan titled *Priorities for Managing Freshwater Resources in a Changing Climate*[3] (CEQ, 2011a), which describes a National Goal, supported by six recommendations, described below:

Interagency Climate Change Adaptation Task Force
Freshwater National Action Plan

National Goal: Government agencies and citizens work collaboratively to manage freshwater resources in response to a changing climate in order to assure adequate water supplies, to protect human life, health and property, and to protect water quality and aquatic ecosystems.

- **Recommendation #1:** Establish a Planning Process and Organizational Framework
- **Recommendation # 2:** Improve Water Resources and Climate Change Information
- **Recommendation # 3:** Strengthen Assessment of Vulnerability
- **Recommendation # 4:** Expand Water Use Efficiency
- **Recommendation # 5:** Support Integrated Water Resources Management
- **Recommendation # 6:** Support Training and Outreach to Build Response Capability

—ICCATF Freshwater National Action Plan (CEQ, 2011a)

The Freshwater NAP lays out 24 key actions that support the six recommendations. For some of the supporting actions, EPA will provide leadership, and for those led by other federal agencies, EPA will participate as a team member, as appropriate.

EPA water program staff and managers also participate on the NOC (NOC, 2011) and the Fish, Wildlife, and Plants (FWP) Workgroup (FWP, 2011), and EPA's NWP commitments in those adaptation plans are also reflected in this *2012 Strategy*.

The second recommendation of the Interagency Task Force report called on every federal agency to develop and implement a climate adaptation plan addressing the challenges posed to our missions and operations. The White House Council on Environmental Quality (CEQ) issued implementation instructions on climate adaptation planning to all federal agencies (CEQ, 2011a and b); initial plans were to be submitted by June 2012, and more complete plans submitted by June 2013. In response, EPA established a Policy on Climate Change Adaptation, issued June 2, 2011 (EPA, 2011a), and formed a cross-EPA Work Group on Climate Change Adaptation Planning (EPA Work Group). The Office of Water (OW) and the 10 EPA Regions participate on the EPA Work Group, ensuring that the two Strategies (NWP's and EPA's) are consistent and mutually reinforcing. EPA submitted its plan to CEQ on June 28, 2012.

[3] Printed copies of the National Action Plan are available by sending an email to the following address: adaptation@ceq.eop.gov, stating addressee, mailing address, and the number of copies desired (limit of three).

Additionally, EPA has adopted Agency-wide goals that call for each program office to incorporate climate change science trend and scenario information into five major scientific models and/or decision-support tools; five rulemaking processes; and five major grant, loan, contract, or technical assistance programs, and sets a target for reducing greenhouse gas emissions through energy and resource conservation (EPA, 2010a). This *2012 Strategy* reflects the NWP's commitment to achieving each of these measures by 2015. (See the section on *Tracking Progress and Measuring Outcomes* in Chapter VI for more discussion.)

Finally, in 2010, EPA convened a forum to discuss how to accelerate progress in protecting the nation's waters. The resulting white paper, titled *Coming Together for Clean Water* (CT4CW), recognizes that climate change is just one of the several stressors to water resources (EPA, 2011b). The *Coming Together* strategy presents a framework for how EPA's NWP will work to address today's clean water challenges, such as stormwater, nutrients, and protecting and restoring watersheds. The *Infrastructure Sustainability Policy* reflects EPA's goal to ensure that federal investments, policies, and actions support water infrastructure in efficient and sustainable locations to best aid existing communities, enhance economic competitiveness, and promote affordable neighborhoods. The NWP *2012 Strategy* should be viewed as an in-depth treatment of climate change, addressing one of the new and challenging issues facing our program, and as an integral and complementary part of overall NWP strategic planning and initiatives.

Despite many successes over recent years, the rate at which waters are being listed for impairment exceeds the rate at which they are being restored. The causes of degradation are in many cases far more complex, and not as visible to the naked eye as they were years ago; the solutions are often available technically, but because the pollution comes from multiple sources, and involves a greater array of pollutants and stressors, it requires new and innovative partnerships and approaches. In some cases EPA and state authorities are limited in scope, and as a result it is challenging to directly address root causes—i.e., population growth, urbanization, agriculture, and other nonpoint source pollution. Building strong and effective partnerships with the widest range of stakeholders, state, local, and tribal partners, and other federal agencies has never been so urgent if we are to protect our water and its multiple uses for generations to come.

—Coming Together for Clean Water, (EPA, 2011b)

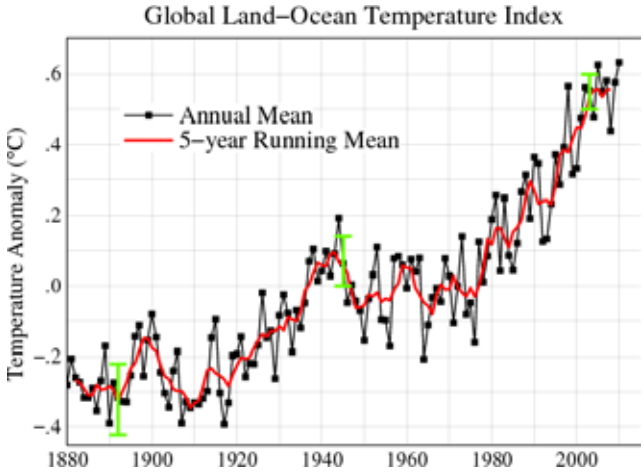
C. Impacts of Climate Change on Water Resources: Recent Literature

Recently published assessments and other reports reinforce the findings in the *2008 Strategy* that climate change has significant implications for water resources and water programs. They support EPA's determination that these implications should be addressed in each part of the NWP in order to achieve EPA's mission of protecting human health and the environment. It is important to note that not all impacts of climate change will necessarily be disruptive to particular programmatic endpoints, and that some could at least in the near term provide beneficial opportunities. However, on balance, the range of challenges posed by the interface between built and natural systems and the changing hydrometeorological background conditions is likely to require response actions in order to minimize detrimental effects to current built and natural systems. The impacts listed here refer to the general risks to water resources posed by climate change, but whether and to what degree these risks are likely to be realized in specific locations will require local assessment. The reader is referred to the original *2008 Strategy*, as well as more recent literature cited below and the references cited in Appendix D, for a more detailed discussion of the implications of climate change for water resources and EPA's water programs. These implications include:

- **Increases in water pollution problems:** Warmer air temperatures will result in warmer water. Warmer waters will hold less dissolved oxygen, making instances of low oxygen levels and "hypoxia" (i.e., when dissolved oxygen declines to the point where aquatic species can no longer survive) more likely; foster harmful algal blooms; and change the toxicity of some pollutants (Figure 1).

  The number of waters categorized as "impaired" is likely to increase, even if pollution levels are stable, with associated impacts on human health from waterborne disease and degradation of aquatic ecosystems.

Figure 1: Global Surface Temperature Change—1880 to 2010 (degrees Celsius)—Compared to Base Period 1951 to 1980



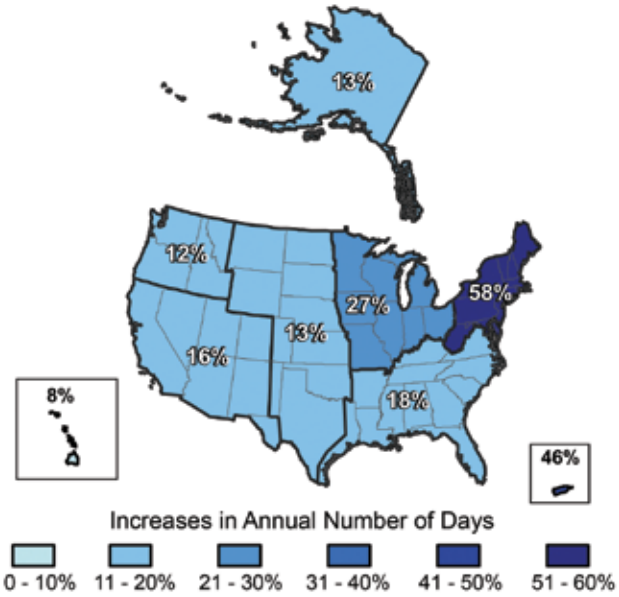
Black curve shows annual average temperatures; red curve shows a five-year running average; green bars indicate the estimated uncertainty in the data during different periods of the record. Source: NASA GISS updated through 2010 at http://data.giss.nasa.gov/gistemp/graphs/.

- **Impacts on water infrastructure and aquatic systems due to more extreme weather events (Figure 2):** Heavier precipitation from tropical and inland storms will increase flood risk, expand flood hazard areas, increase the variability of streamflows (i.e., higher high-flows and lower low-flows), increase the velocity of water during high-flow periods, and increase erosion. These changes will have adverse effects on water quality and aquatic ecosystem health. For example, increases in intense rainfall result in more

nutrients, pathogens, and toxins being washed into water bodies.

- **Changes to water availability:** In some parts of the country, droughts, changing patterns of precipitation and snowmelt, and increased water loss due to evaporation as a result of warmer temperatures will result in changes to the availability of water for drinking and for use in agriculture, industry, and energy production. In other areas, sea level rise and saltwater intrusion will have the same effect. Warmer air temperatures may also result in increased demands on community water supplies, and the water needs for agriculture, industry, and energy production are likely to increase.

Figure 2: Increases in Annual Number of Days With Very Heavy Precipitation



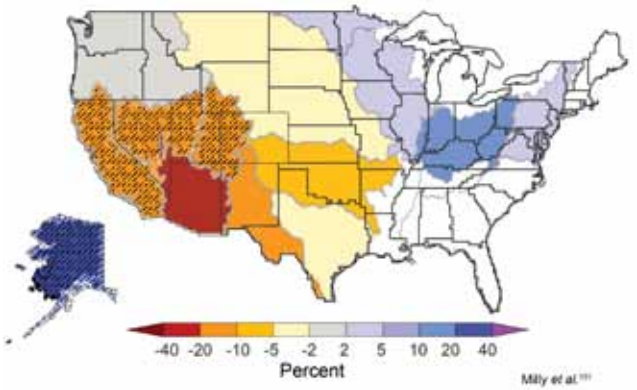
Source: U.S. Global Change Research Program (USGCRP). (2009). Global Climate Change Impacts in the United States, [Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.)]. New York: Cambridge University Press. Retrieved from http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

- **Waterbody boundary movement and displacement:** Rising sea levels will move ocean and estuarine shorelines by inundating lowlands, displacing wetlands, and altering the tidal range in rivers and bays. Changing water flow to lakes and streams, increased evaporation, and changed precipitation in some areas will affect the size of wetlands and lakes. Water levels in the Great Lakes are expected to fall.
- **Changing aquatic biology:** As waters become warmer, the aquatic life they now support will be replaced by other species better adapted to the warmer water (i.e., cold-water fish will be replaced by warmwater fish). This process, however, will occur at an uneven pace, disrupting aquatic system health and allowing nonindigenous and/or invasive species to become established. In the long term (i.e., 50 years), warmer water and changing flows may result in significant deterioration of aquatic ecosystem health in some areas.
- **Collective impacts on coastal areas:** Most areas of the United States will see several water-related impacts, but coastal areas are likely to see multiple impacts associated with climate change (e.g., sea level rise, increased damage from floods and storms, coastal erosion, changes in drinking water supplies, increasing temperature); acidification (e.g., decreases in pH, decreases in carbonate ion availability for calcifying organisms, changes in fish behavior); and nitrogen and phosphorus pollution, which could result in more profound consequences to water resources and ecosystem services. These overlapping impacts make protecting water resources in coastal areas especially challenging.
- **Indirect impacts:** Likely responses to climate change include development of alternative methods of energy and fuel production that reduce emissions of greenhouse gases, as

well as finding ways to sequester carbon generated by energy production. Alternative methods of both energy production and sequestration can have impacts on water resources, including increased water use and withdrawals, potential nonpoint pollution impacts of expanded agricultural production, increased water temperatures due to discharge of process cooling waters, pollution concentration due to low flows, and effects of carbon sequestration on ground water or ocean environments.

As noted, not all near-term impacts of climate change will necessarily be disruptive and could, in some cases, provide benefits. For example, increased precipitation could improve flows supporting aquatic ecosystem health in some areas, and changing sea levels could aid submerged aquatic vegetation. (Figure 3)

Figure 3: Projected Changes in Annual Runoff: 2041–2060



Runoff, which accumulates as streamflow, is the amount of precipitation that is not evaporated, stored as snowpack or soil moisture, or filtered down to ground water. Projected changes in median runoff for 2041–2060, relative to a 1901–1970 baseline, are mapped by water-resource region. Colors indicate percentage changes in runoff. Hatched areas indicate greater confidence due to strong agreement among model projections. White areas indicate divergence among model projections. Results are based on emissions in between the lower and higher emissions scenarios of the IPCC. Image credit: U.S. Global Change Research Program (www.globalchange.gov).

Recent publications on the impacts of climate change include the June 2009 report titled *Global Climate Change Impacts in the United States*, produced by the USGCRP (formerly the U.S. Climate Change Science Program). The report reviews the scientific findings of 21 Synthesis and Assessment Products (SAPs) and builds on previous USGCRP and Intergovernmental Panel on Climate Change (IPCC) assessments. It describes both observed and expected impacts of climate change for the United States and presents regional and sectoral assessments (USGCRP, 2009a). In December 2009, EPA issued the *Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act*. EPA relied on the major scientific assessment reports to find that greenhouse gases pose a risk to public health and welfare. Observed and projected impacts of climate change on water resources in the United States were components of the Findings (EPA, 2009a).

The National Research Council (NRC) produced a set of reports in 2010 at the request of Congress (Public Law 110-161) to study the issues associated with global climate change and provide advice on the most effective steps and strategies that can be taken to respond. The study, titled *America's Climate Choices*, resulted in five reports: *Advancing the Science of Climate Change, Limiting the Magnitude of Future Climate Change, Adapting to the Impacts of Climate Change, Informing Effective Decisions and Actions Related to Climate Change, and Synthesis for Policy Makers*, synthesizing the previous four reports (NRC, 2010a-d).

In late 2010, the NRC produced the report *Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia*, including an associated brochure (NRC, 2010e; NRC, 2011a). The report describes likely ranges of temperature increases during the 21st

century and beyond for a given concentration of greenhouse gases in the atmosphere and associates those temperatures with likely effects on natural and human systems:

> *Scientific progress has increased confidence in the understanding of how global warming levels of 1º, 2º, 3º, 4º, 5ºC, and so on, affects many aspects of the physical climate system, including regional and seasonal changes in temperature and precipitation, as well as effects on hurricanes, sea ice, snow, permafrost, sea level, and ocean acidification. Climate Stabilization Targets attempt to quantify the outcomes of different stabilization targets on the climate system, as much as is possible based on currently available scientific evidence and information* (NRC, 2011a).

The *Climate Stabilization Targets* then presents an indicative (not comprehensive) evaluation of likely impacts of each °C (1°C = 1.8°F) of warming, including, for example:

- 5–10% changes in precipitation across many regions.
- 3–10% increases in the amount of rain falling during the heaviest precipitation events.
- 5–10% changes in streamflow across many river basins.
- 15% decreases in the annually averaged extent of sea ice across the Arctic Ocean, with 25% decreases in the yearly minimum extent in September.
- 5–15% reductions in the yields of crops as currently grown.

Other effects of varying levels of warming include:

- Increases in the number of exceptionally warm summers (i.e., 9 of 10 boreal summers that are "exceptionally warm" in nearly all land areas for about 3°C of global warming, and every summer "exceptionally warm" in nearly all land areas for about 4°C, where an "exceptionally warm" summer is defined as one that is warmer than all but about one of the 20 summers in the last decades of the 20th century).
- 200–400% increases in the area burned by wildfire in parts of the western United States for 1–2°C.
- Increased coral bleaching and net erosion of coral reefs due to warming and changes in ocean acidity (pH) for carbon dioxide (CO_2) levels corresponding to about 1.5–3°C.
- Sea level rise in the range of 0.5 to 1.0 meters in 2100, in a scenario corresponding to about 3°C (plus or minus 1°C), with an associated increase in the number of people at risk from coastal flooding, as well as wetland and dryland losses.

Furthermore, the report underscores the point that "adaptation" is not a one-time event. Rather, we have entered an era of long-term continual change that must be considered by decision-makers to inform ongoing adaptation strategies. The NWP intends to continue to monitor developments in climate change and water science, including new science efforts to support and inform adaptation strategies. Notably, the USGCRP is currently conducting its third National Climate Assessment, scheduled to be final in 2013 (USGCRP, 2012). The NWP intends to incorporate into programs and activities the results of that assessment as well as of ongoing science and decision support products in the coming years.

D. The Economics of Climate Change Actions

Many of the actions we could take to adapt to climate change are actions that provide value independent of changing climate. Siting new water infrastructure in a coastal area at an elevation that is resilient to storm surge in the face of sea level rise would be beneficial even at current sea levels. Coastal wetlands are important resources for a variety of services, of which protection from sea level rise and storm surge is only one component. Sources for drinking water are already at risk; best management practices employed by water utilities and solutions encouraging water conservation and efficiency to deal with climate change impacts may also provide cost-effective relief from pressures caused by growing populations. In this sense, adaptation practices can be no- or low-regret methods to manage risk in the face of uncertainty regarding the pace and magnitude of climate change effects, provided they cost-effectively address stressors in addition to the risks posed by climate change.

Quantifying the projected cost of climate change impacts with any degree of certainty is difficult due to the complexity, variability, and uncertainty in the pace, magnitude, and locally specific impacts of climate change. Likewise, it is hard to monetize the costs and benefits associated with the wide range of mitigation and adaptation opportunities available to water managers in the United States. Nevertheless, assigning a dollar value to actions and inactions related to climate change not only helps society determine its preferred level of mitigation and adaptation, but also provides a common unit of measure to compare among options, helping decision-makers determine where and how to best implement mitigation and adaptation practices. The *EPA Guidelines for Preparing Economic Analyses* (EPA, 2010b) recognizes the complexity of environmental impacts more generally, while also explaining how valuation of such impacts can benefit decision-making.

The NWP intends to monitor developments and work with partners within and outside of EPA to explore ways to characterize costs and benefits to support climate change-related decision-making. A sample of these studies follows.[4]

- Kirshen et al. (2006) quantifies the climate change impacts on water quality, water supply, and water demand, among other areas of impact, in the Boston region. For example, they estimate capital costs to account for managing lower levels of dissolved oxygen due to warmer waters to range between $30 and $39 million.
- Frederick and Schwarz (2000) look at the impact of increased flood damages and drought on the United States due to climate change, and estimate that annual average flood damages may increase from $5 billion in 1995 to $8 billion in 2030 and $18 billion in 2095.
- Dore and Burton (2001) evaluate climate adaptation costs for a variety of actions in Canada. They estimate that expanding wastewater treatment capacity in Toronto to account for more intense precipitation and other impacts could range from $533 million to $9 billion, depending on the level of risk the city is willing to accept.

[4] This list is intended to be illustrative of recent published research. EPA is not endorsing any specific estimate.

- USGCRP's Global Climate Change Impacts in the United States (2009) highlights a water resources adaptation decision. Boston's Deer Island sewage treatment plant was built 1.9 feet higher to account for projected sea level rise during the facility's planned life (through 2050) to avoid future costs to build a protective wall around the plant with pumps to transport effluent over the wall.
- Neuman et al. (2010), in an EPA-supported study, evaluated the costs of sea level rise impacts to the contiguous U.S. coastline. The study found that the cost is much larger than prior estimates suggest—more than $63 billion cumulative discounted cost (at 3%) for a 27-inch rise by 2100, which corresponds to $230 billion in undiscounted cost.
- Workshop report: *Valuation Techniques and Metrics for Climate Change Impacts, Adaptation, and Mitigation Options* (NCA 2011). The goal of this workshop, convened by the interagency National Climate Assessment Task Force, was to provide a snapshot of the capabilities, readiness, and applicability of methodologies for quantitatively valuing climate impacts and adaptation.
- AWWA's recently released report, Buried No Longer, estimates that drinking water infrastructure maintenance and replacement costs will be $1 trillion from 2011–2035 for the current level of service (i.e., the cost of building climate resilience into drinking water infrastructure will be in addition to those maintenance and replacement costs).