STRATUS CONSULTING

Overview of Climate Change Adaptation in the Southeastern United States with a Focus on Water and Coastal Resources

Draft Discussion Paper

Prepared for:

Office of Air and Radiation, Climate Change Division
Office of Water, Water Policy Staff
Region 4
U.S. Environmental Protection Agency
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Acronyms and Abbreviations

ACF	Apalachicola, Chattahoochee, and Flint
ACT	Alabama, Coosa, and Tallapoosa
AP3C	Albemarle-Pamlico Conservation and Communities Collaborative
APNEP	Albemarle-Pamlico NEP
AWWA	American Water Works Association
CBRA	Coastal Barrier Resources Act
CDC	Centers for Disease Control and Prevention
CECAC	Climate, Energy & Commerce Advisory Committee
CEQ	Council on Environmental Quality
CHNEP	Charlotte Harbor National Estuary Program
CRE	Climate Ready Estuaries
CRS	Community Rating System
CRWUWG	Climate Ready Water Utilities Working Group
CSO	Coastal States Organization
CWA	Clean Water Act
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DOI	U.S. Department of the Interior
ECOS	Environmental Council of the States
EMAC	Emergency Management Assistance Compact
EPA	U.S. Environmental Protection Agency
FECC	Florida Energy and Climate Commission
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
GAO	U.S. Government Accounting Office
GHG	greenhouse gas
GWRP	Groundwater Resources Program
IPCC	Intergovernmental Panel on Climate Change
IRLNEP	Indian River Lagoon NEP

LIDAR	Light Detection and Ranging
MERAS	Mississippi Embayment Regional Aquifer System
MS4	municipal separate storm sewer system
NCS	National Climate Service
NDWAC	National Drinking Water Advisory Council
NEP	National Estuary Program
NFIP	National Flood Insurance Program
NGO	nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
PL	Public Law
RISA	Regional Integrated Sciences and Assessments
RPC	regional planning council
SCAC	Shoreline Change Advisory Committee
SGA	Southern Governors' Association
SIFN	Southern Instream Flow Network
SREMAC	Southern Regional Emergency Management Compact
SWP	State Water Plan
TARP	Technology Acceptance and Reciprocity Partnership
TBEP	Tampa Bay Estuary Program
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TVA	Tennessee Valley Authority
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WCIP	Water Conservation Implementation Plan
WMD	water management district
WRA	Water Resources Act
WRDA	Water Resources Development Act
WRF	Water Resource Foundation

1. Introduction

The Southeast may be one of the most vulnerable regions in the United States to climate change (e.g., Smith, 2004; Karl et al., 2009). It has wide-ranging natural resources and vulnerable communities, many of which may be impacted either directly or indirectly by a changing climate.[1] Even if greenhouse gas (GHG) emissions are slowed, or even reduced, in the future, we will not completely prevent some additional warming of the climate.[2] Given this, it is important for stakeholders across the region to enhance their capacity to plan for and adapt to current and future climate change impacts.

Government and other institutions will need the skills, institutional structures, and capacity to plan for and work to mitigate potential impacts such as inundated coastal areas, increased intensity of storms, and changes in water supplies. Since the capabilities of and collaboration among institutions are key factors for adaptation planning and implementation, it is reasonable to ask how well current institutions are situated to address such changes. An additional question is how well the Southeast as a region is situated to adapt to climate change impacts across political lines.

A recent report by the U.S. Government Accounting Office (GAO) on climate change adaptation (GAO, 2009, p. 2) noted that:

> The challenges faced by federal, state, and local officials in their efforts to adapt fell into three categories, based on GAO's analysis of questionnaire results, site visits, and available studies. First, competing priorities make it difficult to pursue adaptation efforts when there may be more immediate needs for attention and resources….Second, a lack of site-specific data, such as local projections of expected changes, can reduce the ability of officials to manage the effects of climate change….Third, adaptation efforts are constrained by a lack of clear roles and responsibilities among federal, state, and local agencies. Of particular note, about 70 percent (124 of 178) of the respondents rated the "lack of clear roles and responsibilities for addressing adaptation across all levels of government" as very or extremely challenging.

1. The "Southeast," as used here, is comprised of the following states within the U.S. Environmental Protection Agency's (EPA's) Region 4 jurisdiction: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

2. If GHG concentrations are held at current levels, global average temperatures could increase up to about 1°F (IPCC, 2007).

The challenges and potential solutions described here for promoting adaptation in the Southeastern United States may help Southern stakeholders begin to address some of the shortcomings identified in the GAO report.

This discussion paper begins with a brief overview of climate change adaptation concepts, including a definition of adaptation, the difference between anticipating and responding to climate change impacts, and whether climate change adaptations are done specifically in response to climate change or for other reasons. The discussion paper then provides an overview of current efforts to promote adaptation management in the United States, including the Southeast region. Next, it presents a brief synopsis of the existing institutions responsible for managing water and coastal resources in the Southeast region and what actions, if any, they have taken to adapt to climate change. The discussion paper then provides a discussion of cross-cutting issues relevant to adaptation in the Southeast for any resource sector and provides some suggested approaches for adaptation stakeholders to collaborate on adaptation issues.

The coastal and water resource sectors were selected to illustrate the issue of climate change adaptation in the Southeast because they are both critical to the environmental and economic health of the region and both are at significant risk from a changing climate. For example, water supplies have become more stressed in the region because of increased demand and droughts. The Southeast also has a long, low-lying coastline that exposes many areas to sea level rise. More extreme precipitation events and intense hurricanes are also a possibility for the Southeastern United States, the impacts of which will likely be exacerbated by higher sea levels.

The coastal and water resource sector examples provided are not intended to be a comprehensive inventory of measures being taken across the region to anticipate and respond to climate change; nor are they meant to imply that other areas of impact are not important. Many other sectors, such as human health, forests, agriculture, wildlife, fisheries, transportation, infrastructure, emergency response, and tourism, are all expected to be affected by climate change. Certain vulnerable parts of the population also will be disproportionately impacted. Instead, the coastal and water resource examples provided here are only meant to illustrate the need for climate change adaptation in the Southeast. This process is expected to be applicable to the wide range of climate impacts facing the region.

The following questions are explored for water resource and coastal resource sectors:

- What institutions manage and regulate the sector?
- How are institutions dealing with current climate-related risks?
- What are the challenges and opportunities for enhancing coordinated efforts on adaptation given current experiences?

This discussion paper was developed to aid participants at an EPA climate change adaptation workshop in Atlanta, Georgia, in February 2010, to identify key regional institutional issues that may be faced by the region as its stakeholders work to adapt to climate change. The discussion paper is not meant to be an exhaustive analysis of climate change adaptation efforts and opportunities in the Southeast, nor is it meant to stipulate required actions; instead, it is only intended to stimulate discussion on the roles of institutions in the Southeast on adaptation and possible collaborations that might enhance efforts on adaptation.

2. Overview of Adaptation

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation to climate change as follows:

> Adaptation to climate change takes place through adjustments to reduce vulnerability or enhance resilience in response to observed or expected changes in climate and associated extreme weather events. Adaptation occurs in physical, ecological and human systems. It involves changes in social and environmental processes, perceptions of climate risk, practices and functions to reduce potential damages or to realize new opportunities. Adaptations include anticipatory and reactive actions, private and public initiatives, and can relate to projected changes in temperature and current climate variations and extremes that may be altered with climate change (Adger et al., 2007, p. 720).

Some adaptations will be made in "anticipation" of climate change. For example, the state of California has proposed reducing water demand by 20% as part of its strategy to adapt to climate change (California Natural Resources Agency, 2009). In contrast, most adaptation actions will likely be "reactive"; that is, they will be made in response to a changing climate or changing conditions. For example, as farmers see crop yields changing, they will likely alter their practices such as the timing of crop planting and harvesting, use of irrigation, application of pesticides or fertilizer, or variety of crop grown. Likewise, government policies on managing affected resources may be updated to reflect changing environmental conditions or societal demands.

Relying exclusively on a reactive approach may result in added or needlessly high costs, such as responding to catastrophic or irreversible effects after the event happens (Easterling et al., 2004). For example, extinction of species is projected to increase dramatically as a result of climate change (Fischlin et al., 2007) and such impacts are essentially irreversible. By not taking steps to assess these vulnerabilities ahead of time, opportunities to adapt efficiently and effectively will be lost (Smith, 1997).

In contrast, anticipating vulnerability and implementing steps to increase preparedness and resiliency can reduce future losses, albeit at the cost of implementing protective measures.

There are two basic types of anticipatory adaptation:

- Those that can be justified because of climate change ("climate change justified adaptations")
- Those that can be justified even without the consideration of climate change ("no regrets adaptations").

Examples of climate change justified adaptations include improving coastal infrastructure such as elevating roadways or structures to anticipate increased storm surge, flooding, and/or sea level rise or restricting development in coastal areas that are expected to experience increased vulnerability. These measures might not be adopted if not for consideration of climate change.

The second type of anticipatory adaptations are measures that can be justified even under current climate conditions. These measures are sometimes referred to as "no regrets actions" because if climate does not change (or does not change as expected), then there is essentially no regret for having implemented the adaptations. Such adaptations make even more sense (i.e., have additional benefits) when climate change is considered. For example, many water conservation programs often can be justified even if climate were not changing (e.g., to address dwindling water supplies and increased competition from population growth). By reducing demand, these programs enable water resources to be used for purposes other than consumption such as instream flow or flood protection, and can provide an additional buffer to cope with droughts. Should climate change reduce water supplies or increase drought intensity, then conservation programs make even more sense. Current adaptation actions are expected to be primarily of the "no regrets" type for several reasons, not the least of which is that it may be easier to justify actions with multiple benefits and which are not based solely on climate change considerations. Justifying large expenditures which may not have benefits for years or decades may be harder for policymakers and the public to accept.[3]

Some impacts of climate change may not be felt in the near-term and the benefits may not be realized for many years. Indeed, there are uncertainties associated with predicting future climate, including the rate and effect of those changes. In such instances, an incremental approach which increases the flexibility of systems to manage or cope with different and changing types of conditions may be appropriate. For example, decisions on long-term investments, such as

3. In recent years, more and more states and municipalities have developed plans to adapt to climate change and it may be easier in the future to support adaptations that are primarily in anticipation of future climate change.

building or retrofitting infrastructure, may include adjustments to reduce future risks over the lifetime of that infrastructure. Flood protection measures, for instance, may be enhanced to anticipate increases in future flooding. Typically, incrementally modifying infrastructure that is being built anyway, such as adding height to dikes or levees or building foundations to accommodate future height adjustments, costs much less than rebuilding at a later date.

3. Overview of Adaptation Efforts in the United States

Adaptation to climate change is being addressed at many levels of government across the United States. The efforts so far are nascent and in many respects not comprehensive. In the Southeast, many different stakeholders are involved with adaptation (see Table 1). Note that this table is meant to illustrate the range of potential stakeholders for adaptation management. It is not meant to be a comprehensive list of all organizations with a stake in climate change adaptation in the Southeast.

This section presents a brief overview of adaptation actions at different levels of government. It begins with an overview of adaptation efforts by local and state governments in the Southeast. It then presents several examples of efforts to address adaptation outside the Southeast region. Finally, it highlights major climate change actions at the federal level. While this is not an exhaustive list or discussion of what governments in the United States are doing, it is indicative of the types of efforts happening in the Southeast and across the country.

3.1 Adaptation Efforts in the Southeast

Adaptation efforts in the Southeast are occurring at both state and local levels. Of the eight states in EPA's Region 4, only Florida has completed a Climate Action Plan and a State Adaptation Plan.[4] North Carolina and South Carolina have included an adaptation plan in their State Climate Action Plans. Even so, at some level, all of the states in the Southeast have started to address climate change in one or more sectors either explicitly or implicitly. For example, Kentucky, Georgia, and Alabama have produced Drought Management Plans that recognize the need to address climate change. Other specific state actions are described below.

4. These Climate Action Plans and State Adaptation Plans were produced by the Center for Climate Strategies (http://www.climatestrategies.us/).

Table 1. Key stakeholders for climate change adaptation in the Southeastern United States

	Government	Universities, nonprofits	Businesses, landowners, citizens
National	U.S. Department of Commerce (National Oceanic and Atmospheric Administration) U.S. Department of Interior (U.S. Geological Survey, Fish and Wildlife Service, Bureau of Reclamation, Bureau of Land Management, National Parks Service, Office of Wildland Fire Coordination, others) U.S. Environmental Protection Agency U.S. Department of Agriculture (U.S. Forest Service, others) U.S. Department of Defense (U.S. Army Corps of Engineers, others) U.S. Department of Health and Human Services (Center for Disease Control) U.S. Department of Transportation, U.S. Department of Housing and Urban Development, U.S. Department of Homeland Security, U.S. Department of Energy, U.S. Global Change Research Program, Council on Environmental Quality, Office of Science Technology and Policy, National Science Foundation, National Aeronautics and Space Administration, Federal Emergency Management Agency, Federal Energy Regulatory Commission, Environmental Council of the States, others		
Southeast regional	State counterparts of national government institutions, Southeast Natural Resources Leadership Group, Southern Governors' Association, Environmental Council of States, Coastal States Organization, Southeast Regional Partnership for Planning and Sustainability, South Atlantic Alliance, others	Land and sea grant universities, regional environmental advocacy organizations, Southeastern Climate Consortium, Southern Regional Climate Center, Regional Integrated Sciences and Assessment organizations, others	Regional and state professional organizations, power producers, large regional landowners, businesses with multiple regional holdings, developers, contractors, others
Local	Regional planning organizations, county/municipal government, local planning organizations, others	Local environmental advocacy organizations, faith organizations, others	Local business owners, local landowners, concerned citizens, others

In 2007, Florida created an Action Team on Energy and Climate Change, which was tasked to develop a comprehensive Florida Energy and Climate Change Action Plan (Center for Climate Strategies, 2008). The Action Plan was developed by key stakeholders and included a section on adaptation. In 2008, Florida's Legislature and Governor created the Florida Energy and Climate Commission (FECC) to be the central state organization on energy and climate change policies, including adaptation. The FECC has been coordinating with the four-county effort under the Southeast Florida Climate Change Compact (see below). Additionally, the Center for Urban and Environmental Solutions published a report, *Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change*, in 2007. This report considers policy options for the following areas: land use planning and building regulation, water supply and delivery, transportation and infrastructure, conservation of natural lands and marine life, beaches and beach management, and extreme events: emergency preparedness and response (Center for Urban and Environmental Solutions, 2007).

In 2005, the North Carolina Legislature created the Climate Action Plan Advisory Group to develop options for the state to address climate change. The group, which included 40 government and non-government stakeholders, delivered its Climate Action Plan report in 2007 (Center for Climate Strategies, 2007). While the report mainly focuses on actions to reduce the state's GHG emissions, it also calls for the creation of a Blue Ribbon Commission on Adaptation to write an adaptation action plan (North Carolina, 2009a). North Carolina's Climate Action Plan also provides a matrix of state adaptation issues such as climate change impacts on coastal resources (e.g., tropical storms, rising sea levels), forestry and agriculture, water quality and quantity (e.g., saltwater intrusion into aquifers, drought risk, flooding, storm water runoff), air quality, public health, economic issues, and other issues (Center for Climate Strategies, 2007).

South Carolina created the South Carolina Climate, Energy & Commerce Advisory Committee (CECAC) in 2007 (EO 2007-04). Similar to the advisory group in North Carolina, CECAC released a report in 2008 that focused primarily on mitigation. The report also called for the creation of a blue ribbon panel on adaptation to climate change to develop a state Climate Change Adaptation Plan (South Carolina, 2009). This recommended plan could help South Carolina identify and address potential climate change impacts (e.g., impacts on public health and natural and wildlife resources). South Carolina also has a Shoreline Change Advisory Committee (SCAC). SCAC recently released a draft report on adapting coastal areas to changing conditions (SCAC, 2009).

A number of counties and municipalities in the Southeast have also started to address climate change adaptation. For example, the Florida counties of Broward, Miami-Dade, Palm Beach, and Monroe signed the Southeast Florida Regional Climate Change Compact to coordinate positions on state and national legislation on climate change and to coordinate activities on mitigation and

adaptation. They also committed to preparing an action plan that will include adaptation strategies (Broward County, 2009).

The Charlotte Harbor National Estuary Program (CHNEP), in cooperation with the city of Punta Gorda, has prepared a city of Punta Gorda Adaptation Plan, which was approved in November 2009. The document identifies current and projected changes and potential vulnerabilities to the Punta Gorda community due to climate change, as well as the alternative adaptations that could be undertaken to address these identified climate change vulnerabilities. CHNEP is also preparing a Climate Change Vulnerability Assessment, which will provide three climate change scenarios and identify vulnerabilities to a range of human and natural resources.

3.2 Adaptation Efforts Outside the Southeast

A number of states outside of the Southeast region have begun development of adaptation plans. Perhaps furthest along is the state of California, whose Department of Natural Resources recently released a draft strategic plan on adaptation (California, 2009). The plan calls for comprehensive assessment and planning for climate change risks. Among other actions, it calls for a 20% reduction in per capita water use consumption by 2020. It also recommends avoiding significant new development in areas that cannot be adequately protected from flooding caused by climate change.

Several other states have developed plans to identify adaptations. Alaska, which may already be facing significant impacts from climate change, created a Climate Change Sub-Cabinet in 2007 to provide advice on climate change. The Sub-Cabinet organized a report by stakeholders on public infrastructure, health and culture, natural systems, and other economic activities. The Sub-Cabinet group has paid particular attention to the immediate needs of communities at risk from flooding and erosion (Alaska, 2009).

Maryland has also taken actions to address climate change adaptation. It established a Climate Change Commission in 2007 to develop an action plan on climate change. The plan, which was released in August 2008, focused on how Maryland can respond to rising sea levels and increasing coastal storms (Maryland, 2009). Following the plan, the Legislature enacted a Living Shoreline Protection Act which requires the Maryland Department of Environmental Protection to create maps that identify which shorelines will be allowed to have hard shore protection and which shores must either retreat or be protected using nonstructural measures [MD Code Environment §16-201 (C)].

Some counties and municipalities have also been taking action on adaptation. For example, King County in Washington designed the Brightwater treatment system (scheduled to be online in 2010) to produce reclaimed water in anticipation of increased drought conditions resulting from

climate change. King County has also developed a King County Climate Plan. One of the specific actions of the Climate Plan is to "produce and promote the use of reclaimed water that can be used for industrial and irrigation purposes to help offset the potential impacts of climate change on summer streamflows and water supplies" (King County, 2007). King County and the International Council for Local Environmental Initiatives also published guidance on how local, regional, and state governments can prepare for climate change (Snover et al., 2007).

Among municipalities, New York City has been a leader in developing a comprehensive program on adaptation. The New York City Panel on Climate Change has recommended that the city prepare for risks such as sea level rise, increased coastal storms, increased freshwater flooding, and more intense heat waves (New York City Panel on Climate Change, 2009). Many other municipalities, ranging in size from Chicago and Seattle to Keene, New Hampshire, have assessed their vulnerability to climate change and begun taking steps to reduce such vulnerabilities.

3.3 Federal Planning Efforts on Climate Change Adaptation

The federal government has taken a number of actions on the planning side[5] to address climate change adaptation. Several federal agencies have started developing strategic plans and even reorganizing to work on adaptation. EPA's National Water Program, for example, developed the *National Water Program Strategy: Response to Climate Change* (U.S. EPA, 2008b). This strategy identifies 44 "key actions" to help water programs adapt to a changing climate. While some of the actions address opportunities for GHG mitigation activities, most directly address adaptation to climate change impacts.

More specifically, the strategy calls for changing the National Water Program to identify and develop adaptive responses to the impacts of climate change. Key priorities include expanding EPA's water research agenda both internally and with other agencies or research entities to incorporate climate change; educating water program professionals and stakeholders on the impacts of climate change on watersheds, water supply, water infrastructure, and water quality, including information and technical assistance to state, local, and tribal water managers; and developing capacity to monitor EPA's program from a climate change perspective on a sustained basis while more systematically addressing climate change impacts both at regional levels and with other agencies. EPA's National Water Program began implementing response actions in 2008, and will continue this work in 2010. EPA is currently revising and updating this strategy to address work in future years.

5. This paper does not address federal *research* efforts on climate change adaptation.

In 2008 the U.S. Department of the Interior (DOI) issued three strategic plans on adaptation (U.S. DOI, 2008). In September 2009, the Climate Change Response Councils were created to improve information sharing; Regional Climate Change Response Centers to integrate climate change information and management strategies in eight regions; and Landscape Conservation Cooperatives to work with states and localities to manage climate change impacts within eight DOI regions (U.S. DOI, 2009). The U.S. Fish and Wildlife Service (USFWS) also released its Climate Change Strategy and Five-Year Action Plan in September 2009 to guide its efforts to respond to the impacts of climate change on fish, wildlife, and their habitats (USFWS, 2009a). The strategic plan calls for developing specific adaptation implementation strategies such as habitat conservation and habitat connectivity, and meeting priority freshwater needs in refuges.

A number of other federal agencies are also developing capacity to assess and address the impacts of climate change. For example, the Federal Highway Administration (FHWA) is preparing for climate change effects on the transportation system (FHWA, 2009) and the Centers for Disease Control and Prevention (CDC) is working to address the health issues that may be associated with global climate change (CDC, 2009). University researchers and nonprofits are also increasingly engaged in finding solutions to the negative aspects of a changing climate.

President Obama signed an Executive Order in October 2009 that requires federal agencies to reduce their GHG emissions and requires them to "evaluate agency climate-change risks and vulnerabilities to manage the effects of climate change on the agency's operations and missions in both the short- and long-term" (The White House, 2009, p. 9). The Council on Environmental Quality (CEQ) is also coordinating a number of interagency work groups on adaptation science, agency adaptation process, water, insurance, and supporting international resilience efforts.

Congress currently has before it several pieces of legislation that include provisions regarding climate change adaptation. Among the most prominent is the Waxman-Markey Bill, which passed in the House of Representatives in June 2009. This bill calls for a national adaptation program as well as strategies on human health and natural resources. The bill provides funding for state adaptation plans and for state, local, and tribal adaptation projects. The Kerry-Boxer Bill recently introduced in the Senate, calls for the federal government to develop a natural resources adaptation plan, funding for state adaptation planning, and support for international adaptation.

As demonstrated by the examples above, the federal government has taken many initial steps toward addressing the need for climate change adaptation strategies. Additional actions are occurring at the local and state levels. To further illustrate adaptation efforts in the Southeast, the following sections focus on the water and coastal resource sectors in the Southeast region and the laws, institutions, and actions associated with protecting these resources. Challenges to adaptation and potential solutions to these challenges are also presented for each sector.

4. Water Resources

Climate change will impact many water resource subsectors in the Southeast. Such resource subsectors include (but are not limited to) groundwater and surface water supply, water quality, inland flooding, instream flows, and drinking water (see Table 2). The list of impact areas and potential impacts of climate change presented in Table 2 are by no means comprehensive, and are presented to briefly overview the range of impacted areas and consequences of climate change, including what entities may be most affected. The interconnectedness of many of these impacted areas will likely make it difficult to independently manage these resources and the consequences of climate change. For example, changes in water supply will affect agricultural production, landscaping/irrigation, water quality, instream flows, etc. As climate change impacts are realized, it may become increasingly important to manage these resources in a more integrated manner, rather than managing each resource subsector independently.

This section highlights four important water resources subsectors that are critical in the Southeast: water supply, water quality, inland flooding, and instream flows. These four resource subsectors illustrate the larger problems facing the water resource sector. Effective management of these subsectors could require addressing many challenges, including exacerbated competition for water resources, impairments of water quality, and altering flood management practices. Climate change also poses a variety of challenges to environmental protection, navigation, irrigation, energy production, recreation, agriculture, ecology, and human consumption. Federal, state, regional, and local government entities will likely be integral to addressing many of these challenges.

4.1 Water Supply

Water supply planning and management in the Southeast will likely become increasingly challenging as climate change, population growth, and urbanization continues and as competition for water resources increases. Water supply management involves managing both surface water and groundwater resources. Both will be affected by climate change, but not necessarily in the same ways. For example, as shown in Table 2, warmer temperatures, reduced precipitation, and changes in the pattern and timing of rainfall in parts of the Southeast will further reduce surface water supplies and create more stress on fish and wildlife, farmers (irrigation of crops and water for livestock), and recreation. In addition, rising sea levels and more intense storm surges will cause salt water to intrude into coastal aquifers (i.e., groundwater), which will likely further reduce the available supply of potable water supplies in the Southeast.

Table 2. Climate change impacts on the water resources subsectors

Water resource subsector	Potential impacts of climate change	Affected entities
Groundwater supply	Salt water intrusion, increased concentration of rainfall in heavy precipitation events leading to less infiltration into groundwater, increased droughts in some areas causing drying of lakes, ponds, and wetlands.	Farmers/agriculture, homeowners and businesses relying on wells, fish and wildlife, landscaping/irrigation.
Surface water supply	Increased frequency of droughts, decreased summer precipitation, increased salinity in coastal areas.	Farmers/agriculture, fish and wildlife, recreation, municipal and industrial consumers, energy companies, including hydropower operations, landscaping/irrigation, navigation, rate payers.
Water quality	Decreased summer precipitation; increased heavy precipitation events, sewer overflow events, human health effects, hypoxic conditions, thermal stratification, algae, nutrient runoff, and lower flows; increased temperatures will reduce dissolved oxygen in streams, lakes, and shallow aquatic habitats which could lead to increased fish kills and losses of aquatic species diversity.	Consumers, fish and wildlife, water treatment plants, vulnerable populations (e.g., elderly, children, poor), endangered and threatened species, recreation.
Inland flooding[a]	Increased heavy precipitation events, more frequent and severe flooding events, increased flood damages and insurance rates, increased incidence of water-borne diseases.	Communities in floodplains, communities without flood insurance, transportation and infrastructure, insurance industry.
Instream flows	Increased heavy precipitation events; decreased summer flows, which decreases water available for cooling and reduces hydropower production, effects on estuaries.	Fish and wildlife, hydropower operations, consumers, recreation, endangered and threatened species, energy companies, rate payers.
Drinking water	Increased frequency of droughts, decreased summer precipitation, increased nonpoint source pollution from heavy rain events, increased costs to treat.	Consumers, especially those who rely on groundwater and surface water intakes from tidal rivers for drinking water. Water treatment facilities.

a. Coastal flooding is discussed in a coastal resource section (Section 5.2).

Groundwater supplies in the Southeast are particularly important because certain areas in the region rely on groundwater for drinking water and irrigation. In Florida and Mississippi, for example, people who are served by public water supplies withdraw nearly 90% of their water supply from groundwater. Mississippi withdraws groundwater to provide 92% of its irrigation water while Alabama, Florida, Georgia, South Carolina, and Tennessee rely on groundwater withdrawals for at least 46% of their irrigation water (Kenny et al., 2009).[6]

The sections below illustrate the institutional and legal arrangements for managing water supplies in the Southeast, some of the current actions by institutions to address climate change, and challenges for future water supply planning in light of climate change.

4.1.1 Management and regulation

Water supply management in the Southeast has become an increasingly important issue in the last 30 years primarily due to population growth, droughts, and urbanization. As such, many states in the Southeast have already been dealing with competing water uses and demands. This section presents a brief history of some of the relevant laws and authorities responsible for managing water supplies in the Southeast.

Different legal frameworks allocate authority to (1) provide standard principles and guidelines for water resource agencies to follow when designing and operating projects, (2) allocate water, and (3) build, maintain, and operate infrastructure for water supply projects. The Water Resources Act (WRA) of 1965 and the Water Resources Development Act (WRDA) of 2007 provide the legal authority for the first responsibility; a variety of state statutes and regulations largely provide the legal authority for the second responsibility; and the WRA of 1958 provides the legal authority for the third responsibility.

Creating principles and guidelines

The WRA of 1965 created the U.S. Water Resource Council, an independent executive agency of the U.S. government, to establish principles, standards, and procedures for preparing regional or river basin plans and for the evaluation of federal water and related land resources projects (42 U.S.C. 1962a-2). The Water Resource Council first published these principles and guidelines in 1973 and a subsequent revision in 1983. Since then, the Water Resources Council has essentially been defunct.

6. Irrigation water is used via sprinklers, micro-irrigation, and surface (flood) systems (Kenny et al., 2009).

The WRDA of 2007 directed the Secretary of the Army to revise the 1983 principles and guidelines [Public Law (PL) 110-114 §2031]. The proposed purpose of these principles and guidelines is to guide national water resources planning for federal agencies [e.g., the U.S. Army Corps of Engineers (USACE), Bureau of Reclamation, Natural Resources Conservation Service, and the Tennessee Valley Authority (TVA)]. The USACE published the first draft of the principles and guidelines in September 2008 and received public comments (73 FR 52960). In the proposed principles and guidelines, USACE (2009a) specifically states that there should be an evaluation of the impacts and potential effects of climate change.[7] The CEQ recently updated these guidelines and also included the need to address risk and uncertainty, including the effects of climate change and future development (CEQ, 2009). Additionally, these revised guidelines recommend that actions be taken to inform the public about how climate change may affect future flood and storm events (CEQ, 2009).

Other nongovernmental organizations (NGOs) also have a stake in water supply planning and management, such as the American Water Works Association (AWWA) and the Water Resource Foundation (WRF).

Allocating water

Traditionally, the courts in the Southeast region have applied the riparian rights doctrine to settle disputes over water resources. This doctrine bases access to water on ownership of land abutting a watercourse. Nevertheless, Southeastern states have enacted new laws or management schemes to move away from a pure riparian rights doctrine (Christy et al., 2005). For example, Alabama, North Carolina, South Carolina, and Tennessee adopted a registration/certification system; Florida adopted a statutory water management scheme; and Georgia, Mississippi, and Kentucky have a broader, statewide permitting program to regulate withdrawal and use (Christy et al., 2005).

The federal role in the allocation of water rights is limited. The Clean Water Act (CWA) states that “the authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired” and that nothing “shall be construed to supersede or abrogate rights to quantities of water which have been established by any State” [33 U.S.C. §

7. Based on requirements in WRDA 2007 [PL 110-114 §2031(b)(4)(A)], USACE submitted the draft principles and guidelines to the National Academy of Sciences for review, who deemed them to be too vague. As a result, CEQ, in coordination with the Office of Management and Budget, facilitated interagency revisions of the proposed principles and guidelines (74 FR 31415) and released the draft revisions on December 3, 2009. CEQ has proposed to extend the principles and guidelines so that they apply to other nontraditional water resource development agencies as well. These guidelines could promote regional coordination of water resources and force water resource agencies to consider the effects of climate change. The principles and guidelines will apply not only to water supply projects, but also to the construction of dams, flood control projects, and navigation, ecosystem restoration, and water distribution systems.

1251 (g)]. One exception to this is for USACE-operated reservoirs. While USACE's primary role is to provide navigation, flood control, and environmental protection, it plays a secondary role by providing water for municipal, industrial, and agricultural uses. Allocating water for these types of projects has become increasingly important in light of climate change and population growth in the Southeast.

As droughts and water shortages have become more common in the Southeast in recent years, USACE has assumed the role of a water supplier in many areas. The USACE, however, does not have the legal authority to sell or allocate water for supply purposes (Carter et al., 2008) unless water supply is a primary use for the reservoir. Instead, it has a responsibility to appropriate allocations or reallocations among the stated purposes for each reservoir, which are generally flood control, navigation, and environmental protection. As droughts and water shortages persist in the Southeast, the issue of federal authority over water supply issues could become more prominent and require attention.

Construction, maintenance, and operation

Under the WRA of 1958, water supply for domestic, municipal, industrial, and other purposes is primarily a state and local responsibility [PL 85-500 §301(a)]. The federal government (e.g., the USACE or the Bureau of Reclamation) assists states and local interests by developing water supplies associated with construction, maintenance, and operation of federal navigation; flood control; irrigation; or multiple purpose projects [PL 85-500 §301(a)]. Furthermore, the WRA of 1958 states that "storage may be included in any reservoir project surveyed, planned, constructed or to be planned, surveyed and/or constructed by the Corps of Engineers or the Bureau of Reclamation to impound water for present or anticipated future demand or need for municipal or industrial water" provided that the state or local interests pay the cost [PL 85-500 §301(b)]. In USACE's southern Atlantic division – which includes all of Florida and parts of Alabama, Georgia, Mississippi, North Carolina, South Carolina, and Virginia – the USACE has 25 contracts with a total storage space of 206,092 acre-feet, yielding 27,400 million gallons of water per day (USACE, 2009c).

Water supply planning occurs, at least initially, at the local level. As demonstrated by issues associated with the Apalachicola, Chattahoochee, and Flint (ACF) and the Alabama, Coosa, and Tallapoosa (ACT) watersheds (Section 4.1.3), however, water supply planning can quickly become a regional, multi-state issue.

Under the WRDA of 2007, the Secretary of the Army is required to promulgate principles and guidelines that adopt a more regional or watershed-based approach [PL 110-114 §2031(b)(3)(D)], incorporating integrated water resources management and adaptive management [PL 110-114 §2031(b)(3)(E)].

4.1.2 Current planning for climate-related risks

Currently in the Southeast, incorporation of climate change into water supply management typically happens at the state level on a case-by-case basis. For example, the region has not had a history of prolonged droughts or water shortages and some Southeastern states have only recently started strategic planning for future water supplies. As another example, coastal states have started to experience salt water intrusion into coastal aquifers, partly due to rising sea levels and more intense storm surges. As a result, many states have started restricting groundwater withdrawals. These efforts may either explicitly recognize climate change as a factor in the management strategy; in other instances, climate change may only be an implicit consideration (or no consideration at all).

Examples of Southeastern states and institutions that are beginning to address climate change impacts on water supply include:

- Florida's Department of Environmental Protection created five water management districts (WMDs) to coordinate regional efforts to manage the state's water supplies, including the impacts of climate change.
- Kentucky, Georgia, and Alabama have Drought Management Plans that include the mention of climate change and the need to change the current program to address future climate.
- Georgia produced a State Water Plan (SWP) in 2008 that called for the Georgia Department of Natural Resources to develop a Water Conservation Implementation Plan (WCIP). The WCIP was released in May 2009. While it does not cite climate change as a large driver for the adaptations, it does consider ways to increase water efficiency and to cope with increasing demands and uncertainty of supplies. The SWP also created 10 regional water planning councils to coordinate water supply management.
- The Metropolitan North Georgia Water Planning District[8] published a Water Supply and Water Conservation Management Plan in May 2009. This plan acknowledges the impacts of climate change on water supply planning and proposes measures (e.g., reclaimed water) to mitigate the impacts of climate change.
- Other states are focusing on vulnerability assessments such as the modeling being conducted in North Carolina.

8. The Metropolitan North Georgia Water Planning District was established by the Georgia General Assembly in 2001. It is separate from Georgia's water planning councils.

Other institutions' activities, such as those of the TVA and the Florida WMDs, provide models for addressing potential climate change impacts on a more regional level. These two organizations are discussed below.

Tennessee Valley Authority

Congress established the TVA in 1933. TVA's mission is to provide affordable energy, environmental stewardship, and economic development for the seven states in the Tennessee River Valley: Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia.[9]

TVA is considered one of the largest water resource management agencies in the United States. Its integrated management of the Tennessee River system helps secure water for drinking, industrial, and agriculture uses; for generating hydropower and cooling coal-fired and nuclear power plants; and for navigation, recreation, and aquatic habitat for plants and animals.

TVA has worked with the seven states in the valley to develop a hydrologic model for the Tennessee River. The model provides a basis for water supply management and planning, which could be used to plan for climate change; however, it is primarily used for scheduling electric power production. TVA uses the model to time releases for hydroelectric production, to ensure supplies of cooling water for its coal and nuclear-fired power plants, and to maintain barge traffic.

Florida Water Management Districts

Florida's history of water management dates back to the 1800s (SJRWMD, 2010). The first form of a WMD (the Everglades Drainage District) was created in 1907. The Okeechobee Flood Control District took over many of the Everglades Drainage District activities in 1929. In 1949, the Florida Legislature created the Central and Southern Florida Flood Control Districts to take over activities by the Okeechobee Flood Control District and (in 1955) the Everglades Drainage District. This district became the South Florida WMD in 1975. In 1961, the Southwest Florida WMD was created. Finally, the Florida WRA created five regional WMDs in 1975. In recent years, the WMD has started to focus more on the impacts of climate change.

Florida's five WMDs provide an example of regional cooperation to address water resource issues and eventually climate change. WMD boundaries are based on the watershed(s) that they manage. The WMD service areas typically include all or parts of many different counties and other federal, state, local, and tribal political (or agency) boundaries. These districts include Northwest Florida, Suwannee River, St. Johns River, South Florida, and Southwest Florida (see

9. Note that Virginia is the only state in the TVA that is not a part of EPA Region 4.

Figure 1). The WMDs administer flood protection programs, develop water management plans for water shortages resulting from drought, acquire lands for water management, administer the stormwater management program, and regulate programs to manage the consumptive use of water, aquifer recharge, well construction, and surface water quality.

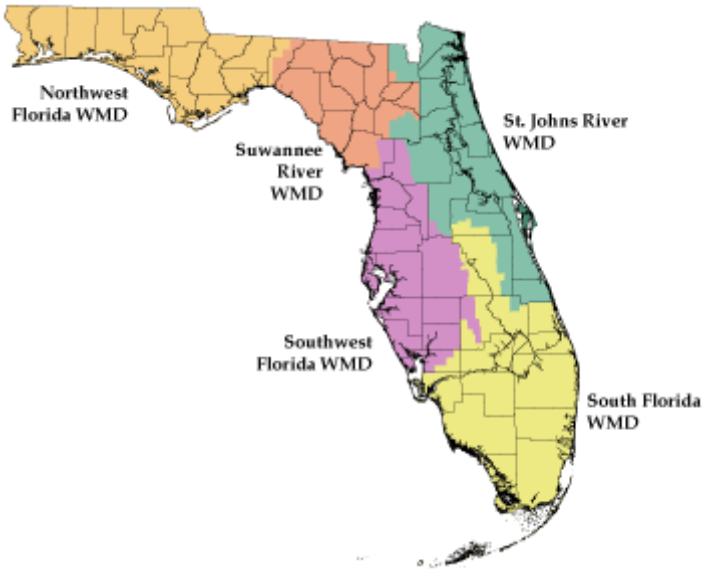

Figure 1. Map of the Florida WMDs.

Source: Florida DEP, 2009b.

The Southwest Florida WMD and the South Florida WMD provide examples of current actions taken by Florida's WMDs. The Southwest Florida WMD has undertaken significant adaptive planning to address future climate change impacts. The Southwest Florida WMD works with all of its local governments (partners) for water supply planning, flood control, water quality, and natural systems protection and outreach. It has a long-standing, successful initiative of 50/50 cost sharing with local partners – the most extensive cooperative funding effort among the WMDs – and funding is distributed on a subregional basis.

On the water supply side, the Southwest Florida WMD funds reservoirs; interconnection of facilities, one of the largest reclaimed water distribution and transmission networks in the country; and the largest saltwater desalination plant in the country. Each of these projects helps ensure diversification of water resources for the Southwest Florida region.

The South Florida WMD recently published a draft white paper summarizing the impacts and vulnerabilities from climate change and considering adaptation actions (Jayantha Obeysekera, South Florida WMD, personal communication, November 30, 2009). The paper incorporates climate outlook forecasts in its water management planning to help balance the needs of urban and agricultural water users and the restoration of the Everglades system (Trimble et al., 2006). It also evaluates future scenarios of water and environmental conditions that influence management decisions on seasonal and multi-seasonal lead times. To date, the South Florida WMD has focused primarily on identifying impacts and vulnerabilities for the region and has not identified or evaluated adaptations actions (Jayantha Obeysekera, South Florida WMD, personal communication, November 30, 2009). However, the South Florida WMD has begun examining the uncertainties of climate change impacts and developing modeling tools necessary for evaluating adaptation strategies.

4.1.3 Challenges

Southeastern states have started to take steps toward addressing climate change impacts on water supply, although in some cases with no explicit consideration of climate change. To date, most actions are still at the planning and assessment phases. Even so, more efforts are likely needed to protect water supplies in the region. In transitioning from planning to action, states in the Southeast will face many challenges, including:

- Southeast regional institutions (see Table 1) that can address climate change within their jurisdictions cover only a portion of the Southeast, especially institutions organized along major river basins.[10] In cases such as TVA or the Florida WMDs, regional authorities have taken an active role in watershed-wide coordination. Other geographic areas or basins either do not have such institutions or those institutions are too new to produce a visible impact.

- The USACE reallocation process can be labor and time intensive, and can result in litigation (as is the case in the ACF-ACT river basins). The WRA of 1958 states that any modification of projects that would "seriously affect the purposes for which the project was authorized, surveyed, planned, or constructed, or which would involve major structural or operational changes shall be made only upon approval of Congress" [PL 85-500 §301(d)]. Therefore, Congressional legislation may be needed to make reallocation less cumbersome. Without some regional coordinating mechanisms, it may be difficult to implement a more flexible process.

10. While some federal agencies have regional offices, this statement refers to regional institutions that are not represented by a headquarters office at the national level. See Table 1 for a clarification of roles.

- To the extent that local authorities must pay for or contribute to adaptation, vulnerable populations with low incomes may not have the resources to pay for water resource infrastructure or other projects needed for adaptation. This may become increasingly important as droughts become more severe in the region. Note that the difficulty of low-income communities paying for adaptation extends to other matters besides water supply. It will likely be a challenge in these communities to adapt to changes in water quality, instream flow requirements, and flood protection. It may also be a challenge for poor coastal communities to adapt to increases in sea level and coastal storm intensity.

- Population growth and economic expansion over recent decades have contributed to increased stress on water supplies in the Southeast. One recent study, for example, found that although the recent drought in the Southeast was severe, it was not unprecedented (Seager et al., 2009). This suggests that socioeconomic changes may be the primary driver behind the increased water shortages during droughts. Continued population and economic growth could continue to play a significant role in further stressing water supplies. To be sure, climate change could exacerbate the situation. This suggests that adaptations should take into account the effects of increased population on demand for water resources in addition to climate change.

Some of the issues involved in managing water supply and adapting to climate change can be identified by examining a case study in detail. The box below highlights the challenges associated with reallocation of water uses in two river basins: the ACF and the ACT river basins. These river systems are collectively referred to as the ACF-ACT river system, comprising 42,400 square miles.

4.2 Water Quality

Institutions and regulations emanating from the CWA have a long track record for managing the quality of the nation's waters with respect to point source pollution, and efforts are underway to better manage nonpoint source pollution. Even so, climate change will still present new challenges and could require new roles and responsibilities for institutions or additional guidance for resource managers. The sections below illustrate the institutional and legal arrangements that underpin water quality management, the current actions by institutions to address climate change, and challenges for future water quality planning in light of climate change.

ACF-ACT river basins

Alabama, Florida, and Georgia share the ACT Basin. Along these river systems there are 10 large dams operated by USACE and 21 non-federal dams. Many were constructed for multiple uses, including hydropower, navigation, recreation, water supply and quality, flood control, and fish and wildlife protection.

The USACE water control manuals (along with the ACF and ACT river basin water control manuals) specify water management operations for each reservoir, including regulation schedules, provisions for storage and releases, and policies and data protocols for flood control and drought contingency operations (NAS, 2009).

The ACF-ACT river system provides habitat for 65 species listed as endangered or threatened under the Endangered Species Act, including four freshwater mussels and the gulf sturgeon (USFWS, 2009b). As a result of drought conditions in 2006, the USACE entered a formal consultation with the USFWS to set flow requirements for endangered species in the lower reaches of the Apalachicola River (NAS, 2009). They also developed an Interim Operation Plan for federal reservoirs in the ACF Basin.

Source: Inkelas, 2009.

Population growth and drought conditions increased water demands and created disputes over allocation of these water resources, which eventually led to litigation that has been ongoing since the 1980s.

On April 3, 2009, staff members from the National Academies' Water Science and Technology Board and others held a one-day workshop, "Water Issues in the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa (ACF-ACT) River Basins." This workshop brought together 50 stakeholders to identify key management challenges, topics of study, and questions need to be answered to support water management decisions. Invited speakers gave presentations on the effects of climate variability, drought, and climate change on the Southeast region and on future management decisions (NAS, 2009). The ultimate conclusion from the workshop is that water demands have started to exceed available supplies and that many water managers and planners need to consider a range of issues, including how climate change will impact future water storage and demand (NAS, 2009).

On July 17, 2009, a U.S. District Court ruled that Congress should approve use of the water from Lake Lanier for water supply. In addition, the Court ordered that all water withdrawals be frozen at current levels for the next three years until Congress authorizes a change in allocation or until some other resolution is reached. If Congress does not approve a reallocation within that period, then water withdrawals from Lake Lanier will revert to "baseline" operation of the mid-1970s (U.S. District Court Middle District of Florida, 2009).

4.2.1 Management and regulation

The CWA sets the foundation for surface water quality policy and regulations in every state and gives EPA the authority to ensure that states comply with its provisions. States develop water quality standards that are equal to or more stringent than the federal standards. They cannot, unless fully justified, have less stringent standards. Every three years, states must review their water quality standards and submit their reviews to EPA for approval [CWA §303(c)(1)]. The water quality standards comprise designated uses of the water body, water quality criteria to protect designated uses, an anti-degradation policy to maintain and protect existing uses, and general policies addressing implementation issues (e.g., low flows, variances, mixing zones). States must also develop lists of impaired waters that do not have controls sufficient to meet water quality standards [CWA §303(d)]. For these impaired waters, states must establish Total Maximum Daily Loads (TMDLs). TMDLs establish the maximum amount of a pollutant (or of pollution) that a water body can receive and still meet water quality standards (U.S. EPA, 2009b).

The National Pollutant Discharge Elimination System (NPDES) is a program under the CWA that regulates the quality of discharges into the nation's water bodies. The NPDES program initially focused on discrete point source discharges (e.g., pipe outfalls) and now also has regulatory programs that deal with potential discharges that might also have been considered nonpoint sources, such as industrial and municipal stormwater [CWA §402(p)]. Under the NPDES program, EPA issues permits for operators of large and small municipal separate storm sewer systems (MS4s) and for runoff associated with industrial operations and construction. Stormwater NPDES permits issued to industry and construction permit operations require implementation of stormwater controls to meet narrative and/or numeric effluent limits as well as documentation of the controls used on-site in a stormwater pollution prevention plan. MS4 permit recipients must develop and implement a stormwater management plan. In their review of this program, the National Academy of Science noted that the success of the stormwater program has been hindered by inadequate monitoring and resources for compliance inspections (NAS, 2008).

EPA Region 4 has been a leader in promoting water quality planning at the watershed level. This is a newer trend that is eventually intended to replace the program-by-program, source-by-source, pollutant-by-pollutant strategy.

4.2.2 Current planning for climate-related risks

Certain EPA programs, including EPA Region 4 programs, address water quality issues in the Southeast and could have an increasing role in supporting adaptation to climate change. EPA's Climate Ready Estuaries (CRE) Program addresses climate change effects. The Gulf of Mexico

Alliance is also a contributor. The CRE and Gulf Alliance programs are addressed in the section on Coastal Resources. Additional efforts include Region 4's efforts on watershed planning and the new Climate Ready Water Utilities program. Descriptions of both national efforts that affect the region and the region's efforts to address climate change impacts on water quality are listed below.

- EPA Region 4 has undertaken a concerted effort to address meeting water quality goals through a watershed approach. The Region has identified priority watersheds and is actively working with local communities to address watershed related water quality problems. This approach addresses all aspects of influence on water quality including potential future changes in flow and pollutant sources.

- In May 2009, the National Drinking Water Advisory Council (NDWAC)[11] approved the formation of the Climate Ready Water Utilities Working Group (CRWUWG). CRWUWG's objective is to make several recommendations to NDWAC about ways to help water utilities develop climate change adaptation and mitigation strategies. This will include helping utilities use existing climate change information, identifying climate change tools, training, and other products to inform management and decision-makers, and identifying incentives for utilities that adopt adaptation and mitigation strategies.

Other examples of possible opportunities to incorporate climate change into planning and decision making include:

- The Southwest Florida WMD has a strong monitoring network for surface- and ground-water resources (including coastal monitoring for salt water intrusion) and provides a large portion of the data used by the Florida Department of Environmental Protection to identify impaired water bodies and to set TMDLs (Miki Renner, Planning Manager, Southwest Florida WMD, personal communication, November 30, 2009).

- The Miami-Dade water and sewer department is planning on allocating $30 billion for capital improvements. Two billion dollars of that will go toward alternative water supply initiatives; $10 billion will go toward water/wastewater system improvements; and $1 billion to protect against sea level rise impacts (CH2MHILL, 2009).

11. NDWAC is a federal advisory committee established and operating under the requirements of the Federal Advisory Committee Act.

4.2.3 Challenges

More actions will probably be needed to deal with the likelihood for increased heavy precipitation events; decreased summer precipitation; and increased episodes of sewer overflow events, human health effects, hypoxic conditions, thermal stratification, algae, nutrient runoff, and lower flows (Table 2). Some of the major challenges associated with planning for these impacts include:

- The ability of institutions to deal with the large amount of pollution from agriculture and urban runoff could be made worse with climate change. More intense precipitation events will likely increase loadings from both nonpoint sources and stormwater loadings. More systematic improvement in the nonpoint source pollution prevention program may be needed to cope with such changes.

- Federal and state programs will likely need to adapt to changing runoff and water quality conditions to ensure water quality protection (e.g., TMDL, NPDES permits, MS4 permits, watershed planning). This could include the need for data and monitoring to detect background changes, as well as methods to take into account more extremes. For example, how should TMDLs and NPDES permits be adjusted to accommodate lower flows resulting from droughts as well as higher flows from intense precipitation? How will increased water temperatures affect water quality standards as well as NPDES permits? What data and revised methods and tools will be needed to aid program managers? How should uncertainty be factored in? Should the permitting process react to observed changes or attempt to anticipate future changes? A reactive process will use observations, but will always be essentially catching up to changing environmental conditions. An anticipatory process can attempt to put pollution controls in place in advance of when they are needed but would present resource and regulatory challenges.

- Water infrastructure is already facing a funding gap to maintain aging systems and accommodate population growth, and climate change will most likely impose additional demands. CH2MHILL (2009) found that for water and wastewater sectors, the estimated range of net present value capital and overhead and managements costs to address climate change needs through 2050 is between $99 and $196 billion for the Southeast alone.[12] However, given the already existing need to retrofit and build infrastructure, climate change adaptation can be incrementally built into capital planning. Another critical question is who should pay. Should the funding burden fall upon a single sector such as municipalities or the private sector or will it be shared across some combination of local, state, and federal sectors?

12. In this study, the Southeast includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia.

4.3 Inland Flooding

Increased inland flooding due to more intense extreme precipitation events will most likely present additional challenges for flood managers in the Southeast. Currently, flood management is initiated and funded at the federal level with states and localities providing oversight and enforcement of regulations. After Hurricane Katrina struck the Gulf Coast, states started to question their preparedness for such storms. The events following Katrina highlighted systematic weaknesses, and raised concerns about institutional capabilities and the capacity to anticipate and respond to changes in climate. The sections below illustrate the institutional and legal arrangements for flood management, the current actions by institutions to address climate change, and challenges for future planning in light of climate change.

4.3.1 Management and regulation

The federal government has a major role in flood management through providing flood control projects, insurance, and floodplain mapping.

Flood control projects

At the federal level, USACE provides several functions for flood management and control in the Southeast and elsewhere. These functions include providing flood risk and water management information, coordinating federal and state agency assistance to local communities for flood hazard mitigation, inspecting and certifying projects, rehabilitating damaged levees, and implementing structural and nonstructural flood damage reduction projects. In May 2006, USACE established the Flood Risk Management Program to coordinate USACE programs and activities with their counterparts in the Department of Homeland Security, the Federal Emergency Management Agency (FEMA), other federal agencies, state organizations, and regional and local agencies. Examples of other organizations include the Association of State Floodplain Managers and the National Association of Flood and Stormwater Management Agencies.

USACE has traditionally paid for a number of flood management projects, though there is now a program that requires local governments to cost-share as well (see Section 4.1.1 regarding the WRA of 1958). Flood management projects are built according to federal regulations. Additionally, USACE uses the 1983 principles and guidelines for detailed planning and design guidance (see Section 4.1.1).

Flood insurance

To provide flood insurance to communities, the federal government created the National Flood Insurance Program (NFIP), which is administered by FEMA. Communities that wish to secure flood insurance must participate in NFIP and sign a community agreement, which contains the requirements set by FEMA for flood control measures to reduce future flood risks. The overall responsibility for enforcement of the community agreement lies with the local zoning and planning organizations. A state agency then has the responsibility to ensure that local governments meet the requirements of the community agreement. If a community does not comply with the community agreement, they are not eligible to receive flood insurance. The private sector (i.e., the insurance carrier) writes the insurance policies, but the NFIP takes on the actuarial risk. Because coverage is limited to $250,000 for homes and $500,000 for commercial properties, property owners sometimes acquire supplemental coverage from private carriers.

Floodplain mapping

FEMA provides funding for floodplain mapping. Currently, most FEMA maps are about 10 years old, which means that some communities have not yet been mapped and some of the old maps may not represent current circumstances. New topographic maps are currently being quality checked and could be available for many areas. North Carolina, for example, has been proactive in updating its floodplain maps. After Hurricane Floyd, it launched an effort to secure sufficient funding to update all of its floodplain maps using high-quality Light Detection and Ranging (LIDAR) data.

4.3.2 Current planning for climate-related risks

FEMA has recently undertaken two activities with regard to climate change. First, it is conducting a study on the impact of climate change on the NFIP, as recommended by the GAO (2007). The FEMA study began in September 2008, and is scheduled to be completed in March 2010. This study will estimate the impacts of climate change on the location and extent of U.S. floodplains, the relationship between the elevation of insured properties and flood water elevations, and the economic structure of the NFIP (FEMA, 2009).

Second, FEMA has an NFIP program component, called the Community Rating System (CRS), which provides financial incentives for implementing practices beyond the minimum NFIP floodplain management standards. In this program, the CRS provides discounts on flood insurance premiums that range from 5% to 45%, with the size of the discount determined by tallying credit points that are assigned to various community floodplain management activities. Currently, there are no CRS credits specifically described as “climate-change activities.” There are, however, flood-protection activities, such as requiring additional freeboard (the height of a dam or levee above high water levels), or requiring long-term coastal erosion-based setbacks

that, while not described as specific to climate change, mitigate aspects of sea level rise and concomitant long-term coastal erosion. The next revision of the CRS manual (probably issued in 2011) may contain new climate change-specific language describing certain CRS activity credits (Mark Crowell, FEMA, personal communication, November 3, 2009).

4.3.3 Challenges

Agencies and programs are already in place to deal with inland and coastal flooding events. With climate change impacts, however, these agencies will likely have to re-evaluate existing policies and procedures to account for climate change. Some of the challenges associated with planning for climate change with regard to coastal and inland flooding include:

- GAO (2007) found that climate changes pose an increased risk to the federal flood insurance program. Keeping FEMA flood maps updated, and producing new maps in places currently not mapped, could help identify high risk areas and hopefully inform development in floodplains.
- As demonstrated by Hurricane Katrina, certain populations, such as the poor and elderly, are particularly vulnerable to extreme weather events.[13] They have fewer financial resources to use to improve flood defenses or to evacuate when those defenses are threatened or fail (Elliott and Pais, 2006). With climate change, it is likely that some low-income communities will face increased flood risk. As a result, support networks, whether offered by charitable organizations, local and state governments, or the federal government, will likely be stretched further.
- Under FEMA's grandfathering policy, when new maps show a given area to be more vulnerable than before, existing policyholders have the option of having their flood insurance rate based on either the old map or the new map. As a result, the "price signal" from increasing risk does not necessarily encourage property owners to undertake measures that reduce the risk of flood damages to existing structures (CCSP, 2009).
- The sustainability of flood-prone communities may be questionable if increased protection measures are not implemented or are unaffordable. The risks may increase to a point where it is no longer appropriate to try to increase protection. Instead, complete or partial abandonment may be more appropriate. While relocation of communities has been limited to date, scenarios of this type are possible and the capacity to address such

13. No single extreme event can be attributed to climate change, and it is not implied here that Hurricane Katrina was caused by climate change. Rather, it is used to demonstrate the impact on certain vulnerable populations of extreme weather events.

increased needs should be considered.[14] Development and zoning decisions that incorporate climate change information may be needed in order to minimize damage to infrastructure from inland and coastal flooding.

- More precise and accurate climate modeling should help provide improved projections of changes in future flooding. While many floods result from increased seasonal precipitation over large areas (e.g., floods in the Midwest resulting from high winter and spring precipitation), other floods are the result of intense storms at a small scale. For such events, models that provide projections at smaller spatial scales as well as on shorter time scales (e.g., 3 or 6 hours) are needed. Downscaling techniques, such as regional climate models or statistical models, may be able to provide projections at higher resolution than the global climate models typically do. But there are cautions with using such downscaling techniques, at least in their current capacities. One is that downscaling does not necessarily improve the accuracy of projections. A second is that the global models often differ on regional changes in climate. One model might project wetter conditions, while another might project drier conditions. Downscaling typically does not resolve such differences. So, while downscaling can provide results at a spatial scale that is likely to be more useful to support adaptation at a local scale, more work needs to be done to reduce uncertainties about regional changes in climate. In the meantime, it would be beneficial to provide guidance on how best to use existing climate projections for those wishing to take action now while model downscaling capacity improves.

- Updating floodplain maps will likely become an even larger challenge as rainfall becomes more concentrated during extreme events. Flood mapping has already lagged behind the need (GAO, 2007), as development and infrastructure change the hydrology of floodplains.

4.4 Instream Flow

Maintaining adequate instream flow for fish and wildlife, as required by the CWA, is sometimes at odds with providing sufficient water for navigation, energy generation, municipal and industrial uses, and agricultural irrigation. Increasingly persistent drought conditions will likely put additional pressure on federal and state resource agencies to meet all of these competing demands.

The sections below describe the current institutions responsible for setting instream flows, as well as potential adaptations to current climate-related risks and challenges for future planning.

14. Because they will have fewer resources available to protect against increased flood risks, low-income communities may face disproportionate pressures to relocate.

4.4.1 Management and regulation

Many institutions are involved with instream flow issues, including resource agencies, recreational interest groups, downstream water users, industrial and hydropower groups, and others. Establishing instream flow requirements has impacts on water supply, endangered species, and water quality. States have the ultimate authority and responsibility to set instream flow levels, typically within its environmental department. In North Carolina, for example, several authorities acting under a variety of laws have various responsibilities. These authorities include the NC Utilities Commission (Certificate of Public Convenience and Necessity), the Division of Land Resources (Dam Safety Law), the Environmental Management Commission (Water Use Act of 1967), and the Division of Water Quality (Section 401 of the CWA). In Florida, WMDs develop a list of priority water bodies that require a minimum flow level and work with the Florida Office of Water and Policy to establish the flow levels.

Not all of the states in the Southeast have statewide instream flow standards (e.g., Alabama, Kentucky, Mississippi, and North Carolina). North Carolina, for example, has standards for setting instream flows only when a project is involved (e.g., building or relicensing a dam); it does not have standards to set flows for other purposes. Water quantity has not historically been a large issue until the last 10 years, so instream flows will likely present new challenges for states, especially if severe droughts in the region continue.

At the federal level, resource agencies (National Marine Fisheries Service and the USFWS) sometimes partner with states to set the instream flow requirements, particularly when a listed species has the potential to be affected. The USACE is involved under the CWA for issuing Section 404 permits and under the National Environmental Policy Act requirements. The Federal Energy Regulatory Commission (FERC) is involved under the Federal Power Act for relicensing the operation of dams, which creates opportunities to improve instream flows that are impacted by dam operations.

Several actions can trigger the need to set instream flow requirements, such as a new listing of a threatened or endangered species, irrigation needs, relicensing of dams, and creating new dams. The more common drivers for instream flow requirements include consumption and hydrologic alteration. Municipal and industrial uses have increased in more populated states to the point that they are impacting aquatic habitat. States and resource agencies are compelled to establish instream flow requirements under the CWA. While federal agencies are involved with instream flow issues, there are currently no federal guidelines to standardize how instream flows should be assessed or what to do in the event that agencies cannot meet standards.

Several NGOs are active on this issue as well. The Instream Flow Council works with state and provincial fish and wildlife management agencies in the United States and Canada. The Southern Instream Flow Network (SIFN) works with states to create instream flow policies by providing

resources and avenues for communication. The Nature Conservancy (TNC) is actively working with USACE on instream flow issues in the Southeast. Industrial and hydropower groups (e.g., Southern Company and Duke Energy) have also made efforts to work with resource agencies and other stakeholders to balance their interests with conservation efforts associated with instream flows. The Environmental Defense Fund recently started working with North Carolina to fund a pilot study to test a new methodology for developing flow levels in the state.

Southern Instream Flow Network

The newly formed SIFN has been aiding Southeastern states and resource agencies in handling instream flow management. Established by the Southeast Aquatic Resources Partnership in January 2008, SIFN works with 15 states in the Southeastern Association of Fish and Wildlife Agencies[15] to promote education about instream flow issues in the Southeast. SIFN plays a major role to facilitate and open lines of communication between state and environmental agencies, which was previously very limited.

SIFN helps state agencies build on shared experiences to develop expertise on instream flow issues. It held a workshop the first week of December 2009 to bring stakeholders together to develop a research agenda to answer questions states have about managing and protecting instream flows, such as identifying research needs to help address major climate change issues. About 70 people attended the workshop, including representatives from most of the 15 states (Scott Robinson, SIFN, personal communication, December 2, 2009).

While SIFN and resource agencies in the region are still at the stage of evaluating vulnerabilities and impacts, they plan to address adaptation issues in the future.

4.4.2 Current planning for climate-related risks

Alabama, North Carolina, and South Carolina have legislative committees and regulatory agencies reviewing instream flow and water allocation. The South Carolina legislature debated, but did not pass, legislation on this issue last year. The recent severe drought in the Southeast was a major factor in motivating legislators and agencies to consider water allocation issues. Climate change is a stated impetus for some states, but many other issues are also involved.

In Florida, the WMDs regulate withdrawals on a site-specific basis. They will permit only certain levels of resource impacts, beyond which users are required to fund alternative sources. The Southwest Florida WMD sets minimum flows and levels for a variety of water bodies to ensure

15. The 15 states include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

that the water needed for wildlife and to sustain natural systems is available prior to human withdrawals. In some areas it is known that these flows and levels are already below the minimum needed for natural systems. To address this, the Southwest Florida WMD has developed detailed and long-term recovery strategies (Miki Renner, Planning Manager, Southwest Florida WMD, personal communication, November 30, 2009).

TNC has been working with USACE to change the operation of dams in the Savannah River. TNC provides scientific expertise to USACE to help preserve instream flows while maintaining the authorized purpose of dams (TNC, 2009b).

4.4.3 Challenges

It is likely that in many regions of the Southeast, low-flow levels will drop over time, particularly in summers with lower precipitation levels and increased evaporation. In addition, higher temperatures will likely increase the need for higher flows for higher energy production and cooling. Changes in runoff patterns are also a concern. Currently, instream flow requirements in the Southeastern states do not make provisions for climate change impacts, making management of instream flows increasingly difficult to realize.

Some of the major challenges associated with planning for climate change with regard to instream flow management include:

- Current institutions are working to create and maintain guidelines. Standard guidelines may be needed for creating instream flow levels that sufficiently incorporate climate predictions.
- Currently, the tools and policies for instream flow management are established on a case-by-case basis and are not generally built into hydrologic models. More systematic approaches to react to observed changes in low-flow levels or anticipate future changes in such levels may be needed.
- Effective and comprehensive monitoring networks may be needed to observe changes in instream flows and identify when flows fall below desired levels. Monitoring is critical to provide information to inform decision-makers and the public about changes in the environment. Unfortunately, the stream gage network has not been enhanced in recent decades and has slightly deteriorated (USGS, 2009). If anything, the network may need to be enhanced in light of climate change.
- Other related challenges include reducing water consumption to minimize impacts on instream flows, as well as fish and wildlife, improving aquifer recharge that feeds streams, increasing efficient use of water, and finding alternative sources of water.

Population growth and increased demands for food production may also place burdens on instream flows.

- Improving projections of future climate change. In many areas it is not clear whether runoff will increase or decrease and the degree to which it will change. More precise projections may help in planning for changes in instream flow levels.

5. Coastal Resources

Climate change will impact coastal resources in the Southeast, including (but not limited to) inundation and erosion from sea level rise, coastal flooding, salt water intrusion, higher ocean temperatures, ocean acidification, and hydrologic changes (see Table 3). The list of potential impacts presented in Table 3 is by no means comprehensive. Instead, they are presented to give a sense of the range of potential consequences of climate change and the entities that will likely be most affected. Similar to the water resource sector, as climate change impacts are realized, it will likely become increasingly important to manage these resources more holistically, rather than managing each resource independently.

Table 3. Climate change impacts on the coastal resources sector

Coastal Resource Subsector	Potential Impacts	Affected Entities
Inundation and erosion	Landward migration of wetlands assuming room to move; loss of beaches, wetlands, and barrier islands; conversion of marshlands to open water; conversion of farms, forests, and residential lands to wetland or open-water marshland; decreased nursery habitat for coastal fish	Coastal wetlands and barrier islands; infrastructure; fisheries; tourism; coastal residents; coastal businesses; public access along shore
Coastal flooding	Increased intensity and destructive capacity of coastal storms and storm surges; increased heavy precipitation events; increased costs of flood insurance	Transportation; infrastructure; residents and businesses in coastal floodplains
Salt water intrusion	Increased salinity of estuaries, aquifers, and low-lying soils, resulting from rising sea levels; reduced freshwater inflow during droughts; higher storm surges	People who rely on groundwater or tidal freshwater rivers for irrigation or drinking water; fish and wildlife
Other environmental changes, including higher temperatures, ocean acidification, and hydrologic changes	Changes in marine and estuarine ecosystems, including changes in biodiversity, species composition, and ecosystem productivity; increased runoff from the land; decreased pH in ocean waters	Coastal and marine ecosystems including wetlands, fisheries, and coral reefs; recreation and tourism; commercial and recreational fishing

For the purpose of this analysis, we focus on three resource subsectors: inundation and erosion from sea level rise, coastal flooding from storms (including ecosystems), and salt water intrusion into aquifers. These three resource subsectors illustrate the larger problems facing the coastal resource sector. Although sea level rise and coastal storms drive the impacts in these subsectors, each issue is regulated by different entities at different levels of government. This section describes the regulations and authorities for each subsector, as well as the current status of climate change planning and the unique challenges.

5.1 Inundation and Erosion from Sea Level Rise

As sea levels rise, low-lying coastal areas will likely be increasingly at risk. Wetlands, beaches, and other shorelines are projected to both erode and become inundated, impairing both environment and human settlements. Some wetlands are particularly vulnerable if they cannot migrate landward as sea levels rise (i.e., if human development or other factors prevent landward migration).

The sections below describe institutions that manage inundation and erosion, current actions, if any, by institutions to address climate change, and challenges for future planning in light of climate change.

5.1.1 Management and regulation

Although no single federal agency has been tasked with the responsibility to develop a response to sea level rise (CCSP, 2009), several federal programs have started to address this issue. Individual states and localities have traditionally managed the coastline and many have started to plan for sea level rise on their own. Most governmental agencies that manage or regulate coastal activities make decisions that – in effect – constitute an *implicit* baseline response to sea level rise (CCSP, 2009). This subsection summarizes the relatively few governmental programs that *explicitly* address the rising sea.

While adaptation to climate change in coastal areas has generally been at the state level, there are some federal programs that work to protect coastal communities and ecosystems. The Coastal Zone Management Act (CZMA) of 1972 directed the National Oceanic and Atmospheric Administration (NOAA) to create two national programs: the National Coastal Zone Management (CZM) Program and the National Estuarine Research Reserve System. The overall objective of the CZMA is to “preserve, protect, develop, and where possible, to restore or enhance the resources of the nation’s coastal zone” (U.S.C. Title 16, Chapter 33, §1452). Since 1990, the CZMA has included sea level rise in the list of hazards that states should address. The CZM program provides funding to states that voluntarily develop a coastal management

program. These coastal management programs help states manage and balance competing uses of and impacts to coastal resources. To receive federal funding these programs must, among other things, protect natural resources, manage development in high hazard areas, and coordinate with federal actions. In the Southeast, Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina all have an approved coastal management program under CZMA.

Another federal program, the Climate Ready Estuaries Program, works with the National Estuary Programs (NEPs) and other coastal managers to assess climate change vulnerabilities, develop and implement adaptation strategies, engage and educate stakeholders, and share the lessons learned with other coastal managers (U.S. EPA, 2009a).

For the last decade, USACE has included the prospect of rising sea level in its planning guidance (CCSP, 2009). Revised guidance from July 2009 requires that USACE provides (USACE, 2009d, p. 1):

> …guidance for incorporating the direct and indirect physical effects of projected future sea-level change in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects. Recent climate research by the Intergovernmental Panel on Climate Change (IPCC) predicts continued or accelerated global warming for the 21st Century and possibly beyond, which will cause a continued or accelerated rise in global mean sea level. Impacts to coastal and estuarine zones caused by sea-level change must be considered in all phases of Civil Works programs.

Decisions regarding coastal resources are also made at the local level (CCSP, 2009, p. 176):

> At the local level, officials make assumptions about which land will be protected in order to understand which lands will truly become inundated and how shorelines will actually change, which existing wetlands will be lost, whether wetlands will be able to migrate inland, the potential environmental consequences, and the population whose homes would be threatened and the implications of sea-level rise for public access and floodplain management.

5.1.2 Current planning for climate-related risks

When it comes to protecting property, there are two broad options for adapting to sea level rise: shoreline protection and retreat. Shoreline protection can modify the short- and long-term risks associated with flooding, erosion, or inundation of land or structures along with causing potentially significant ecological effects. Shoreline protection does not necessarily involve protection of the shore or beach itself (CCSP, 2009). Shoreline protection typically comes in two

forms: shoreline armoring and land and structure elevation.[16] Shoreline armoring involves replacement of the natural shoreline with an artificial surface in order to maintain the shoreline in its current position or to prevent flooding (CCSP, 2009). Methods used for shoreline armoring include enhanced living shorelines, energy absorbing shorelines, sea walls, bulkheads, retaining structures, revetments, dikes, dunes, tide gates, and storm surge barriers (CCSP, 2009).

Shoreline armoring may protect development from smaller short-term effects, but can result in the loss of beaches via erosion with little or reduced protection for larger storm events. Current protection methods are having significant adverse effects on shoreline ecosystems. Newer methods utilizing soft shorelines, natural systems, and energy absorption techniques can provide equivalent short-term protection, enhanced longer-term protection, and significantly better ecological conditions. Land and structure elevation involves rebuilding or modifying structures located in high-risk areas so that they are higher up from the ground. Shore protection is usually implemented in reaction to past and ongoing erosion or flooding.

Retreat (or relocation), on the other hand, "emphasizes the management of human expectations" (CCSP, 2009, p. 93). It could involve requiring the relocation of inundated or threatened structures, using buyout programs to compensate landowners, using conservation easements or acquisition programs to prevent development, using setbacks to prevent development of high-risk lands, using floodplain regulations to prohibit development based on elevation, using rolling easements, using density restrictions, or using size limitations (CCSP, 2009).

North Carolina, for example, has policies that limit development in vulnerable areas, such as setback rules that require buildings being constructed or reconstructed to be set back a certain distance from where the shoreline is located when construction permits are issued (CCSP, 2009). It also has policies that discourage protection, e.g., not allowing "hard" shoreline armoring, such as seawalls and revetments. The use of hard shoreline armoring along estuarine shores, however, is allowed landward of any wetlands. Beach nourishment (i.e., adding sand to beaches) is the most common approach in North Carolina to protect buildings and roads along the ocean coastline (CCSP, 2009). In other states in the Southeast, restrictions on building hard armoring structures vary. There is no policy against building hard shore protection structures along most estuarine shorelines in the Southeast states.

16. Other, "softer" shoreline protection options also exist, such as those offered by the Living Shoreline project.

State and local governments in the Southeast have taken many actions to adapt to rising sea levels. Examples of what states are doing to protect beaches and shorelines include:

- South Carolina's Coastal Zone Management Program created a Shoreline Change Initiative in 2007 to guide the management of beachfront and estuarine shorelines and address concerns about intensifying sea level rise and coastal storms. The SCAC recently published a report outlining adaptation recommendations for future climate change impacts (SCDHE, 2009).

- North Carolina's Division of Coastal Management, in collaboration with the Division of Water Resources, will address sea level rise and other issues in the state's first comprehensive beach and inlet management plan (CSO, 2008b). The North Carolina Division of Coastal Management recently conducted a survey to identify public perceptions of sea level rise impacts in North Carolina. This survey is part of an effort by North Carolina's Division of Coastal Management, Coastal Resources Commission, and Department of Environment and Natural Resources to address potential responses to sea level rise in the state. The survey results will also inform the Coastal Resources Commission's policy on sea level rise.

- North Carolina started conducting a study – The North Carolina Sea Level Rise Risk Management Study – in February 2009 to assess the impacts of sea level rise and increased storminess and to develop a risk management policy (North Carolina, 2009b).

- Florida's five regional planning councils (RPCs) and Walton County worked with EPA to map areas that might be inundated by an astronomical high tide in addition to a 5-foot rise in sea level. The South Florida RPC completed a "Climate Change Community Toolbox" to help local governments plan for and adapt to climate change. The Toolbox includes LIDAR maps showing areas likely to be inundated by 1, 2, 3, and 5-foot rises in sea level, fact sheets describing climate change impacts on Miami-Dade County, and adaptation resources.

- The Southwest Florida WMD Wetland Restoration Program restores wetland habitats in the Tampa Bay ecosystem. This program incorporates sea level rise projections in its planning (assuming a 12- to 18-inch sea level rise scenario over 100 years) and has included high-marsh components to allow low-marsh habitats to migrate landward as sea levels rise.

Currently, four of the six NEPs in the Southeast participate in EPA's Climate Ready Estuaries Program: the Albemarle-Pamlico NEP (APNEP) in North Carolina, the Indian River Lagoon NEP (IRLNEP), the Charlotte Harbor NEP (CHNEP), and Tampa Bay Estuary Program (TBEP) in Florida. Each NEP is currently addressing climate change impacts.

- The CHNEP, in collaboration with the city of Punta Gorda, Florida, has completed a climate change adaptation plan for the city. The plan was approved by the City Council for inclusion in their comprehensive plan in November 2009. This is the first NEP adaptation plan of its kind to be completed in the United States.
- The APNEP is working with the Nicholas Institute for Environmental Policy Solutions at Duke University to interview local and state elected officials to assess their understanding of climate change issues and to discuss what adaptation efforts are occurring. Results from these interviews will be used to develop a climate change and adaptation communication strategy for local policy makers.
- TBEP is working with EPA and all Gulf Coast NEPs to develop a manual to help communities incorporate climate change impacts into habitat restoration and protection.
- The IRLNEP in Florida is working with the city of Satellite Beach to conduct a sea level rise vulnerability assessment. This assessment will help identify strategies to reduce risk, plan for adaptation, and provide outreach and education to local decision-makers. This project began in October 2009 and is expected to be completed by September 2010.

There have also been partnerships between NGOs and federal resource agencies to address climate change in the Southeast. For example, TNC's North Carolina chapter and the USFWS have collaborated on an experimental, innovative adaptation project at Alligator River National Wildlife Refuge in the hopes of making it more resilient to sea level rise and salt water intrusion. This refuge is facing shoreline erosion, changing plant communities (forested wetlands to marsh), and salt water intrusion. This project will do three things to adapt to these changes: (1) install water control structures to reduce salt water intrusion of the refuge's interior; (2) build oyster reefs to dampen wave action before waves get to the shore and also increase biodiversity; and (3) plant more saline-tolerant tree species (Mike Bryant, USFWS, personal communication, December 2, 2009). Duke Energy has provided $1 million to fund this project.

Actions at the county and community levels to address climate change impacts from sea level rise include:

- "Miami-Dade County in Florida has been studying its vulnerability to sea-level rise, including developing maps to indicate which areas are at greatest risk of inundation. The county is hardening facilities to better withstand hurricanes, monitoring the salt front, examining membrane technology for desalinating seawater, and creating a climate advisory task force to advise the county commission" (CCSP, 2009, p. 162).

- Broward, Miami-Dade, Palm Beach, and Monroe counties signed the Southeast Florida Regional Climate Change Compact to coordinate positions on state and national legislation on climate change and to coordinate activities on mitigation and adaptation. They also committed to preparing an action plan that will include adaptation strategies (Broward County, 2009).

- "The Albemarle-Pamlico Peninsula is among North Carolina's poorest areas. Four of its five counties are classified as economically distressed by the state, with high unemployment rates, along with low average household incomes" (CCSP, 2009, p. 230). In 2007, TNC, USFWS, the National Audubon Society, Environmental Defense, Ducks Unlimited, the North Carolina Coastal Federation, and others started the Albemarle-Pamlico Conservation and Communities Collaborative (AP3C). The purpose of AP3C is to provide a forum for communities to share concerns about climate change impacts on natural resources and wildlife and to explore opportunities to improve land management practices, restore habitats, and protect lands and water (TNC, 2009a). "Although this initiative is only in its infancy, sea-level rise will be one of the first and most important issues the partnership will address" (CCSP, 2009, p. 230).

With respect to managing climate change impacts on coastal ecosystems, actions at the federal, state, and local levels have been limited. NOAA's Living Shoreline Initiative Grant Program (Living Shorelines) mitigates the impacts of inundation and erosion for coastal wetlands. NOAA's Restoration Center developed the Living Shorelines Program in 2004. While this project does not specifically reference climate change, it is addressing its impacts. This project provides funding to applicants who seek to restore and protect wetland habitats using natural materials, such as wetland grasses, submerged aquatic vegetation, natural fiber logs, low-crested rock sills, and living breakwaters. To date, Alabama, Florida, and North Carolina have received funding under the Living Shorelines Program. In addition, NOAA received $167 million in February 2009 to restore coastal habitat. Alabama, Florida, North Carolina, and South Carolina have applied for and received funds under this new initiative.

5.1.3 Challenges

Rising seas and the likelihood of increased intensity of tropical cyclones pose risks to existing coastal development and ecosystems such as wetlands. The risks from climate change are likely to be made worse should past trends in coastal development continue. Increased development will likely place more people and property in areas facing increased threats from climate change. In addition, development could further harm coastal ecosystems and put them at greater risk from climate change. Although several federal, state, and local programs address coastal resource management, more coordination is needed to improve coastal management in light of climate change.

Some of the major challenges associated with planning for climate change with regard to inundation and erosion from sea level rise are:

- Some measures to manage coastal resources can increase vulnerability to climate change. Over-pumping of coastal aquifers, for example, can increase the rate of salt water intrusion and cause more subsidence. More subsidence will most likely put more land at risk of inundation, threatening more coastal property and habitats. The combined effect of these practices and climate change should be incorporated into future planning.

- Steps taken to protect development along the coast can harm beaches and ecosystems. In particular, hard structures such as sea walls can result in erosion of beaches and generally block inland migration of wetlands (e.g., CCSP, 2009; Jones and Strange, 2009). Some states have prohibited hard structures in favor of softer living shoreline approaches (CCSP, 2009). Such policies can enhance the ability of beaches and wetlands to adapt to sea level rise. However, living shoreline approaches are often more expensive than hard structures. As noted above, with acceleration in sea level rise and increased intensification of coastal storms, the pressures on decision-makers to address such issues will likely increase.

- More attention is needed to address prevention or minimization of loss of wetlands from coastal inundation. Particular consideration should be given to facilitating wetlands migration landward as sea levels rise. While programs, such as Living Shorelines, provide funding for wetland restoration, more initiatives would be necessary to help a broader range of wetland systems currently threatened by inundation.

- Addressing what to do with homes in flood inundation zones before and after destructive storms will likely become a more pressing issue if storm intensity increases and sea levels continue to rise. Federal and state agencies may need to consider retreat and abandonment of threatened and damaged properties.

- New structures are already elevated to the base flood elevation (to get insurance), and some owners are choosing to elevate existing structures (CCSP, 2009). Nevertheless, minimizing the long-term damages of sea level rise could require some combination of limiting development in high-risk areas, designating additional coastal areas as ineligible for federal subsidies [e.g., Coastal Barrier Resources Act (CBRA)], or conditioning continued development on eventual relocation as sea level rises (e.g., Titus, 1998).

- Some Southeastern states require that structures inundated by erosion be removed. Others limit or prohibit use of hard structures to protect coastal property from erosion. With rising sea levels and projected accelerated rates of sea level rise, the need for implementing such strategies will likely increase in the future.

- Poorer populations will likely have a difficult time affording adaptation measures, such as elevating homes or paying for rising insurance costs. Policies may be needed to help these communities receive assistance to adapt to rising sea levels.

- As governments consider the possibility of restrictions on coastal development and increased shore protection, a key question will often be who should pay: property owners, local government, state governments, or the federal government? Property owners are increasingly challenging governmental actions, not only regulations that prevent development, but also shore protection activities which require permission by landowners to proceed as planned. The U.S. Supreme Court recently heard a case from a homeowner challenging the right of the state of Florida to claim land that it had renourished (*Stop the Beach Renourishment v. Florida Department of Environmental Protection* 08-1151).

- A recent National Academy of Sciences report makes 11 recommendations to improve coastal mapping and charting, which will likely provide a variety of challenges for coastal resource managers and decision-makers in the Southeast, such as achieving national consistency in data collection methods, providing timely data, making data available to the public, and increasing collaboration and coordination (NRC, 2004).

5.2 Coastal Flooding from Storms

As sea level rises and storm intensity increases, the height of storm surges from hurricanes and other storms can be expected to increase. In addition, more intense coastal storms will likely result in coastal flooding from both higher storm surges and increased precipitation (and wind damages may increase as well). Increased precipitation from coastal storms will also contribute to increased inland flooding. While Section 4.3 discusses both coastal and inland flooding, this section highlights issues specific to coastal flooding in the Southeast.

5.2.1 Management and regulation

Management and regulation for coastal flooding and inland flooding share similarities (Section 4.3) and have clear lines of authority in the case of emergency management. With coastal flooding, however, there are other institutions with additional responsibilities.

Examples of programs that address coastal flooding include:

- The USACE has a Coastal Storm Damage Reduction Program to develop new flood and coastal storm damage reduction technologies (USACE, 2009b).
- NOAA's Coastal Storms Program is a partnership between NOAA and other federal, state, and local organizations to help coastal communities become more resilient to impacts from coastal storms and flooding.
- The National Hurricane Program is a multi-agency partnership between FEMA, NOAA, the National Weather Service, the U.S. Department of Transportation, and USACE that provides funding and assistance to states and localities to develop hurricane evacuation plans.
- The NOAA/EPA Coastal and Waterfront Smart Growth Program helps communities make decisions about development, including within the context of climate change.
- States have emergency management divisions that are responsible for responding to coastal flooding.

5.2.2 Current planning for climate-related risks

The ongoing efforts to address erosion and inundation enumerated in Section 5.1.2 generally address the implications of increased flooding as well. We briefly examine some additional efforts that address flooding but not erosion or inundation.

FEMA publishes a Coastal Construction Manual (FEMA 55) that documents state-of-the-art and best practices in coastal construction in accordance with information and recommendations contained in several pertinent publications. These publications include the International Residential Code, the International Building Code, NFIP regulations and technical bulletins, and other relevant publications. The last major update to the Coastal Construction Manual was in 2000. This version (as with previous versions) contains limited information explicitly addressing the direct effects of sea level rise on coastal construction design and siting.

FEMA's Mitigation Directorate is in the preliminary stages of substantially revising the Coastal Construction Manual. This revision will include a new section that will summarize what is currently known about the effects of climate change on our coastal regions. It will also make recommendations concerning coastal construction siting and design within the context of potential climate change impacts (Mark Crowell, FEMA, personal communication, November 3, 2009).

The South Florida WMD plans to identify coastal structures vulnerable to sea level rise and to identify which basins would require additional pumping during coastal flooding events. One strategy to deal with coastal flooding is called forward pumping. Forward pumping helps recharge aquifers by using injection wells to artificially maintain freshwater pressure.

North Carolina's Office of Geospatial and Technology Management in the Division of Emergency Management received a $5 million grant from FEMA to conduct a three-year, statewide risk assessment and mitigation strategy demonstration of the potential impacts of climate change-induced sea level rise. To conduct this study, North Carolina is working with an engineering firm (Dewberry), state government agencies, and universities to develop sea level rise scenarios. These scenarios could assist in the development of a methodology to show what the shoreline and barrier islands will look like under each scenario. Additional analysis will include estimating changes in storm surges and hurricanes (e.g., wind speeds) and using these estimates to generate sea level and flooding scenarios for 2025, 2050, 2075, and 2100. The U.S. Department of Homeland Security and FEMA will use these results to assess the long-term fiscal implications of climate change and will share these results with other states.

Dewberry is also working with WMDs in 18 Florida counties to model sea, lake, and overland surges from hurricanes and perform LIDAR hydraulic and hydrologic floodplain modeling.

5.2.3 Challenges

Note that many of the challenges identified for inland flooding and for coastal erosion and inundation are also relevant for coastal flooding. Some additional major challenges include:

- Coastal flood risks will likely increase for two reasons: sea levels are rising and tropical cyclones are projected to become more intense. Both of these factors will likely increase storm surges. Increasing intensity of coastal storms will increase wind speeds and precipitation. So, coastal communities, and even areas further inland, will likely face higher storm surges, more damaging winds, and increased freshwater flooding from more intense precipitation events associated with hurricanes and tropical storms. Protective measures, such as building codes, landscape requirements, limitations on location or density of development, or evacuation procedures, may need to be regularly updated to

account for increasing risks to coastal areas. Regularly revisiting laws, regulations, and codes relevant for such risks will likely be a challenge for decisions-makers at the local, state, and national levels.

- Updating flood zone maps will likely become an even larger challenge as sea level rise accelerates and coastal storms become more intense. Flood mapping has already lagged behind the need (GAO, 2007). As the rate of inundation increases and as coastal storms become more intense, more coastal areas will likely become either permanently inundated or face increasing risk of flooding from coastal storms.

- Improved projections of sea level rise and changes in coastal storms will likely be needed. Narrowing the range of sea level rise projections or publishing probabilities of sea level rise can help coastal planners anticipate future changes. So too, more precise projections of changes in coastal storm intensity, frequency, and location can help in planning for changes in risks from future storms.

- Emergency preparedness programs may need to account for increased risks from climate change. With more locations, inhabitants, and structures facing risks from inundation, storm surge, increased wind speeds, and inland flooding from increased precipitation, warning procedures, evacuation measures, and recovery efforts may need to be enhanced.

- Coastal management authorities may need to consider new policies or enhance existing ones that allow for inland migration of coastal ecosystems, in particular wetland and barrier islands. Wetlands, barrier islands, and beaches will likely be lost without policies that allow migration. This may require abandonment or relocation of structures in high hazard areas that are blocking ecosystem or island migration. This may also require limitations and even prohibitions on building hard structures to protect coastal settlements. One of the most significant challenges may be deciding whether to favor protection of existing settlements at the potential cost of losing beaches and ecosystems or favoring inland migration of such systems at the cost of abandoning or relocating existing settlements. And if so, where and how. Accommodation of more frequent coastal flooding by elevating structures is one option that can be explored.

- In addition to the fundamental pathways of shore protection and retreat (discussed in the section on erosion and inundation) the “accommodation” pathway may be a viable medium-term approach in some areas. Under this approach, shores and floodplains continue to migrate inland as with the retreat pathway, but people continue to inhabit the coastal zone and simply tolerate increased flooding, through a combination of flood proofing structures, elevating homes (but not land surfaces), more frequent evacuations, and a toleration of more flooding.

5.3 Salt Water Intrusion

As sea level rises, saline water advances upstream and inland. Increased salinity can make such aquifers and water withdrawn from tidal rivers non-potable or require additional treatment. This section identifies the institutions responsible for managing salt water intrusion in the Southeast and actions they are taking to deal with climate change impacts. It also highlights challenges associated with adapting to climate change.

5.3.1 Management and regulation

For communities in the Southeast that rely on groundwater for drinking water, salt water intrusion is primarily a water quality and supply issue that is dealt with mostly at the state and local levels.[17] Many people in the Southeast rely on water from aquifers that are already overpumped. Overpumping of aquifers can exacerbate the problem of salt water intrusion (Bill Holman, Director of State Policy, Nicholas Institute, personal communication, October 14, 2009). For example, in Florida 90% of the state's population relies on groundwater resources for their drinking water (Florida DEP, 2009a; Kenny et al., 2009). Additionally, over 50% of all other water needs including agricultural, industry, and mining are supplied by groundwater resources (Florida DEP, 2009a; Kenny et al., 2009). Groundwater also serves as the source for Florida's many springs and provides a significant input to many of Florida's lakes and rivers (Florida DEP, 2009a).

All coastal states in the Southeast have a mechanism to both regulate water withdrawals and monitor salinity levels. To date, states have focused more on the groundwater depletion issue than on salt water intrusion (Bill Holman, Director of State Policy, Nicholas Institute, personal communication, October 14, 2009).

At the federal level, the U.S. Geological Survey (USGS) has a Groundwater Resources Program (GWRP) that supports applied research into the effects of climate variability on groundwater availability. In 2008, the GWRP began a program to better understand the impacts of climate variability on groundwater resources. They also initiated a project called the Mississippi Embayment Regional Aquifer System (MERAS), which was conducted by researchers in the USGS Water Science Centers in Colorado, California, and Arkansas. This project could increase the understanding of the effects of annual, interannual, and multidecadal climate variabilities on the hydraulic budget of MERAS, including recharge, discharge, and change in storage.

The USGS-funded Climate Response Network (partnership between USGS and state and local agencies) examines the effects of climate change on groundwater levels in unconfined aquifers

17. This is an issue that EPA also addresses through its Source Water Protection Program.

or near-surface confined aquifers minimally affected by pumping or other anthropogenic stresses.

Surface water withdrawals account for approximately three-quarters of Florida's total withdrawals (Kenny et al., 2009).[18] In southwestern Florida, a number of freshwater intakes are in low-lying areas that could potentially become salty as sea level rises.

5.3.2 Current planning for climate-related risks

The Southwest Florida WMD has an extensive coastal monitoring program to track salt water intrusion. Like the rest of the state, this region of Florida relies heavily on groundwater for drinking water, which makes it particularly vulnerable to salt water intrusion. In areas where minimum flows and levels are exceeded, new groundwater permits are not being issued. Instead, the WMD assists agriculture, industry, and individuals in these areas to become more efficient. They are also considering the potential to use reclaimed water to rehydrate the coastal area and hold back the salt water intrusion line. Considering the continuing transition of land use from agriculture to residential, there may be less demand to pump groundwater in the future (Miki Renner, Planning Manager, Southwest Florida WMD, personal communication, November 30, 2009).

5.3.3 Challenges

Some of the challenges associated with planning for climate change with regard to salt water intrusion include:

- States and municipalities may need to consider alternative sources of drinking water as well fields become saline. Not only will climate change likely reduce the supply of freshwater from coastal aquifers because of salt intrusion, it could also decrease surface runoff and infiltration to groundwater, particularly in the Deep South where precipitation is more likely to decrease with changing climatic conditions.

- Desalination is expensive. Poorer communities will probably have a more difficult time than wealthier communities in paying for development or purchase of alternative water supplies. Rooftop collection may provide inexpensive water, but it also involves a capital investment for storage tanks as well as training for purification.

18. Most of the surface water withdrawals in Florida are for thermoelectric power water withdrawals (Kenny et al., 2009). Groundwater is used primarily for public supply, domestic supply, irrigation, agriculture, livestock, aquaculture, and mining (Kenny et al., 2009).

6. Cross-cutting Issues, Challenges, and Opportunities

Many states, local governments, and nonprofits in the Southeast have started to consider the impacts of climate change and have developed efforts to identify, study, and mitigate vulnerabilities. Some states have taken the lead in addressing specific impacts of climate change by developing adaptation plans and policies. Florida, in particular, has started to systematically address the need for adaptation and is currently working on a Climate Adaptation Plan. North Carolina and South Carolina indicated their intention to create such a plan and are in the early stages of the process (Cruce, 2009).

With that as a backdrop, this section discusses cross-cutting issues experienced across the Southeast as well as *potential* coordinating roles that governments and other institutions could play in adapting to climate change across the region. Such regional coordinating measures and broad-scale activities could support state and local adaptation projects in the Southeast by providing strategic focus, a forum for information exchange, opportunities for training, and other benefits. This section is not meant to imply that adaptation should be coordinated solely at the federal or state level. Rather, it is meant to explore the potential utility of broad-scale, regional coordination for climate adaptation.

Arguments for a regionally coordinated approach to adaptation include: (1) climate impacts typically cross many political jurisdictions (e.g., changes in river flow and lake levels); as such, solutions would benefit from a coordinated response; (2) individual government entities can develop jurisdiction-specific adaptation programs, but this risks inconsistent approaches which may undercut actions in neighboring jurisdictions; and (3) in times of shrinking budgets, the resources and expertise needed to develop and implement solutions can best be leveraged through a coordinated approach. An example of a current need for a more regionally coordinated approach (as discussed above) is that as water supplies continue to tighten, federal, state, and local institutions will likely have to work together to develop solutions for coordinating management of river basins crossing state boundaries or for addressing species migration.

To illustrate the complex array of institutions already engaged in the climate change adaptation arena, the following sections begin by summarizing the findings associated with adaptation efforts for water and coastal resource sectors (discussed in Sections 4 and 5 above). The discussion goes on to highlight key challenges and potential solutions for addressing adaptation for any resource sector in the Southeast in a more coordinated fashion. The section concludes with examples of three existing regional institutions that, among others, could potentially play a greater role in coordinating regional adaptation activities in the Southeast.

6.1 Water and Coastal Resource Adaptations

Table 4 summarizes key adaptation actions for each of the subsectors discussed in Sections 4 and 5. It also illustrates the major climate risks, the different institutions involved with managing the resources, and key challenges for future adaptation efforts. A central theme of this table is the number of institutions working on climate change and the role they have on multiple issues. For example, USACE works on water supply, instream flow, inland and coastal flooding, and inundation and erosion from sea level rise.

6.2 Cross-cutting Considerations

The bullets below briefly describe some of these cross-cutting issues and challenges that apply to all climate-sensitive resource sectors. They also describe some roles that institutions could play and opportunities for coordination among institutions in the region to meet these challenges.

- **Disseminating information on climate change to decision-makers and the public, especially vulnerable populations, in a timely and relevant way**. Information on climate change can often be hard to obtain and to understand, especially with respect to adaptation actions. Additionally, there are multiple sources of information on climate change, and it can be hard for users of such information, particularly decision-makers, to judge the quality and reliability of sources, as well as whether datasets should be combined or used separately. Information on climate change is often not provided at the geographic level at which decisions are made. The new national assessment planned by the U.S. Global Change Research Program is an opportunity to develop and disseminate improved regional climate information.

  Roles that institutions could play. The federal government is having discussions about creating a "National Climate Service" (NCS) to disseminate information on climate change and provide technical support to decision-makers and the public. If created, the NCS could gather and organize climate change projections, downscaled data, and information on impacts and would have as one of its goals making such information accessible and useful for decision-makers and the public. Associations like AWWA and SIFN can also help disseminate information related to specific resource sectors in a useful manner. AWWA, for example, provides research and information about safe drinking water; SIFN coordinates states actions on instream flows.

Table 4. Institutions, major climate change risks, solutions, and challenges by subsector

Subsector	Institutions	Major climate risks	Current solutions	Coordination challenges
Water supply	USACE, CEQ, EPA, state environmental/water agencies, Bureau of Reclamation, Natural Resource Conservation Service, power companies, municipalities	Salt water intrusion; increased heavy precipitation events leading to less infiltration into groundwater; increased frequency of droughts in some areas could cause drying of lakes, ponds, and wetlands; decreased summer precipitation.	Several states have produced (or are currently producing) water management and drought management plans that address climate change. Other states have focused efforts on conducting vulnerability assessments.	Regional coordination mechanism(s) to help states and localities respond to climate change in a more consistent and effective way. Population growth and economic expansion will likely further reduce existing water supplies.
Water quality	EPA, state environmental/water agencies, municipalities	Decreased summer precipitation; increased heavy precipitation events; sewer overflow events; human health effects; hypoxic conditions; thermal stratification, algae, nutrient runoff, and lower flows; increased temperatures will reduce dissolved oxygen in streams, lakes, and shallow aquatic habitats, which could lead to increased fish kills and losses of aquatic species diversity.	EPA, states, and local governments implement components of the CWA to address water quality. EPA identified adapting implementation of core water programs in the context of a changing climate as a major goal of its *National Water Program Strategy: Response to Climate Change*, and is currently exploring how to best do so. State and local adaptation actions are limited.	Consistent approaches across federal, state, and local entities to address climate exacerbated water quality problems. Capacity of current institutions to address increasing nonpoint pollution exacerbated by climate change. Consideration of changing runoff and water quality conditions to ensure current programs remain protective of water quality. Updating existing infrastructure to be responsive to climate change and creating guidelines for new infrastructure building efforts.

Table 4. Institutions, major climate change risks, solutions, and challenges by subsector (cont.)

Subsector	Institutions	Major climate risks	Current solutions	Coordination challenges
Inland flooding	USACE, FEMA, Department of Homeland Security, state emergency management departments	Increased heavy precipitation events, more frequent and severe flooding events, increased flood damages and insurance rates, increased incidence of waterborne diseases.	FEMA is conducting a study to estimate the impacts of climate change on (1) the location and extent of U.S. floodplains, (2) the relationship between the elevation of insured properties and flood water elevations, and (3) the economic structure of the NFIP. FEMA's new Community Rating System Manual will include climate change information.	Updating of floodplain maps. Consideration of relocating vulnerable communities to avoid adverse flooding impacts. Projecting future flooding impacts and incorporating in federal, state, regional, and local planning.
Instream flows	Utilities, state environmental agencies, National Marine Fisheries Service, USFWS, USACE, EPA, Instream Flow Council, SIFN, TNC, industrial and power/hydropower groups	Increased heavy precipitation events; decreased summer flows, which decreases water available for cooling and reduces power/hydropower production; wildlife needs (e.g., threatened and endangered species).	Several states have statewide instream flow standards. Some states in process of developing statewide instream flow standards.	Creating and maintaining guidelines incorporating climate change. Developing more systematic approaches to evaluate instream flows. Improved projections for and consideration of low-flow conditions incorporating climate change. Finding alternative solutions to alleviate stress on water resources.

Table 4. Institutions, major climate change risks, solutions, and challenges by subsector (cont.)

Subsector	Institutions	Major climate risks	Current solutions	Coordination challenges
Inundation and erosion from sea level rise	State coastal zone management departments, USACE, EPA (e.g., Climate Ready Estuaries), USFWS, NOAA, TNC, municipalities	Landward migration of wetlands assuming room to move; loss of beaches, wetlands, and barrier islands; conversion of marshlands to open water and forests to marshland; decreased nursery habitat for coastal fish. Examine need for and options to protect coastal cities.	All southeastern coastal states have Coastal Management Programs that deal with climate change impacts at some level. The four NEPs also have programs in place to address climate change impacts. Local authorities have also taken steps to address climate change.	No single federal agency has been charged with taking the lead in developing a policy on preparing for sea level rise. Improve ways to monitor and when appropriate, enforce existing policies regarding shoreline protection and retreat. Address impediments to wetlands and other coastal habitats adapting to sea level rise. Enable and enhance regional coordination and standardization of policies to protect coastal infrastructure and habitat.
Coastal flooding from storms	NOAA, FEMA, USACE, state emergency management departments	Increased intensity and destructive capacity of coastal storms and storm surges; increased heavy precipitation events; increased costs of flood insurance.	Some state emergency management divisions have started to deal with climate change. Limited action at the state and federal levels.	Re-evaluate storm protection and emergency preparedness measures in light of climate change.
Salt water intrusion	State environmental agencies, USGS, EPA	Increased sea levels.	Currently thought of as more of a groundwater supply issue rather than a climate change issue.	Need to consider alternative sources for drinking water.

Decision-makers at all levels of government could benefit from having an adaptation information clearinghouse, perhaps in the form of a website. Such a website could help provide an inventory of data on climate science, impacts and vulnerability, and adaptation responses. Federal agencies have capacity to maintain and regularly update a database of climate change impacts and adaptation information. The Department of Transportation, for example, manages a clearinghouse of transportation-related information on climate change impacts and adaptation for decision-makers and the public (U.S. DOT, 2010).

An additional sorting of information specific to each sector (or subsector) would also have value. An example of a website that contains specific, local adaptations is the United Nation's Framework Convention on Climate Change's Local Coping Strategies Database (UNFCCC, 2010). This database provides examples of what other countries or localities are currently doing to adapt to climate change. A website like this could be helpful to local communities who are trying to get a sense of the options available for adaptation. Creating such a website would require the federal government to coordinate with states and localities to identify current or proposed actions. It could also facilitate opening lines of communication about climate change.

Creating such a clearinghouse is not a function that only the federal government currently can perform. The WRF is creating a clearinghouse of information on climate change impacts and adaptation for use by the water utilities communities. Other associations could create clearinghouses for their respective sectors. The advantage of encouraging associations to develop clearinghouses is that they understand their members' needs and can tailor the information to those particular needs. The disadvantages include not having one location with information about all climate change information needs and limitations on financial resources to create and maintain clearinghouses.

- **Providing technical assistance and support for using climate change information in decision-making (i.e., education and outreach).** The scale, form, and complexity of modeling outputs, as well as contradictory results from different models, can leave decision-makers and the public confused about what is known about climate change and how to make adaptation decisions. Climate model projections are often not in a form that can be immediately used in traditional decision-making models, such as those for engineering design. In addition, improved mechanisms to incorporate uncertainty into decision-making could help decision-makers evaluate adaptation in light of uncertainties associated with climate change and other key factors such as population growth.

Roles that institutions could play. Translating information, integrating local information, and developing tailored methods for local use have been assisted with the help of so-called "boundary organizations." A boundary organization is one that can work with scientists and users to facilitate the development of locally validated and

useable information. Universities associated with NOAA's Regional Integrated Sciences and Assessments (RISA) program, regional research centers, NGOs, and consulting companies have been serving as such boundary organizations and have been successful in working with communities. RPCs are also playing an important role in communicating climate information. The Southeast has three established RISAs: the Southern Climate Impacts Planning Program (includes Texas, Louisiana, Arkansas, Tennessee, Oklahoma, and Mississippi), the Carolinas Integrated Sciences and Assessments (includes North and South Carolina), and the Southeast Climate Consortium (includes Alabama, Florida, and Georgia). Land Grant and Sea Grant Universities are increasingly investing in climate change science and adaptive management studies.

A number of NGOs have produced user-friendly information on climate change. For example, TNC and the Environmental Defense Fund are already working with communities in the Southeast on a variety of projects.

- **Analyze current laws, regulations, and policies to determine if they promote or inhibit adaptation.** Analysis could occur at appropriate levels of government to promote a consideration of climate change in government actions. For example, local comprehensive land use plans could be examined to assess whether they enable or block migrations of species, habitats, beaches, or inhibit changes in societal land uses that may be needed to adapt to climate change. In addition, local ordinances could be examined to consider potential climate impacts in their specifications of what can be built and where, as well as whether changes in design standards may be appropriate (e.g., building codes).

  The analysis of laws, regulations, and policies could also identify barriers to adaptation or policies or programs that promote behaviors that increase vulnerability. For example, a fixed allocation of water supplies may inhibit adaptations to climate change such as water conservation or trading. State insurance policies that prohibit or limit risk-based insurance pricing (e.g., homeowners pay similar insurance rates regardless of whether they live in relatively risky or safe areas) may discourage homeowners from taking actions to reduce their exposure to extreme climate events. An example of attempting to reduce such barriers is the CBRA. It reduces activities of agencies that are at cross-purposes with each other by prohibiting federal subsidies for flood insurance in certain undeveloped shoreline areas.

  Roles that institutions could play. Governments at all levels could examine their policies and programs with regard to whether they will promote or discourage adaptation to climate change. A number of municipalities, states, and federal agencies have begun to do this. For example, the federal government could examine existing policies to assess whether they could promote adaptation and remove barriers. A key challenge for the federal government may be to facilitate coordination among different agencies with

jurisdiction in the same sector (e.g., USACE, Bureau of Reclamation, and EPA with regard to policies and programs on water resources).

States can also play a role similar to the federal government. Florida, for example, has undertaken an extensive evaluation of needs to incorporate climate change adaptation into its policies. However, conducting such evaluations is expensive and implementing changes will involve additional costs. In these cash-strapped times, many states will likely have difficulty financing assessment and implementation of adaptation policies and measures. Federal support for state adaptation efforts could help many states undertake such activities.

Municipalities could also analyze their vulnerability to climate change and examine their policies with regard to adaptation. To be sure, only large municipalities will likely have the financial resources and staff capabilities needed to carry out such analyses. Medium- to small-sized municipalities would likely need financial and technical assistance to examine vulnerability and adaptation.

In addition, NGOs could support government efforts to address adaptation. The International Council for Local Environmental Initiatives has been working with a number of medium- and small-sized municipalities on developing adaptation policies. The Rockefeller Foundation gave a grant to the Center for Clean Air Policy to support municipal adaptation and supported New York City's adaptation program. Such organizations as the National Organization of Mayors could also provide technical support for municipal adaptation, while the National Council of State Legislators and the National Governors' Association could provide technical support to states on adaptation.

One possibility to promote regional coordination is for Southeastern states to initiate a dialogue to compare policies, share experiences, and identify opportunities to harmonize policies and practices that promote adaptation efforts across the Southeast. An examination of the experiences of organizations both within and external to the Southeast would aid in identifying and reducing barriers to adaptation (see Section 6.3).

- **Assessing and addressing the needs of vulnerable communities or populations.** Certain populations in the Southeast such as children, the elderly, and the poor will likely be disproportionately affected by climate change impacts. They will most likely be less able to invest in protective measures such as making homes more flood- or hurricane-proof, evacuating when necessary (e.g., during storm and heatwaves), paying higher insurance rates, or relocating. These communities may benefit from improved access to information on emergency management and response, and increased resources to enable adaptation (e.g., for elevating structures, retreat, building or updating water infrastructure, cooling centers during heatwaves).

Roles that institutions could play: Identifying and addressing the needs of vulnerable populations presents an important challenge to various institutions, particularly in the Southeast with its large population of people especially vulnerable to climate impacts. Governments may need to plan to identify and reach out to such vulnerable communities to reduce their climate risks and help in responding to disasters and other problems. The consideration of the effect of policies and programs on vulnerable populations could also include the effect of actual adaptation alternatives on such communities. Equity in decision-making is another consideration.

An existing group of environmental justice organizations assists vulnerable populations in the Southeast to respond to environmental stresses. These resources could partner with governments to expand their traditional efforts to consider the potential for adaptation planning within these communities.

- **Establishing effective monitoring systems to track changes in climate.** Comprehensive and broad monitoring networks would likely improve understanding of how climate is changing and what impacts it is having on the Southeast's environment, public health, infrastructure, and economy.

- **Roles that institutions could play.** Both the federal and state government are likely to play key roles in carrying out and providing funding and technical support for monitoring. NOAA, EPA, and the USGS are federal agencies with significant roles on monitoring. The states' role, in many cases, is to carry out the monitoring.

  In the Southeast, there is an opportunity for states to increasingly collaborate to expand and harmonize their monitoring efforts. Such an approach would provide better, more robust, and consistent datasets; leverage resources for maximum spatial and temporal coverage; and provide for a more holistic picture of baseline and changing conditions across the region.

- **Improving research to reduce uncertainties**. Uncertainties exist in both our understanding of how the climate is changing and how different systems are affected by (and can adapt to) such changes. Uncertainty can be a key reason that decision-makers are reticent to act on climate change predictions. Research will continue to be needed to help improve our understanding of how climate is predicted to change, its consequences, and how as a society we can adapt to such changes. For example, improved projections of regional and local climate change could help decision-makers decide how to respond to the risks posed to their communities. Improved knowledge of impacts and mitigation technologies could inform the kinds of adaptations that may be needed.

Improvements may be needed not just in reducing the coarseness of projections, but also in reducing differences among model projections for regions and in better projecting changes in climate variability and extreme events. In addition, more research could improve understanding the sensitivity of systems to climate change and how well they can adapt to such changes. With regard to adaptation policies, there are many options for research, including improved understanding of individual behavior and risk-taking, how to overcome barriers, and how to improve effectiveness of adaptation policies.

Roles that institutions could play. Research efforts to reduce uncertainties in our understanding of climate change and adaptation considerations in the Southeast could be supported by federal and state governments and through partnerships with communities and NGOs or universities. These efforts could also work to ensure that policy and adaptation program needs are informing research planning and prioritization. Indeed, numerous research institutions are already doing this type of work. Opportunities exist to enhance collaboration, share information, develop resources, and educate decision-makers and the public.

- **Funding for adaptation**. Many adaptation efforts may require additional financial resources to be implemented. Building infrastructure, purchasing land, investing in emergency preparedness, performing research, disseminating information, providing technical support and training, implementing adaptation projects, and monitoring project effectiveness will all require financial and other support. Lack of financial resources may serve as the determining factor prohibiting implementation of many adaptation projects. Failure to make prudent investments in adaptation may result in considerably greater costs in the future.

Roles that institutions could play. Funding will likely have to come from a variety of sources. For example, legislation currently before the U.S. Congress includes provisions for using some revenue proceeds to support adaptation efforts. Other sources of funding may be needed as well. The use of cooperative efforts among all parties may become more important to leverage ever shrinking resources.

States and municipalities may currently lack the financial resources to implement many of the available adaptation options. Even as the economy improves, adequate resources for adaptation at the state and local levels may be lacking. In the Southeast, enhancing collaborative efforts could help lead to common solutions in some areas and stakeholders could consider pooling resources to solve these common problems.

6.3 Potential Roles for Regional Institutions

A cross-cutting theme in many of the subsectors discussed in this discussion paper is the importance of regional institutions in addressing adaptation. Impacts are not confined to government jurisdictional boundaries and institutions that coordinate among themselves and across jurisdictions (even across sectors) can help develop appropriate regional strategies for adaptation.

This section highlights examples of several regional institutions that could play a role in enabling regional coordination on adaptation efforts in the Southeast. Example institutions that might have the capacity to help states adapt to climate change include the Southern Governors' Association (SGA), the Environmental Council of the States (ECOS), and the Coastal States Organization (CSO). They are discussed in the sections below. In addition to these three organizations, other organizations may also play a role in helping states adapt to climate change. Indeed, TVA and the Florida WMDs already facilitate regional coordination of resource management and could serve as examples for such coordination elsewhere in the Southeast. RPCs can also have an important role.

6.3.1 Examples of regional institutions in the Southeast

The Southern Governors' Association (SGA) is the oldest and historically the largest of the regional governors' associations. Since its inception in 1934, SGA has represented the common interests of Southern states' chief executives and provided a vehicle for promoting them.

SGA members include 16 states and two territories: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, U.S. Virgin Islands, Virginia, and West Virginia.

SGA recently undertook an effort to produce a regional cost-benefit analysis of state policy options on climate change. SGA entered into a contract with the Center for Climate Strategies to produce an assessment of the region's policy options and potential economic impacts associated with them. Preliminary findings from the assessment were presented at SGA's annual meeting in August 2009, and the final report was issued in October 2009 (Center for Climate Strategies, 2009).

The completion of the assessment of policy options was the first step toward a regional effort. A few of the member states are in various stages of developing their own climate programs, with Florida in an advanced stage.

SGA has previous experiences facilitating collaboration among its member states, including the recently developed Emergency Management Assistance Compact (EMAC). EMAC is a national compact adopted by nearly every state in the nation that provides a legal structure for a state to request emergency assistance from another state.

EMAC grew out of the destruction Florida suffered from Hurricane Andrew. Florida used SGA to initiate discussions with other states and develop a mutual aid agreement among SGA states, the U.S. Virgin Islands, and Puerto Rico. The Southern Regional Emergency Management Compact (SREMAC) model was considered successful and was adopted nationwide under the new name EMAC.

The Environmental Council of the States (ECOS) is the national nonprofit, non-partisan association of state and territorial environmental agency leaders. ECOS was established in 1993 to improve the capability of state environmental agencies and their leaders to protect and improve human health and the environment.

ECOS works through state government agencies to coordinate environmental protection afforded by both federal and state law.

One example of a role ECOS played was its facilitation of states' Technology Acceptance and Reciprocity Partnership (TARP). ECOS facilitated an effort by the commissioners and secretaries of TARP states to develop common testing protocols for all states. This effort focused on improving communication and information sharing among state regulators, more efficient permit reviews, more environmental technologies available to solve tough environmental problems, and better relationships with technology vendors.

ECOS is not a Southeast regional organization, but a national organization. However, ECOS has worked at a regional level upon the request of states.

With regard to climate change to date, the Climate and Energy Subcommittee of ECOS' Air Committee has primarily focused on state concerns about national climate and energy legislation, reduction of GHG emissions by the Western Climate Initiative and Northeastern and New England states, and GHG emission reporting systems and rules. Coordination of adaptation-related technical analyses and potential state roles may be explored.

The Coastal States Organization (CSO) was formed in 1970 to represent the interests of the 35 coastal states on legislative and policy issues related to the unique waterfront environment of these states. CSO stresses coordination between federal programs and state partners while maintaining an emphasis on state sovereignty. Its goals include assessment of programs originating in different federal agencies such as NOAA, EPA, USACE, FEMA, and USGS to

avoid duplication of effort at the federal level, to maximize benefits at the state level, and to engage in issues relating to federal funding for state-based ocean and coastal programs.

Headquartered in Washington, DC, CSO's membership is appointed by the governors of the individual states to participate in the organization.

CSO considers facilitation of collaboration among coastal states a primary mission of the organization. The organization provides regular communication on the states' behalf between states and federal agencies, and between differing federal agencies engaged in similar activities.

CSO recently issued a policy statement recommending that "the Administration and Congress should develop a national coastal adaptation strategy to ensure intergovernmental coordination on coastal adaptation to climate change; to clearly define the roles of various agencies; and to identify the mechanisms by which federal programs will coordinate with state partners on coastal adaptation issues" (CSO, 2008a, p. 2). CSO has further recommended that Congress and the Administration recognize the role of coastal states in adapting to climate change by reauthorizing the CZMA, ensuring consultation with coastal states when developing new climate change initiatives, developing a strategy to identify information needs to effectively respond to natural hazards and ecosystem changes driven by climate change, coordinating federal activities, and clarifying the roles and responsibilities of coastal states and federal agencies in climate change adaptation activities (CSO, 2008a). Coordinating and integrating across multiple states, partnering with the federal government and NGOs (e.g., TNC and the World Wildlife Fund), and facilitating the creation of efficiencies and coordination in climate change adaptation programs and initiatives can be explored.

6.4 Summary

To date, the Southeast has taken a variety of steps to adapt to climate change. A number of states have begun addressing adaptation, as have some counties and municipalities. In addition, many NGOs are becoming more involved in adaptation. The activity of the federal government on adaptation is increasing as well. And while these steps are encouraging, many agencies, states, municipalities, private sector firms, and NGOs are only beginning to address adaptation considerations.

Adaptation will not be as effective as it might be if government and other entities operate in isolation of one another. One option to enhance adaptation work in the Southeast is increased regional coordination of activities to reduce redundancies, create consistent policies, and leverage resources. The Southeast will likely have to rely on existing institutions to respond to climate change and may require reorganizing or restructuring existing institutions to increase their capacity in this area. A coordinated effort across organizations in the region could help to

ease the burden of this new work effort. The Southeast could also look for opportunities to create new institutions, where greater efficiency and coordination could result, and address evolving adaptation needs.

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