Climate Change Adaptation: Information On Selected Federal Efforts To Adapt To A Changing Climate (GAO-10-114SP, October 7, 2009), an E-supplement to GAO-10-113

Read the Full Report: Climate Change Adaptation: Strategic Federal Planning Could Help Government Officials Make More Informed Decisions (GAO-10-113)

Background Information

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Background Information

We obtained information from 13 selected federal departments and agencies on their current and planned climate change adaptation efforts as part of a broader review of climate change adaptation (see GAO-10-113). We present this information to provide a more complete picture of the activities that federal agencies consider to be related to climate change adaptation than has been available publicly. We obtained this information directly from the agencies participating in the U.S. Global Change Research Program.[1]

Importantly, we did not modify the content of the agency submissions (except to remove references to named individuals) or assess its validity. In addition, because this information represents the efforts of a selected group of federal agencies, the agency activities compiled in this report should not be considered a comprehensive list of all recent and ongoing climate change adaptation efforts across the federal government.

A more detailed discussion of our scope and methodology is contained in our report Climate Change Adaptation: Strategic Federal Planning Could Help Government Officials Make More Informed Decisions, GAO-10-113. We conducted this performance audit from September 2008 to October 2009 in accordance with generally accepted government auditing standards.

[1]The U.S. Global Change Research Program (USGCRP) coordinates and integrates federal research on changes in the global environment and their implications for society. We did not receive a submission from the Smithsonian Institution. In addition to the agencies that participate in USGCRP, we also obtained a summary of current and planned adaptation-related efforts from the Federal Emergency Management Agency, part of the U.S. Department of Homeland Security, because of prior GAO adaptation-related work on its National Flood Insurance Program.

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The following page contains a list of the departments and agencies included in the compilation that follows.

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List of Participating Departments and Agencies

U.S. Department of Agriculture
Agricultural Marketing Service
Agricultural Research Service
Cooperative State Research, Education, and Extension Service
Economic Research Service
Farm Service Agency
Forest Service
Natural Resources Conservation Service

U.S. Department of Commerce
National Oceanic and Atmospheric Administration

U.S. Department of Defense
Office of the Secretary of Defense
Army
Navy
Air Force
Marine Corps
U.S. Army Corps of Engineers

U.S. Department of Energy

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institutes of Health

U.S. Department of Homeland Security
Federal Emergency Management Agency

U.S. Department of the Interior

U.S. Department of State and
U.S. Agency for International Development

U.S. Department of Transportation
Office of Transportation Policy

U.S. Environmental Protection Agency

National Aeronautics and Space Administration

National Science Foundation

The U.S. Department of Agriculture (USDA) submitted information on its adaptation-related efforts on June 17, 2009. USDA was given the opportunity to review its initial submission and sent updated information on September 8, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to USDA.

U.S. Department of Agriculture

"The patterns of land use, agriculture, forestry, and grazing land management in the United States and globally are shaped by climate. Human-induced climate change is occurring and these changes will continue. As the climate changes, those responsible for managing land and water resources will need new information to help with their decision-making. For example, producers will need information to guide them on what to plant, when to plant, and what management strategies to employ during the growing season. Foresters, farmers, and ranchers will need information for management of risks posed by pests and fire. Water resource managers will need information for allocation of water resources between the demands of urban and rural populations, industry, agriculture, and ecosystem services. USDA policymakers will need information to guide them in implementing or retooling programs impacting or impacted by climate change. At all levels, global food production data and projections will be necessary for anticipating large-scale socioeconomic feedbacks into U.S. production systems.

USDA is unique among many federal departments in that its agencies cover a broad spectrum of missions including research, applications and technology transfer, public land management, technical assistance, and communications and delivery. Climate change has the potential to confound USDA efforts to meet these core obligations and responsibilities to the Nation.

Adapting practices to respond to changing and more variable climate is necessary for addressing challenges to the stability of ecosystems and the essential goods and services they provide. Existing USDA programs attempt to introduce new technologies and practices for adaptation in the most efficient and least disruptive ways. While there may be new opportunities created by changes in local climates, adjustments will be challenging.

Mechanisms for adaptation are critical for continued commodity (food, fiber, energy) production, conservation of natural resources, and food security. The goal of USDA's climate change adaptation strategy is to create the knowledge and technologies to ameliorate the detrimental effects of climate change and to take advantage of elements of climate change that may be potentially beneficial to agriculture, forestry, and rangeland, and natural resources management. As summarized below, USDA's adaptation efforts are aimed at identifying potential future measures and address the related environmental, economic, and social

challenges these changes present. These activities are performed by multiple agencies, acting in coordination through USDA's Global Change Program Office.

- Develop a suite of strategies that enable farmers, ranchers, and resource managers to cope with the challenges associated with drought, heat stress, excessive moisture, longer growing seasons, plant community changes, and changes of disease and pest prevalence;
- Evaluate sustainable practices for agricultural production and alternative strategies for increasing ecosystem resilience that enable the utilization of potentially beneficial aspects of climate change;
- Evaluate management actions that increase the resilience of forest and grassland processes, composition, and structure to better withstand the combined stresses of changing climate, pests, pollutants, and wildfire;
- Analyze economic costs and benefits of producer and market responses to changing climatic regimes, taking into account producer incentives and trade-offs across alternative responses;
- Evaluate management actions for maintenance and enhancement of ecosystem services such as water supply, wildlife, biodiversity, clean air, high quality soils, and recreation within the context of global change;
- Develop metrics for evaluating and monitoring adaptive strategies;
- Improve life-cycle analysis and management strategy assessments.

What follows is an account of current activities by individual USDA agencies to address each of these points to best empower farmers, foresters, ranchers, land owners, resource managers, policy-makers, and Federal agencies with the science-based knowledge to adapt to the risks, challenges and opportunities of climate change.

Agricultural Marketing Service

The mission of the USDA's Agricultural Marketing Service (AMS) is to facilitate the competitive and efficient marketing of agricultural products.

AMS offers clients audit and accreditation services to facilitate the marketing of agricultural products. These verification services instill confidence throughout the global marketplace and provide solutions that ensure suppliers uniformly apply customer identified and accepted methodologies, Standards, or specified requirements within specific sectors of agriculture.

Agricultural producers are constantly striving for new and innovative ways to market their products and meet customer demands. One emerging marketing method that relates to adaptation is to attach "green marketing claims" to agriculturally produced products. AMS is currently reviewing applications to verify "green marketing claims". Products derived from livestock or crops grown in an environmentally responsible manner could be marketed as such.

AMS verification services have the potential to connect USDA conservation programs with AMS verification programs and offer clients another marketing option for their products. For example, if a producer participates in a Natural Resources Conservation Service Conservation Programs, a regional or national greenhouse gas registry program, or another type of recognized energy conservation program, s/he can combine these practices into an USDA/AMS verified quality management system and uniquely market their agricultural products, setting them aside from other products in the marketplace. AMS verification services offer producers of agricultural products the ability to package their products to a broadening niche market and maximize their marketing dollars while supporting climate change initiatives.

Agricultural Research Service

ARS Research to Enable Agriculture to Adapt to Climate Change is focused on five main problems:

- Understand the responses of agricultural systems to anticipated climate change.
- Understand the impact of anticipated climate change on endemic and exotic pests, weeds and diseases.
- Evaluate germplasm and identify genetic variation that will respond positively to climate change.
- Evaluate and adapt agronomic management to climate change.
- Identify and develop scalable methodologies for assessing potential impacts and adaptation of agriculture to climate change.

Understand the responses of agricultural systems to anticipated climate change.

Understanding the impacts of interacting factors of global change on production quantity and quality of managed and natural ecosystems has emerged as a priority research need. Improved models are needed to more accurately predict how climate change will alter water availability, water use efficiency, nutrient requirements, and pools and fluxes of C, N, and other potentially limiting elements for plant productivity. The interactive effects of soil moisture, soil fertility, temperature, and O_3 on C_3 and C_4 crop responses to elevated CO_2 must be understood. Improved knowledge of the spatial and temporal dynamics of soil-plant-atmosphere interactions is needed. Knowledge is lacking on how shifts in rangeland plant species composition affect pools and fluxes of C and N to impact plant biomass productivity. It is also crucial to understand how landscape soil variation interacts with phenology and species change to mediate CO_2/climate impacts on productivity. How grazing will interact with climate change to further influence species composition and productivity is largely unknown.

Anticipated Products

- Understanding of how climate change affects crop and forage quality.
- Understanding of the interacting impacts of elevated CO_2, O_3, precipitation, and temperature on agricultural systems including nitrogen requirements, yield and quality responses.
- Data on impacts of elevated CO_2 on plant stomatal responses to soil water deficits and air vapor pressure deficits.
- Models of the mechanisms underlying improved water use efficiency at elevated CO_2 and its effects on yield.
- Management systems, including crop selection, to improve water use efficiency.
- Improved methods to measure and model interactions in soil-plant-atmosphere systems.

Understand the impact of anticipated climate change on endemic and exotic pests, weeds and diseases.

Assessment of trophic interaction changes under global change, including interactions of pests and pathogens, grazers and weeds, and measurement and modeling of the impact of these trophic interactions on agricultural production are needed. The ability to predict changes in the locations and severity of invasive agricultural pests, weeds, and diseases with current and projected changes in CO_2, temperature, and water availability are needed. Quantification of the degree to which warming, changes of precipitation, and CO_2 enrichment increase the susceptibility of agro-systems to invasion; understanding how invasions are exacerbated by interactions of the availability of natural enemies with CO_2, temperature, and precipitation; understanding how CO_2 enrichment and warming interact with disturbances to influence plant invasion and native ecosystem recovery; understanding how nutrient availability affects invasive species growth and native rangeland susceptibility. Other needed predictions include latitudinal range shifts and likely impacts of invasive species as a result of warming, changes in precipitation, and CO_2 enrichment. Changes in management that will mitigate and control future infestations associated with expected range shifts, including herbicide management and impact of increased CO_2 and temperature on plant resistance to invasive pests and diseases, need to be identified.

Anticipated Products

- Risk assessment tools for predicting the effects of anticipated global change on weeds, pests, and diseases in different agricultural systems.
- Characterization of likely impacts of climate and CO_2 on the establishment, success and spread of invasive weeds, pests, and diseases including anticipated production losses for U.S. agricultural systems.
- Assessment of climate change and CO_2 increases on current agricultural management techniques (chemical, biological and physical) for endemic and invasive weeds, pests, and diseases, and establishment of new IPM guidelines.

- New conceptual knowledge, databases, and parameters for input to mechanistic models of C and nutrient cycling, plant biomass productivity, species phenology, and species changes.
- Guidelines on impacts of increasing atmospheric CO_2 and climate change on plant biomass productivity and rates of C cycling and storage in rangeland systems.
- Best management practices for sustainable rangeland production and maintenance of ancillary ecosystem services under future climate change.
- Statistical and spatial models of future invasive species ranges.
- State/transition models to predict invasions in rangelands under future CO_2 and climate scenarios.
- Delineation of identity and attributes of likely future invasive species.
- Guidelines for management practices to mitigate future invasions and control of existing invasive populations.

Evaluate germplasm and identify genetic variation that will respond positively to climate change.

A better understanding of the genomic and genetic basis for the variability of crop responses to climate change is required. Optimal germplasm for enhanced performance under elevated levels of atmospheric CO_2 and O_3, increased temperatures, and precipitation excesses and deficits need to be identified. There is a need to evaluate and utilize wild relatives and ancestral germplasm of crop species as unique sources of genes to adapt crops to all aspects of climate change.

Anticipated Products

- Germplasm that is adapted to factors of climate change including improved tolerance to O_3, water use efficiency.
- Crop cultivars that maximize productivity at elevated CO_2 and/or elevated temperature.
- Molecular markers for crop CO_2 responsiveness, O_3 tolerance, and temperature limitations.
- Identify and characterize key genes regulating effects of temperature on phenology and reproductive growth factors.
- Identification of crop ancestors exhibiting variation in response to O_3 and CO_2.

Evaluate and adapt agronomic management to climate change.

Climate change presents threats to agricultural production systems as well as opportunities to improve and expand production. Adjustments to production system inputs, tillage, crop species, crop rotations, and harvest strategies, as well as altered use and assessment of natural resources are anticipated responses to both threats and opportunities of climate change. ARS conducts research to increase the resilience of agronomic systems to climate change and to enable exploitation of opportunities that may arise.

Anticipated Products

- Management practices that increase the resilience of cropping systems to temperature and precipitation extremes.
- Information that quantifies the interactions among agronomic systems, management practices, and climate variation that can be used to assess future food security.
- Improved plant growth and agronomic models that can be used to evaluate potential management scenarios across a wide range of cropping systems, soils, and climate.
- Information on the capacity of cropping systems to sequester C in response to CO_2 and knowledge of underlying mechanism for residue decomposition.
- Suitable management strategies and methods to control invasive agronomic weeds with climate change.
- Improved understanding of weed community shifts under climate change scenarios.

Identify and develop scalable methodologies for assessing potential impacts and adaptation of agriculture to climate change.

A strengthened capacity is needed to predict potential impacts of climate change on agricultural production and on natural resources, including water and nutrients. Better predictions are sought by growers, processors, agricultural industries, and local, state, and federal agencies. Improved prediction at different geographic scales will allow stakeholders to more effectively assess how climate change will impact agricultural production and the environment, and identify specific opportunities or vulnerabilities. ARS will conduct research to improve crop growth and ecophysiological models, develop technologies for merging data from different spatial and temporal scales, and structure research outcomes for use by decision makers at local to global scales.

Anticipated Products

- Models of crop responses to climate change and evaluation protocols for those models.
- Algorithm for moving information across spatial and temporal scales.
- Methods to handle complex biophysical interactions across scales.
- Meta-analysis of major crop responses to climate change.
- National database for characterization of crop or system responses to climate change.
- Recommendations for best management practices for adapting agriculture to global change.
- High resolution local database for detailed case studies characterizing crop or system responses to climate change.
- Remote sensing methods for monitoring and mapping evapotranspiration and drought across spatial scales.

Cooperative State Research, Education, and Extension Service

CSREES is the USDA's major extramural research agency, funding individuals: institutions: and public, private, and non-profit organizations. Through grants offered by CSREES, the USDA enables researchers throughout the United States to solve problems critical to our farmers, consumers, and communities. CSREES supports research, education, and extension activities at partner institutions through three main funding mechanisms: competitive grants; formula grants; and non-competitive grants and agreements.

CSREES has funded projects related to the adaption of natural resource management practices to changes in climate. One such project funded through a competitive grant is on developing fundamental tools and an interactive human-environment system that links economics, climate change, and environmental models and uses the coupled modeling framework to increase fundamental understanding of the interactions and feedbacks between Land Cover/Land Use Change (LCLUC) and key drivers of LCLUC in the Upper Mississippi River Basin. The project will apply the integrated human-environment system to study the impacts of LCLUC and how changes in the conservation policy driver affect LCLUC under current climate conditions. The project will also investigate the LCLUC implications of the conservation policy driver, examine the potential feedback of LCLUC to the climate, and assess the environmental and economic impacts of the LCLUC under the various scenarios for a range of behavioral adaptations to climate change in this region for the next 5 to 50 years. This project is being conducted by the Center for Agriculture and Rural Development at Iowa State University.

Through a Federal Administration Research Grant managed by CSREES, a consortium of research and extension faculty from seven academic institutions from Florida, Georgia, Alabama and North Carolina have been conducting a project on developing a decision support system for reducing agricultural risks caused by climate variability. The goals of the project is to inform farmers, ranchers, foresters, water resource managers, industry and policy makers about climate risks and to indentify management practices that can reduce risks and increase benefits by using climate information. A web-based decision support system which includes climate forecasts, state and regional outlooks for climate related risks to agriculture and water resources, commodity-base information and decision support for local users, watershed-based forecast applications to water resources management, and feedback and evaluation of forecast tools and information product, has been developed and is undergoing expansion and improvements. This public web-based tool, called *AgClimate*, assists agricultural producers and natural resource managers in the Southeastern US to adapt to changes in environmental conditions driven by climate variables.

Hatch formula funds have been used by many land-grant institutions to conduct research on agricultural adaptation to climate change. One such project is being conducted by seventeen land-grant institutions from the North Central region of the US as a multisite project on the impact on climate and soils on crop selection and management. The research aims to improve yield forecasts for marketability of crops, better decision making for irrigation, and efficient pest management techniques for agriculture production in each of the participating states.

Economic Research Service

The Economic Research Service (ERS) conducts research to inform public and private decision making on economic and policy issues involving food, farming, natural resources, and rural development. Current ERS research, analysis, data, and market outlook programs can address questions about the effects of climate change and strategies to respond to changing conditions. The research provides information about food and commodity markets, resource availability, productivity (yields), global trade patterns, food security, environmental quality, and agricultural research needs to help stakeholders develop and compare adaptation strategies. Examples of ERS programs that can contribute are:

- USDA Agricultural Projections (Baseline) currently provides projections for the farm sector for the next 10 years, and ERS is a major contributor to the activity. These annual projections cover agricultural commodities, agricultural trade, and aggregate indicators of the sector, such as farm income and food prices. The projections are a conditional scenario based on specific assumptions regarding the macroeconomy, agricultural and trade policies, the weather, and international developments. Longer term projections will be needed to address the impacts of changing climate conditions beyond the next 10 years.
- The ERS Market Outlook Program details current changes and events in world commodity markets in monthly reports. Domestic and international models can be used to estimate production activities, agricultural trade, and global food security for alternative climate change scenarios. Longer term analyses will be needed to address the impacts of alternative climate change scenarios.
- ERS research on agricultural R&D and productivity growth in crops and livestock provides a basis to develop public and private research investment strategies to address yield changes, environmental stresses, and resource constraints.
- Farmers will adapt to changing climate conditions and to policies designed to mitigate climate change by altering their farming practices. ERS research on agricultural practice adoption, costs of production, and farm profitability will help policymakers understand changes in farming practices and the geographic distribution of crop and livestock production, and will evaluate the impacts of risk management policies and conservation incentives.

Farm Service Agency

- The Conservation Reserve Program enables agricultural producers to reduce nitrous oxide and fossil fuel emissions as land is converted from crop production to permanent vegetative cover. In addition, the CRP rule provides that contract holders may sell carbon sequestration or other environmental credits associated with land enrolled in CRP, thereby providing a new income source from associated ecosystem services.
- Facilitate crop reporting by agricultural producers to capture records of actual crops planted, failed, or prevented from being planted, including crops or methods not previously considered usual and customary to a local area
- Local county FSA committees have the authority, with State FSA committee approval, to change crop reporting deadlines, final planting dates, and normal harvest dates to reflect changes in the growing season or to approve new double-cropping crop combinations with adequate justification
- In the future, FSA is scheduled to be able to take crop acreage reports using geographical information systems (GIS) and Common Land Units (CLUs), significantly reducing per unit costs
- FSA is continually upgrading and improving how it collects imagery for compliance checking. We have moved almost entirely to the use of large format digital cameras that allow acquiring more simultaneous image band collection such as color, infrared, and natural color, as well as stereo collection. We also provide for higher resolution acquisition as a secondary contract product that can be purchased by our partners. The improvements allow more and better analysis of images.
- FSA, which has historically been called upon to administer ad hoc disaster programs, is currently working on implementation of five permanent disaster programs authorized by the Food, Conservation, and Energy Act of 2008: Emergency Assistance for Livestock, Honeybees, and Farm Raised Fish Program; Livestock Indemnity Program; Livestock Forage Disaster Program; Supplemental Revenue Assistance Payments Program; and Tree Assistance Program.
- Through CRP, FSA will provide leadership in preserving open space in a flexible and dynamic manner. Because the program utilizes contracts rather than permanent easements, CRP can, over time, allow the configuration of open space to change as climate changes lead to vegetative and wildlife species population movements.
- Since 2005, FSA has negotiated four Conservation Reserve Enhancement Program (CREP) agreements whose main objective is conserving agricultural irrigation water. Agreement provisions include incentives from State and local water use authorities to retire irrigation water previously used on irrigated cropland now enrolled in CREP. In three states, the

water would be retired for the duration of the CREP contract and, in the other state, permanently. It is likely that more CREP partnerships to conserve agricultural irrigation water will be developed in the future.

Forest Service

The US Forest Service (FS) conducts scientific research aimed at sustainable management of 191 million acres of national forests and grasslands, as well as providing support for state and private forestry. Management is aimed at continuous provision of the suite of ecosystems products and services which forests and grasslands provide. Hence, activities that lead to adapting ecosystems to changing climate and climatic variability are part of almost all Forest Service actions. The list of current climate change adaptation activities is summarized here. A more comprehensive project list is given in Appendix A.

In addition to about $27 million devoted specifically to global change research, about a third of which is adaptation research, much of the FS support for implementing climate change adaptation into direct management of the land, fall into five broad categories.

Climate change working groups

In many places, FS (management) regions have partnered with FS research stations, and with other land management groups to form working groups and task forces that provide advice, information, and common approaches to adapting ecosystems to climate change. Region 8 (southern US) created a "Climate Change Working Group" to monitor effects of disturbances related to climate change. Region 6 (Pacific Northwest) partnered with the Pacific Northwest Research Station to form a "Climate Change Strategy Group" to manage forests to better adapt to climate change. Region 9 (Northern Midwest and Northeast) formed a "Climate Change Catapult Team" to implement adaptation actions related to climate change, including creation of a "Climate Change Action Plan" which includes adaptation among its four themes. The Pacific Northwest Research Station (PNW) participates in "Climate Change Coordination (C3)" group with EPA, US F&WS, NPS, BIA, BLM, NRCS, USGS, NFS, NMFS, US ACE and Bonneville Power Administration in an interagency coordination group on climate change. Several other interagency climate change working groups are being formed or being created.

Climate change resource centers, decision support materials

Much effort in climate change adaptation is being applied to create climate change resource centers and to develop decision support materials. For example, three western research stations have partnered to create the "Climate Change Resource Center (CCRC)," a website widely used as an information resource by

forest managers. Decision support materials are many, and include the development of downscaled future climate data, regionalized with ecosystem feedback for the southern US, and based on regional global change models (RegCM) provided by the National Center for Atmospheric Research. The Southern Research Station (SRS) is developing a forest plan template aimed at integrating climate change adaptation into the National Forest Plan Revision (NFPR) process. PNW scientists are producing web based decision support tools to guide forest managers in selecting appropriate genetic stock for healthy growth under future climate conditions. With scientists from other western research stations, they are producing a toolkit for adapting to climate change on the western National Forests.

Educational courses and workshops

FS scientists have partnered with forest management regions to produce a wide variety of educational courses and workshops aimed at natural resource managers. For example, FS scientists and the Western Wildlands Environmental Threat Assessment Center (WWETAC) organized a "Comprehensive Climate Change Educational (C3E) Program: Adapting to Climate Change on Public Wildlands in the Western US." In collaboration with Region 6 and the University of Washington, PNW scientists have produced a "Climate Change 101" course for forest managers and resource specialists. Climate change adaptation workshops for federal, state and private land managers have been held in New Mexico, Wyoming and elsewhere, including "Climate Change Science Days" at Kootenai National Forest, Idaho Panhandle National Forest, Dakota Prairie Grasslands, and Custer National Forest. Specialized courses have been presented on "Bull Trout and Climate Change," "Vegetation Models and Climate Change for Practitioners," and "Adaptation of Forests" at the NPS workshop on climate change at the crown of the continent.

Adaptation assessments

Forest Service assessments have been aimed specifically at providing syntheses of literature and understanding needed to select the most appropriate management approaches to adapting forests and grasslands. PNW scientists are modeling effects of climate change on wildlife habitats and species in Alaska as the basis for a synthesis to identify adaptation options. WWETAC with Oregon State University is assessing the genetic and silvicultural options for adaptation in the Pacific Northwest. WWETAC with other FS researchers is synthesizing existing information to develop "climate smart" pest models. Working with the Canadian Forest Service, FS scientists are adapting risk assessment protocols to assess the effects of climate change on future dynamics of the gypsy moth in the Pacific Northwest. Similar groups are assessing interactions between future climate and bark beetle outbreaks in the western US, and between climate and tree pathogens in the western US. These groups are also developing west-wide threats/risk mapping tools (NETAM) to map the future risks to forests and grasslands from multiple stresses, including maps of future climate change, wildfire, invasive

species, pest outbreaks and land use change. In addition, FS scientists led writing teams on the USGCRP Synthesis and Assessment Products that included effects of climate change on land resources (SAP 4.3), and adaptation options on federal lands (SAP 4.4).

Case studies, pilot projects, model forests

FS is deeply involved in using case studies and pilot projects to test the utility of various adaptation strategies. For example, Region 1 (Northern Rocky Mountains) and RMRS are working on four climate change case studies on national forests in North Dakota, Montana and Idaho. Nine test sites are being established in the Pacific Northwest to examine effects of climate on different seed sources. PNW is also developing replicate case studies of adaptation management options in the Olympic and Okanogan-Wenatchee-Colville National Forests and Olympic National Park. SRS is establishing a "Climate Change Pilot Forest" to better understand climate change options in forest planning. The Northern Research Station (NRS) has partnered with Region 9 to create a "Climate Change Model Forest" located in central Wisconsin, and aimed at demonstrating climate adaptation approaches.

Natural Resources Conservation Service

NRCS provides incentives and supports voluntary actions by private landowners to manage GHG emissions and carbon sequestration through a portfolio of conservation programs including the Environmental Quality Incentives Program, Wildlife Habitat Incentives Program, Conservation Stewardship Program, Grassland Reserve Program, and Wetlands Reserve Program. Mechanisms for adaptation to climate change are critical for conservation of natural resources, continued production, and food security. NRCS works with partners to develop new technologies and tools to enable producers to make appropriate adaptive management decisions and to prepare for environmental stresses such as drought, changes in disease or pest prevalence and floods. NRCS plans to focus with its partners on developing the knowledge and tools needed to enable adaptation to climate change and to improve the resilience of natural and managed ecosystems. Conservation systems will need to be designed to deal with expected changes in climate and enhancements to existing systems targeted for change. As these new methods, tools, and assessments for evaluating the effectiveness of conservation systems come on line and the knowledge to protect and enhance our natural resources in the face of a changing climate increases, we plan to assist our clients in identifying systems and options that will effectively adapt their operations to climate change. These advances may include:

- Identifying and prioritizing geographic areas and land management systems most vulnerable to climate change, including soils, landscapes, and ecosystems as mediated or affected by management and land use systems.

- Evaluating sustainable agricultural activities and alternative strategies for increasing ecosystem resilience.
- Developing a Soil Change (Dynamic Soil Properties) Inventory to evaluate land use and management effects on soil quality and to estimate soil resilience, soil resistance and soil changes in various ecological systems.
- Improving life-cycle analyses and management strategies for assessments.
- Designing conservation technology and systems that can assist producers with adapting to actual and expected climate change.
- Identifying and/or developing necessary climate databases to accurately reflect expected climate changes for use in NRCS natural resource predictive tools and models.
- Improving and optimizing expansion of SNOTEL and SCAN sites to improve farming and ranching production under changing climate scenarios.

Appendix A

Comprehensive list of Forest Service climate change adaptation activities

Region 1 is working with Rocky Mountain Research Station on four climate change case studies. These are occurring on the Kootenai/Idaho Panhandle National Forests (completed), Dakota Prairie National Grassland (began in Dec. 2008), and eastern Custer National Forest and the Helena/Lewis & Clark National Forests (slated for spring '09). The case studies will include a "science day" of presentations on climate change and an adaptation options workshop.

Region 1 has also committed to fund acquisition of regional climate trend and projection information for the Northern Rockies and Northern Great Plains. Region 8 created a Climate Change Working Group to monitor the effects of disturbances potentially related to a changing climate. Forest Inventory and Analysis data will be used to monitor regionwide changes in forest composition, density, seral stages, and tree health; permanent plots will also be reinventoried after disturbances to track changes. Data from the Eastern Forest Environmental Threat Assessment Center will be used to determine the cause of disturbances and track any increases in weather-related disturbances.

Northern Research Station is working with Region 9 to help the Region's foresters understand and cope with potential climate change effects and develop adaptation strategies. The goal is to increase employee awareness of climate change and expected future impacts and to identify options for adapting future forests to climate change. Specific attention will be paid to including the best available climate change science in the forest planning process.

The Southern Research Institute's Southern Institute of Forest Genetics and Ecosystems Biology is developing innovative approaches to answer climate

change questions, including how forests will change in response to climate conditions and how forest management can play a role in adapting forest ecosystems to climate change. Scientists are using study sites across the South, experimenting with methods that range from electronics to genetics. http://www.srs.fs.usda.gov/sifg/

Regionalized Climate Change Scenarios with Ecosystem Feedback for the Southern US: The Center for Forest Disturbance Science is building an integrated regional climate modeling framework, that includes the co-variant risk associated with climate change disturbance regimes and demographic change and provides high-resolution climate change scenarios in the southern US, and to assess the ability of ecosystem/climate feedbacks to mitigate or intensify GC impacts. Initially the NCAR regional climate model (RegCM) will be used to downscale Intergovernmental Panel on Climate Change (IPCC) projections from a number of Global Circulation Models (GCMs) to a southern domain with 10 km resolution. In subsequent years with continued or increased funding, they will conduct similar simulations for past land use / land cover change (LULCC) due to agriculture-forest conversion and urbanization, future demographic shifts projected by the SRS Southern Forest Futures Project, and alternative future urbanization and ecosystem management strategies. Deliverables include a report describing the framework, results and implications; datasets in digital and image formats of regional climate change in the South for further use by other research groups; along with detailed description of results on the unit website and in manuscripts.

The Southern Research Station is establishing a "Climate Change Pilot Forest" to better understand climate change in forest planning. The project seeks to introduce forest managers to processes, knowledge, and tools that help them easily assemble and analyze information to reveal bioclimatic relationships and elucidate the consequences of alternative management choices. EFETAC researchers are collaborating with Region 8 forest planners, universities, and non-government organizations (NGO's) to understand how forest resources will be impacted by global warming and climate change during the next 20 years. Together, they will develop a template that the National Forests can use within the National Forest Plan Revision (NFPR) process. This template will present the natural resource issues likely to impact particular forests in coming decades, provide standard peer-reviewed scientific text that can be inserted into the NFPR, and direct forest planners and stakeholders to specific resource information pertaining to that area or forest. Current efforts are focused on multiple forests within the Southern Region (Region 8); future efforts will include forests of the Eastern Region (Region 9).

Pacific Northwest Research Station is conducting a Seed Source Movement Study. Nine test sites are being established using Douglas-fir native stands in order to make broad inferences and understand adaptation to climate change. A seedling genecology study, a greenhouse study to look at the effect of different winter

chilling hours on budburst, and a study to examine the association of adaptive traits and DNA sequence variation are linked to the nine test sites.

Pacific Southwest Research Station's Sierra Nevada Research Center has a research team addressing issues ranging from basic research on ecological response to climate and landscape change to applications in national forest management, conservation, and restoration.
http://www.fs.fed.us/psw/programs/snrc/climate_landscape/

The Pacific Southwest Research Station (PSW) is working on Restoration of Ecosystem Processes. PSW's Institute of Pacific Islands Forestry aims to provide a scientifically sound basis for the reconstruction and functioning of damaged ecosystems that are self-supporting and, at least to some degree, resilient to subsequent change. Research in Hawaii, the Federated States of Micronesia, and Costa Rica is providing information on how different species interact with each other and their environment during ecosystem development, as well as on specific requirements of tree species used in restoration efforts.
http://www.fs.fed.us/psw/topics/ecosystem_processes/tropical/restoration/

The Sequoia National Forest and the Giant Sequoia National Monument have partnered with the PSW Research Station, the Sequoia-Kings Canyon National Parks, and the U.S. Geological Survey to develop a multi-agency adaptive research program that crosses boundaries between the forest, monument, and parks and to establish a joint Research Learning Center. http://www.fs.fed.us/r5/climate/

Region 6 partnered with Pacific Northwest Research Station to form a Climate Change Strategy Group to develop ways to reduce the agency's carbon footprint and manage forests to better adapt to climate change. Task teams work on awareness and education, NEPA, adaptation and mitigation, sustainable operations, and synthesis and assessment tools. The group held a Climate Change Short Course in May 2008 to familiarize employees with current climate change information and concepts. Two hundred employees attended the short course. A DVD of the Short Course is available.

In Region 9, a Climate Change Catapult Team was formed by Regional staff to implement actions related to climate change. Region 9 is currently developing a Climate Change Action Plan., which focuses on four themes: adaptation, mitigation, sustainable operations, and communications/outreach. Working groups will be established for each theme.

"Reforestation, Nurseries, and Genetics Resources" (RNGR) is a collaborative effort between State and Private Forestry and Research and Development to develop genetically resistant planting stock and collect and preserve germplasm from existing natural populations to conserve at-risk species. RNGR addresses the need for seed information and services related to adapting ecosystems to both climate change and invasive species. With funding from State and Private

Forestry, the program provides nurseries with the latest technical information. http://www.rngr.net/

Adaptation of Urban Forest Resources to Climate Change: the synergistic effect of rapid land use change caused by urbanization and the projected climate change will create a unique combination of environmental consequences that will significantly affect not only natural ecosystems but also people. To address this complex issue, Southern Research Station (SRS-4952) will implement a multifaceted research program that examines not only the social and biophysical components in urban and urbanizing landscapes but also the best mechanisms for science delivery. The types of questions being asked include: How do the carbon and nitrogen cycles change with urbanization and what are the implications of these changes on ecosystem structure, function, and services? What recreational indices and measurements are needed to forecast changes in recreational usages because of climate change and how can these indices be applied to RPA forecasting? Because climate change will affect minority populations the greatest, what are the needs of minority populations to minimize climate effects and how can the urban forest be used to lessen these effects? Finally, what are the best methods for science delivery on the effect of climate change on natural ecosystems and people for different audiences in urban and urbanizing landscapes?

Southern Research Station is conducting an Economic Analysis of Climate Change in the Southern U.S. to forecast the effects of climate change on forest condition and use. In conjunction with natural resource projection modeling being conducted for the RPA and for the Southern Forest Futures Project, SRS will continue to work on forecasting the effects of climate change on the structure of forests. These forecasts address not only the direct biophysical determinants of change, but also the indirect changes caused by human responses to climate changes. These include both changes in land use and changes in timber management activities due to altered productivity and increased demands for both carbon stored in forests and the harvest of trees to generate bio-based energy.

The Southern Research Station is studying soil impacts associated with bioenergy harvesting. The Southern Research Station's Silvicultural Assessment on the Daniel Boone NF in Kentucky is examining alternative silvicultural treatments in oak-hickory forests. One of the primary outputs is woody biomass for energy production. An additional assessment of soil impacts will be conducted on the completed harvesting units to characterize residues and carbon effects of the treatments.

The Southern Research Station is conducting a life cycle analysis for biomass Harvesting Operations in the Southern US. The Southern Research Station is making a new effort to collect information about the life cycle emissions profile for various types of biomass harvesting operations around the country. The data will be included in the National LCA Database maintained by the National

Renewable Energy Lab. This component of the effort will quantify fuel consumption and emissions associated with whole-tree mixed product harvesting as well as biomass thinning in the southern US.

The Southern Research Station is studying the effect of various woody biomass feedstocks on the Production of Synthesis Gas. A project that began on the Kisatchie National Forest to find end uses for negative value woody debris removed for their red-cockaded woodpecker habitat improvement program, this project evaluates the potential of various undervalued species and fuels loading understory material as chemical feedstocks in gasification systems. This project connects the developing cellulosic ethanol industry and the wood supply through existing wood quality and FIA databases.

Pacific Northwest Research Station scientists have prepared a synthesis that will be published shortly that addresses the following two questions:

- What forest and range management practices are best for optimizing carbon uptake and preventing carbon release from forests and rangelands? and
- What are the current opportunities (market mechanisms, certification/eco-labeling schemes, government subsidies or incentives) for forest owners and ranchers who would like to obtain income from carbon-oriented management; how are these opportunities perceived by them; and what are the barriers and constraints landowners face in taking advantage of these opportunities?

Pacific Northwest Research Station scientists are modeling effects of climate change on wildlife habitats and species in Alaska. They are synthesizing data and models of climatology, vegetation, and land cover response, and the implications for wildlife species and habitats in North Slope, Brooks Range, and Yukon Flats regions of northern and central Alaska. The synthesis will identify options for adaptation.

Decision Support for Management Identification of Best Forest Treatments for Lifecycle Carbon Offsets, Fire Reduction, and Avoiding Future Costs: PNW scientists have demonstrated application of a site- and landscape-specific tree list-based decision-support tool for selecting forest management action priorities in the Western United States that best mitigate carbon emissions while reducing fire risk and future costs (adapting management to climate change).

Global Climate Change and Policy Analyses: Decision Support Concerning Impacts, Mitigation Strategies, and Adaptation for the Forest and Agricultural Sectors

An analysis of land market adjustments, interregional migration of production (e.g., northerly migration of production capacity), substitution in consumption between wood and nonwood products (reflected in overall growth in wood

products use) and between sawtimber and pulpwood, and alteration of forest stand management provides input for the development of adaptation strategies.

PNW scientists are developing decision support tools for determining appropriate provenances for future climates. They are creating a web-based decision support tool to help managers select appropriate genetic stock for adapting to future climates will be available in the summer of 2009. This tool will allow a much wider dissemination of current knowledge concerning appropriate genetic stock than is currently possible through individual consultations and traditional technology transfer activities.

Forest Service researchers are producing a toolkit for adapting to climate change on Western National Forests ("Incorporating Climate into Resource Management and Planning"). PNW scientists, along with colleagues from PSW and RMRS developed and evaluated a set of decision-support tools and reference materials that incorporate climate-change considerations into decision-making on western national forests. These tools are broadly relevant to other managers, policy-makers, and scientists. We developed adaptation management resource materials in multiple formats, conducting replicate case studies on the Olympic and Okanogan-Wenatchee-Colville National Forests and Olympic National Park to develop and evaluate decision support for adaptation to climate change.

PNW scientists are studying the decline of Yellow-Cedar in order to better understand management of a tree sensitive to climate in Southeast Alaska. Silvicultural methods of artificial regeneration and active management are being developed to adapt yellow-cedar management to changing climate that has reduced snowpack and compromised root systems through spring freezing.

PNW, RMRS, PSW, and the Western Wildland Threat Assessment Center, have collaborated to create the Climate Change Resource Center (CCRC), a web site that is widely used as an information resource by forest managers.

Pacific Northwest Research Station created a Climate Change 101 course in collaboration with Region 6 and the University of Washington. With those partners, PNW presented an introductory 2 day course to about 200 managers and resource specialists. The course covered the basics of climate change as well as strategies and opportunities for adaptation.

Region 6 and PNW convened Climate Change Strategy working groups to develop strategies for adaptation, mitigation, education, sustainable operations, planning, and policy. The workgroups are actively providing advice to units as they develop options for adaptation to climate change.

Climate Change Coordination (C^3): PNW participates with EPA, US F&WS, NPS, BIA, BLM, NRCS, USGS, NFS, NMFS, Bonneville Power Authority, and Army CoE in an interagency coordination group on climate change. Currently the group is prioritizing management questions regarding adaptation and mitigation from each

of the agencies. We will then identify likely sources of information or science resources available to address the questions, or document the need for additional research or synthesis.

PNW scientists are actively engaged with a variety of partners in the region to provide science support regarding adaptation and mitigation to federal, tribal, state, and local governments, and to private organizations and the public. This support takes the form of workshops, seminars, presentations, and consultations:

In November 2006, climate change scientists from the three western research stations developed a west-wide assessment proposal: Assessing and Adapting to the Effects of Climate Change on Western Ecosystems. This proposal outlines a climate change R&D effort that will provide state-of-science information on climate change and the physical, ecological, and socioeconomic consequences.

The Western Wildland Environmental Threat Assessment Center works with the three western research stations (PNW, RMRS, and PSW) to address ecosystem vulnerability and the interaction of climate change with other stressors and land management under various climate change scenarios. Work is focused on coordination of three case study assessments in the western U.S.

The Western Wildland Environmental Threat Assessment Center is working with PSW and UC Berkeley to conduct a Historic Analysis of Wildfire, Insects, and Climate Interactions. This project continues the development of probabilistic risk models for forest disturbances like wildfire and forest insect outbreaks. The project is mining existing historical data with novel nonparametric, spatially and temporally explicit statistical models.

The Western Wildland Environmental Threat Assessment Center is working with Oregon State University on a study of forest management under climate change; they are doing a synthesis of genetic and silvicultural options for the Pacific Northwest. The cooperators are evaluating how climate change will affect forest trees in the Pacific Northwest (PNW), and then assessing genetic and silvicultural options aimed at maintaining the adaptability, productivity, and value of PNW forests under a range of climate change scenarios. The overall goal is to provide practical information to guide forest management and policy decisions within land management organizations.

The Western Wildland Environmental Threat Assessment Center hosted a workshop in June 2007 with PNW MAPPS team, RMRS, PSW, ESSA, and FHTET, to synthesize existing knowledge and develop “climate-smart” pest models. For this workshop, focus was on major native insects and diseases, potential climate change, and forest resource issues. The goal of the workshop is to develop a conceptual model for moving forward with the integration of climate change into existing pest and vegetation models. Results from this workshop are feeding into new projects.

The Western Wildland Environmental Threat Assessment Center is working with Utah State University, FHP R4&6, and the Canadian Forest Service to adapt an existing risk assessment protocol to assess the effect of climate change in the Pacific Northwest on the future dynamics of the gypsy moth. Gypsy moth is a potentially threatening exotic insect to Pacific Northwest forest ecosystems. Logan et al. (in press, *Ecological Application*) developed a spatially explicit risk assessment protocol for assessing the impacts of gypsy moth introduction and spread under two General Circulation Models (CGCM1 and HADCM2SUL) for the state of Utah. They are working to do a similar risk assessment for gypsy moth and climate change in the Pacific Northwest.

The Western Wildland Environmental Threat Assessment Center is conducting a rapid threat assessment of the potential interactions between climate change and bark beetle population dynamics in the western U.S. with the following partners: FHTET, FHP, Western FS Regions, Western Stations Bark Beetle Research Group. We are developing a data and expert opinion based assessment of the interactions between climate change and the future population dynamics of bark beetles in the western U.S. that can be completed rapidly so that information can be transferred to relevant clients.

The Western Wildland Environmental Threat Assessment Center is conducting a rapid threat assessment of the potential interactions between climate change and tree pathogen dynamics in the western U.S. with the following partners: FHTET, FHP, Western FS Regional Pathologists, Western Stations Research Pathologist. This project is compiling literature and synthesizing known information concerning climate, climate change, and forest diseases in the Western United States. For the Western States, the document will summarize what is known about climate's influence (temperature and moisture primarily) on forest fungi, bacteria, nematodes, other microbes, and abiotic damage agents. In a latter phase of the project, the changes in these relationships under various climate change scenarios (i.e. hotter and wetter, hotter and drier, colder and wetter, colder and drier) will be described to identify threats and predict changes. Experts in various organisms will be identified and canvassed, and a literature search conducted to identify climate relationships. The information will be compiled and then synthesized so it is accessible and applicable for various professionals.

The Western Wildland Environmental Threat Assessment Center is creating west-wide threats/risk mapping tools (NETAM) with partners FHTET, FHP, and RSAC. The goal of this cooperative work with RSAC is to create a system in which forest and rangeland policy makers and managers can access maps of the relative risks to forests and rangelands from multiple competing or exacerbating stresses, including climate change, fire, invasive species, disease, pest outbreaks, and land-use change. This system will be used to generate overlapping maps of risk from each of these major threats to western US forests.

The Western Wildland Environmental Threat Assessment Center, in partnership with the Westwide Climate Change Initiative is conducting a Westside Climate

Change Initiative Workshop. The workshop will be part of the western region case study assessment process. This workshop will bring together scientists, managers, and other stakeholder's involved in the three case study areas. This initial workshop would include parties from all interested case study areas. The workshop will guide the direction of the case studies, provide a general structure, and foster collaboration and interaction.

With the Washington Office and the Rocky Mountain Research Station, the Western Wildland Environmental Threat Assessment Center will conduct a workshop on Exploring Quantitative Approaches for Vegetation Management and Forest planning under a Changing Climate. Workshop goals and objectives are to (1) evaluate and document the purposes, limitations, strengths and weaknesses of the different classes of models that can be used to project future vegetation with climate change, and (2) provide a forum for discussion between modelers, planners and managers on ways to increase the use and effectiveness of various vegetation management models in a changing climate. The desired outcomes of the workshop are (1) managers and planners will have an improved understanding of the strengths, weaknesses and limitations of the various models, including a clearer knowledge of the questions that each model can and cannot answer, and (2) modelers will have a better sense of the questions being posed by the planning community and will be better able to plan for the improvement of their models to accommodate these needs. Results from this workshop will be used to develop a short-course training module for managers and planners.

Comprehensive Climate Change Educational (C3E) Program: Adapting to climate change on public wildlands in the Western U.S. Partners: (CAP program), Westwide climate change initiative, (RMRS). Climate change research has become a priority issue and WWETAC, PNW, and the FS need to respond broadly and quickly. Effective knowledge management is critical. The training/education needs for public land managers is large and urgent. WWETAC has a central role and can coordinate a comprehensive series of resources and events to achieve effective education of the FS workforce in climate change. A workshop on Exploring Quantitative Approaches for Vegetation Management and Forest Planning under a Changing Climate (described above) is planned that forms an excellent module for the larger program. However, this component needs to be built into a framework that includes all relevant topics and a variety of training modalities. WWETAC, in coordination with the Westwide Climate Change Initiative, will work to design courseware that uses this new and efficient means of real-time, on-demand training and collaboration. Products will include multiple media training material (web, video, live courses, etc.).

The Northern Research Station (NRS) made significant contributions to the national bioenergy "growth platform" and conducted the first R9 climate change, mitigation and adaptation workshop at the Ottawa National Forest workshop.

NRS received a grant from the national global change research program and conducted a workshop titled “Silvicultural Strategies for an Uncertain Climate Future” that involved

NRS silviculture units and R9 land managers.

Region 9 hosted a Forest Service/Nature Conservancy partnership meeting that focused on assessment of protected areas under climate change

The Forest Products Lab provided exceptional leadership in organizing partnership to develop technologies for converting biomass to biofuel.

NRS established a Forest Service/Princeton University Climate Change Partnership.

NRS established an Eastern “Climate Change Resource Center,” a web site to complement the Western web site.

Rocky Mountain Research Station (RMRS) scientists collaborated to develop the RMRS Climate Change Strategic Plan.

The “New Mexico Forestry and Climate Change Workshop” held November 20, 2008 provided foresters and other natural resource professionals up-to-date information on climate change and forests in New Mexico, including on-going research at RMRS; presentations available at www.forestguild.org/nmfccworkshop.html.

Working with NFS and State Agencies in Wyoming, RMRS organized the first climate change workshop on natural resource management in Wyoming: 6/16/08. Talks are available on the web.

RMRS scientists gave talks at National Forest Service meetings on topics of climate change, adaptation and mitigation: Region 1 Discussion Group on Climate Change (3/7/2008), Region 2 Renewable Resources Climate Change Workshop (2/26/2008, talks available on the web), Region 2 Climate Awareness Day (5/20/2008), family meetings on the Pike San Isabel NF and the Pikes Peak District, Region 3 Business Managers (3/1-2/2008), the national meeting of the USFS Public Affairs Officers (3/4/2008).

Working with USFWS, RMRS scientists organized the symposium “Bull trout and climate change: risks, uncertainties, and opportunities for mapping the future” at the Western Division American Fisheries Society meeting (5/2008), providing an overview from leading experts across the Pacific Northwest of the current science pertaining to climate, potential impacts to stream habitats, and bull trout biology. Talks are available on the web.

RMRS and the Western Wildlands Environmental Threat Assessment Center organized a 2 day workshop entitled Vegetation Models and Climate Change for practitioners.

At the 8th National Conference on Science, Policy and the Environment, RMRS and PSW scientists led a breakout session on Forest Management and Climate Change, as part of the Climate Change: Science and Solutions, 8th National Conference on Science, Policy, and the Environment. Washington, DC. 1/17/2008. RMRS received 5 grants from the FS National Global Change Research Program:

- Development and Delivery of a Climate-Driven Forest Vegetation Simulator
- Designing wildlife corridors for a changing climate
- Climate-Change Toolkit for Western Forest Service Managers and Decision-Makers; Incorporating Climate into Everyday Resource Management; (PSW, PNW, and RMRS).
- Tools to Assess and Assist Vulnerable Species At Risk From Climate Change
- Forests and Carbon Storage – A Synthesis of the Science for Policymakers.

Rocky Mountain Research Station scientists organized a special symposium entitled "Potential impacts of climate change on diseases in natural ecosystems: Using history to predict the future" and gave talks at the Centennial annual meeting of the American Phytopathological Society, 26-30 July 2008, Minneapolis, MN

The Rocky Mountain Research Station and Region 1 Climate Change Partnership has the objectives of building on and expanding the on-going public, stakeholder, and employee collaboration to address climate change in resource management and planning, and providing technology transfer and help understanding and sorting through the scientific literature. Towards that end a series of Climate Change Science Days have been and are planned in FY2009. These science days bring together experts in climate change and natural resource management. Before each Science Day, a sample of employees was interviewed in advance to determine topics of discussion and depth of presentations for the Science Day.

- Kootenai National Forest, October 14, attendees included 40 employees, and an evening session with public;
- Idaho Panhandle National Forest, October 15 – combined employee and stakeholders – 120 attendees,
- Dakota Prairie Grasslands, December 5 – 50 employees – no public session,
- Custer National Forest, December 12 – 20 employees and one reporter, 5) Lewis and Clark and Helena National Forests, late spring 2009.

Rocky Mountain Research Station scientists have synthesized key information from SAP 4.4 Report “Adaptation Options for Climate-Sensitive Ecosystems” in a 2 page format designed to be accessible to resource managers.

Working with National Park Service and USGS staff, Rocky Mountain Research Station organized a ½ day session on Adaptation in the NPS Workshop 'Climate Change in the Crown of the continent: Identifying multi-jurisdictional Strategies, December 1-3, 2008. Attendees to the workshop included National Park Service, NFS staff, tribal groups, state agency staffs and NGOS.

Rocky Mountain Research Station hosted a "Climate Change: Consequences for Birds" Symposium at the 2009 annual meeting of the Cooper Ornithological Society, April 18, 2009 (http://www.birdmeetings.org/cos2009/symposia.htm).

FS International Programs

In collaboration with the International Union of Forest Research

Organizations and the UN Food and Agriculture Organization, the Forest Service International Programs office helped sponsor a large conference in Sweden focusing on the challenge of adapting forest ecosystems and dependent communities to climate change. One of International Programs' country-specific projects involves working in the Middle East and North Africa to establish climate change adaptation strategies and identify incentives to improve land use practices and policies in semiarid zones at risk of desertification."

Additional Update as of September 8, 2009

The Risk Management Agency has contracted with a research group to provide a technical report on Climate Change Impacts on Federal Crop Insurance and develop a program impact model. The contractor has submitted preliminary results and the final contractor report is due by December of this year. The report focuses primarily on changes in climate and the resulting changes in crop yield distributions, shifts in production regions, and changes in management practices. With increasing variability of climate, there may be a need to incorporate catastrophic modeling to maintain actuarial soundness for certain crops. The crop insurance program may also be impacted through changes in the expected losses that necessitate modifications to the program. Using information contained in the report and other information, the Risk Management Agency will evaluate how it can adapt the crop insurance program to accommodate potential climate change scenarios."

The National Oceanic and Atmospheric Administration (NOAA) submitted information on its adaptation-related efforts on May 11, 2009. NOAA was given the opportunity to review its initial submission and did not send us any changes or updates for this e-supplement. GAO did not assess the validity of this submission. Any questions should be directed to NOAA.

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

"NOAA provides scientific data and information for adaptation to others. NOAA's climate information services build on a long history of providing authoritative climate science, based upon extensive observations, data stewardship, monitoring, research, modeling and assessment. NOAA's climate services include: developing and delivering operational climate information, products and services; supporting informal and formal education and training; supporting research on the impacts of climate variability and change; supporting the development of assessments and adaptation strategies from international to local levels; and collaborating with stakeholders to enhance their capacity to use climate information and related resources. Climate information such as drought forecasts, long-term precipitation trends, fire forecasts, and frequency and intensity of coastal storms, are all examples of information developed by NOAA that can inform the development of adaptation plans and strategies. We are collaborating with federal, state, local, tribal, academic, and private sector partners on adaptation activities within specific geographic regions and on issues such as water, coastal and marine resources, agriculture, energy, health, and infrastructure.

As many climate-related changes are being observed in the United States and abroad, NOAA is witnessing a corresponding increase in demand for our products and services. As the influences of climate change further grow over time, we expect to see an increased need for the tools and services needed to transition science into sound decisions. These tools include assessments of climate impacts at the appropriate scales, baseline data and predictions, sustained support for regional institutions, information products with quantifiable details, user-friendly maps and visualizations to communicate risk, and training and capacity building, to name a few. NOAA will likely need to increase its own capacity in these areas to serve the increased needs of the Nation while helping to improve public awareness and increasing coordination and integration of information services conducted with our federal, academic and private partners.

What specific actions and policies has your agency put in place – or is planning to put in place, or is exploring putting in place – to ameliorate or otherwise deal with the influences and impacts of climate change in the domains where your agency has jurisdiction? How does NOAA assess the effectiveness of climate change adaptation?

NOAA's adaptation planning efforts cover marine fisheries, coastal and ocean habitat and ecosystems, and supports and informs coastal planning and development efforts, maritime transportation, water resource management, and other government and private sector adaptation issues like insurance, energy and agriculture. Additionally, NOAA directly and indirectly supports significant adaptation planning activities done by other public and private efforts by providing climate information and services capabilities. For the last several years, NOAA has been working toward a strong climate science foundation that connects research, service providers, and users. This work has drawn from the agency's extensive experience in working with stakeholders and from our world-renowned expertise in climate monitoring, modeling and research.

NOAA is now in the process of defining goals and principles for use in guiding the development a NOAA National Climate Service. The overarching goal of a National Climate Service is to provide the essential climate change information needed for effective decision-making. NOAA, both a producer and user of weather and climate information, is working to integrate its observations and predictions, improve delivery of integrated climate information to ocean and coastal decision makers, and provide tools to effectively use this information to assess risks and implement effective management strategies. Improving the development and delivery of climate services offers untold economic, public health and safety, and national security benefits.

NOAA is developing an integrated process for mainstreaming adaptation into our resource management activities and transferring climate science to society to allow for informed decisions at the Federal, state and local levels. Our current adaptation activities can be grouped into the following areas: science and monitoring in support of adaptation services, partnerships and applied information services in support of adaptation with applications for water resources, living marine resources and habitats, and coastal communities, as well as related international activities. (For more details, an illustrative list of adaptation-related activities in the areas listed here is included below as Appendix 1.)

Since climate change influences events across timescales from months to centuries, we must learn to adapt to a moving target, which makes the issue of evaluation an especially important and difficult topic. Any monitoring and evaluation efforts need to be conducted in a dynamic way to accommodate uncertain and/or shifting information. Climate adaptation assessment is a relatively new area for NOAA, and to begin to address it, NOAA is examining

existing methodologies and building its capacity to reach out to stakeholders. For example, through NOAA's Regional Integrated Sciences and Assessments Program (RISA), our researchers work directly with people who have an investment in activities, resources, or property that may be vulnerable to climatic impacts. These stakeholders hold the key to understanding what kinds of information can aid the public and how best to provide that information. Effective assessments of adaptation efforts would likely need to build on data and partnerships of this type. NOAA welcomes information from its partners regarding this issue as we seek to develop assessment strategies.

NOAA has begun to interact with other agencies in a broader effort to organize climate information across agencies and to maintain the resilience of the Nation's ecosystem services. NOAA sees opportunities to work more closely with the Departments of Interior and Agriculture, for example, to initiate consultations with land and water resource managers. This would enable an ongoing process for synthesizing information and begin to improve the relevance of the information provided. Out of such efforts, NOAA hopes to identify best practices to be shared across agencies. Through its existing capabilities, partners and networks, NOAA has begun to provide climate and information services to address society's needs while we work to evolve our services to meet the increased pace and nature of these demands.

Appendix 1

Science and Monitoring in Support of Adaptation Services:

NOAA is the Nation's provider of weather and climate data, science and information. NOAA's climate information services are based upon extensive observations, data stewardship, monitoring, research, modeling, predictions, projections, and assessments. Climate information such as drought forecasts, long-term precipitation trends, fire forecasts, and frequency and intensity of coastal storms, are all examples of information developed by NOAA that can inform the development of adaptation plans and strategies by decision makers and resources managers.

- *NOAA plays a lead role in the scientific assessments* of climate change impacts and science
- *NOAA maintains key observing systems* for monitoring coastal, ocean, atmosphere, and ecosystem data and observations including biological and physical ocean conditions
- *NOAA is steward of climate-related data* and information and maintains the world's largest active archive of weather and climate data
- *NOAA provides critical weather and climate predictions and projections*, as well as key climate model simulations for national and international climate assessments such as IPCC
- *NOAA develops regional and coastal climatologies*

Partnerships and Applied Information Services in Support of Adaptation – Applications to Water Resources

Climate variability and change affect the function and operation of existing water infrastructure — including hydropower, structural flood defenses, drainage, and irrigation systems — as well as water management practices. NOAA's climate programs provide the Nation with services and information to improve management of climate sensitive sectors such as water resources through observations, analyses and predictions, decision support tools, and sustained user interaction.

- *NOAA has significant experience in understanding user information needs* and developing and delivering products and services that respond to those needs

Partnerships and Applied Information Services in Support of Adaptation – Applications to Living Marine Resources and Habitats

Climate change information is being incorporated into coastal and ocean living marine resource and coastal ecosystem management decisions within NOAA through an increasing emphasis on an ecosystem approach to management and other efforts. NOAA works to help coastal communities acquire, protect, conserve, and restore coastal habitats, not only for the aesthetic and natural habitat benefits, but also because they provide important services to reduce the impacts of storms, flooding, and other coastal hazards.

- *NOAA participates in and leads many state of knowledge assessments* for specific user-focused issues (e.g., water resource management, marine and coastal resources, disaster management)

Partnerships and Applied Information Services in Support of Adaptation – Applications to Coastal Communities

Through a federal-state partnership under its Coastal Zone Management Program, NOAA provides national leadership, technical assistance and funding to state and territory coastal management programs to plan for and adapt to climate change. Climate change related projects include creating sea level rise inundation models, developing plans for adapting to climate change, understanding changing ecosystem function and services, changes in ecosystem health and marine animal disease under existing and predicted climate change impacts, and establishing new guidelines for dealing with sea level rise.

- *NOAA has a growing number of collaborative efforts* with other federal agencies to produce more effective decision support tools

NOAA's International Activities in Support of Adaptation

NOAA recognizes that climate is an issue of global concern. NOAA sustains global partnerships to complement its observations, analysis, and data stewardship activities, providing input and feedback that enhances our understanding of the global climate system. NOAA's climate programs regularly interact and collaborate with a range of international climate organizations and supports work that results in substantial contributions to adaptation efforts worldwide. For example, NOAA-sponsored projects in Asia, Latin America and Africa are setting the standard for using a science-based approach to enhance society's ability to understand, anticipate and manage climate risk in order to improve human welfare in the developing world. The above examples are only a small subset of NOAA's work in climate adaptation activities. Beginning in 2008, NOAA has undertaken an effort to begin to develop an integrated climate service within NOAA to develop and deliver a broader range of operational climate information products and services; support research on the impacts of climate variability and change on human and natural environments; support and preserve the climate data record; support the development of assessments and adaptation strategies from international to local levels; and collaborate with stakeholders on enhancing their capacity to use climate information and related decision-support resources."

The U.S. Department of Defense (DOD) submitted information on its adaptation-related efforts on June 23, 2009. DOD was given the opportunity to review its initial submission and sent updated information on September 3, 2009. The information submitted pertained to the Office of the Secretary of Defense, Army, Navy, Air Force, and Marine Corps. Separately, the U.S. Army Corps of Engineers (USACE) submitted information on its adaptation-related efforts on March 20, 2009 and sent updated information on September 11, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to DOD or USACE.

U.S. Department of Defense

- "The Department of Defense (DoD) is proactively taking a variety of steps to adapt to climate change while also working with the White House Office of Energy and Climate Change to develop an Administration approach to climate change challenges.

- In responding to the GAO engagement, DoD is using the Intergovernmental Panel on Climate Change definition of adaptive capacity and adaptation: "Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." Adaptation is "the adjustment in human or natural systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." In general, climate change adaptation efforts are complicated by lack of clearly defined and scaled regional-level climate change impact assessments and lack of knowledge regarding how the climate may respond in the long term to mitigation efforts, but initial efforts to grapple with climate change issues are underway. Some examples are provided in this memo.

- It is appropriate to express a certain degree of caution at affirmatively defining all these activities as "climate change adaptation activities" due to the lack of a comprehensive national climate change adaptation strategy and action plan. Also, many of these activities, while they may help adapt to the impacts of climate change, serve other national defense purposes as well. Finally, since the mid-1990s the Office of Deputy Under Secretary of Defense for Installations and Environment and the Services have incorporated into their approach to land and water management the principles of ecosystem-based management including one of its key tenets, adaptive management. These approaches not only have led to sustainable use of natural resources to support mission needs and meet stewardship requirements, but also may contribute to ecosystem resilience in the face of climate change. Maintaining ecosystem resilience is a key adaptation strategy given the uncertainty of potential impacts.

- The ongoing Quadrennial Defense Review is examining the capabilities of the armed forces to respond to the consequences of climate change, in particular, preparedness for natural disasters from extreme weather events and other missions the armed forces may be asked to support inside the United States and overseas, as tasked by Section 951 of the 2008 National Defense Authorization Act. All of the Services and numerous DoD agencies are participating in this effort.

- Representative examples of the types of DoD activities that will contribute to climate change adaptation are briefly described below.

Office of the Secretary of Defense

- DoD Legacy Resource Management Program (Legacy). The Legacy program has begun to invest in national and regional efforts that will assist the Department in defining an adaptation strategy that will support the long-term sustainability of its natural and cultural resources. Current initiatives include:

    - A partnership with the National Wildlife Federation, the Association of Fish and Wildlife Agencies, the U.S. Fish and Wildlife Service and other federal agencies to develop a guidance manual that will summarize currently available natural resource-focused vulnerability assessment tools. A follow-up workshop to present key assessment tools to DoD natural resource managers is planned for March 2010.
    - A Pacific Regional workshop in February 2010 that will identify and prioritize potential management strategies for listed and at-risk species expected to be adversely affected by climate change.
    - A project to assess sea level rise scenarios on seven North Carolina military installations in order to aid decision-making regarding management of their natural resources and infrastructure.

- *Sustaining Military Readiness (SMR) Conference 2009*. The SMR Conference, held August 9-14 in Phoenix, AZ, included plenary sessions and workshops highlighting the need to assess and address current and potential impacts of energy and climate change on military readiness.

- *DoD's Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP)* have within the last couple of years initiated research and demonstration activities related to climate change in terms of impact assessment, adaptation, and mitigation:

    - During FY09 SERDP initiated four research projects focused on developing the methods, tools, and models necessary for DoD coastal installations to

assess the potential impacts of sea level rise and associated storm surge phenomena on installation infrastructure. The four projects purposely address different geophysical settings, physical forcing mechanisms, and different degrees of vulnerability assessment to reflect that climate change impacts, and the information needed to assess those impacts, will differ greatly by geographic region. Knowledge gained by these projects and application of the resultant products will assist DoD installations first in assessing potential impacts and then in using that information to develop adaptation strategies.

- Also during FY09, SERDP has initiated natural resource-related research projects associated with southeastern ecosystems that focus on potential climate change impacts to shoreline bird populations, test adaptation strategies for coastal marsh plant communities, and incorporate climate change into setting recovery objectives for southeastern ecological systems.

- SERDP has been funding since 2006 an ecosystem-based research program, the Defense Coastal/Estuarine Research Program (DCERP), at Marine Corps Base Camp Lejeune. The ongoing research projects under DCERP include studies of potential coastal marsh response to sea level rise and management strategies that facilitate an adaptive marsh response and geomorphological studies of barrier islands and their response to storms. As a planned long-term research program, DCERP has the potential to incorporate additional climate-change related research, including specific adaptation studies.

- SERDP has selected for FY10 funding three research proposals that address the interaction of invasive species, fire, and climate change on training and testing lands in the Southwest. In addition, four additional FY10 research proposals selected for funding will address the ecology and management of southwestern ephemeral and intermittent stream systems on Department of Defense lands under climate change.

- ESTCP demonstration projects include renewable energy projects and energy efficiency projects, in particular projects associated with improving building energy efficiency. Both SERDP and ESTCP are funding projects associated with microgrid technologies that not only will enable DoD installations to incorporate renewable generation into their energy mix, but also will be adaptive in that microgrid technology will enable installations to safely island themselves from the main grid in times of emergency.

Army

- *Army Sustainability Program.* Installation Sustainability Plans broadly address the physical components of installations (facilities, infrastructure, ranges and ecosystems) and their interactions and interrelations to create a sustainable environment while maintaining an adaptive ability to support current and future missions. This is an example of the kind of DoD activities that can help adapt to the impacts of climate change while serving other national defense purposes. Army sustainability planning focused on life-cycle cost effective investments over a 25-year period and includes: greater energy efficiency and surety (engaging in back-up/supplementary electricity generations and smart grids), more efficient use of fuels, green acquisition and purchasing, and ecosystem-based natural resources management. Many of these activities can also be considered as steps to mitigate or adapt to climate change.

- *Army Water Sustainability Study:* Climate change predictions in the southeast and southwest United States indicate a potential for more severe and extended drought conditions in those areas. This ongoing study will evaluate the vulnerability of Army installations to potential water shortages over the next 30 years. The study will evaluate current and predicted water use patterns on and near Army installations in the U.S., and compare them to sources and predicted availability of water around these installations. Currently ongoing at Ft Bragg, NC, and Ft Bliss, TX, the sustainable water assessment methodology is planned to be tested at an additional 10 U.S. installations and selected Army installations overseas.

Navy

- *Task Force Climate Change.* The Navy established Task Force Climate change (TFCC) in May 2009. TFCC is chartered to develop a Roadmap for Navy action regarding the Arctic specifically, and climate change in general. This organization consists of representatives from the Chief of Naval Operations' staff, Fleet Forces Command, Navy Program Offices, academia, interagency partners, and research and development activities. It will make recommendations to senior Navy officers regarding investments in climate change adaptation, as well as associated changes in policy, strategy, mission, and plans.

- *Naval Studies Board FY09 Study.* Navy recently sponsored a Naval Studies Board study on the National Security Implications of Climate Change on U.S. Naval forces (Navy, Marine Corps and Coast Guard), to be completed late 2010. This study will help the Navy develop future robust climate change adaptation strategies.

- *Navy Strategy.* The Navy incorporated the opening of the Arctic caused by climate change in the Naval Services' "Cooperative Strategy for 21st Century Sea Power," published in 2007, thereby ensuring that the Naval Services' strategic framework would allow for future climate change adaptation activities.

- *Education and Training.* Navy reviewed the curriculum of the U.S. Naval Academy's Oceanography Department and recommended addition of a course on climate, thereby ensuring that our future Officers will be better prepared to develop and refine climate change adaptation activities when they are in positions to do so.

Air Force

- *Education and Leadership Awareness*
  The Air Command and Staff College (ACSC) is the Air Force's intermediate professional military education (PME) school. It prepares field grade officers of all services (primarily majors and major selects), international officers, and U.S. civilians to assume positions of higher responsibility within the military and other government arenas, shaping and molding tomorrow's leaders and commanders. The curriculum of the in-residence program at the ACSC includes a lesson plan on Environmental Security that is structured to include climate change and energy security as emerging issues of national and international importance. The ACSC Distance Learning (DL) Master's Degree Program also incorporates discussions of environmental security and energy security. The Center for Naval Analysis publication *National Security and the Threat of Climate Change* and the Woodrow Wilson Center for Scholars Environmental Change and Security Project Report *Environmental Security Heats Up* serve as the core of the lesson plans.

- *Development of a Planning Framework for Climate Change*
  To better understand both the projected threats posed to Air Force operations by climate change and the type of information that will be needed to inform climate change-related policy decisions, Air Force personnel have been monitoring public, private sector, and non-governmental organizations for climate change and related national security studies. Such organizations include the National Intelligence Council, the U.S. Climate Change Research Program, the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the U.N. Intergovernmental Panel on Climate Change (IPCC), the Center for Naval Analysis (CNA), the Center for a New American Security (CNAS), the Center for Strategic and International Studies (CSIS), the World Resources Institute (WRI) and the Pew Center. Information gleaned from available studies and analyses will be considered in the development of an Air Force planning framework for climate change and will inform future policy decisions regarding appropriate management and adaptation strategies.

The Office of the Deputy Assistant Secretary of the Air Force, Energy, Environment, Safety and Occupational Health (SAF/IEE) has established an Energy and Climate Change Issues Team with broad representation from Headquarters Air Force offices responsible for developing policies, plans and programs, establishing requirements and providing resources for the entire Air Force enterprise. The team will assist the Air Force in developing plans and policies for adapting to the challenges posed by climate change by ensuring mission and operational impacts are considered across the Air Force.

- *Whole-of-Government Considerations*
  To maintain a whole-of-government perspective of issues related to climate change mitigation and adaptation, SAF/IEE personnel have attended and participated in briefings and professional forums sponsored by and targeting federal and national scientific organizations. Focusing on climate change impacts to infrastructure, natural resources, and water resources, and the adaptation challenges facing planners, resource managers and decision makers they have included:

  - Bi-monthly meetings of the Interagency Forum on Climate Change Impacts and Adaptations

  - The March 2009 National Academy of Sciences Summit on America's Climate Choices (which included special panels on Adapting to the Impacts of Climate Change and Informing Effective Decisions and Actions Related to Climate Change)
  - The October 2008 Colloquium on National Security Implications of Climate Change sponsored by the U.S. Joint Forces Command

  - Department of Energy national laboratory climate modeler briefings on Climate and Conflict Challenges Affecting Department of Defense and Air Force Installations and Operations.

Marine Corps

- *General Planning Approach.* The U.S. Marine Corps (USMC) is constantly assessing, planning and implementing projects and activities that support our ability to meet the mission of the USMC. Some of these activities, although not primarily directed to support climate change adaptation efforts, nonetheless may assist in these efforts and provide mutual benefits. The effects of climate change are characterized by a degree of variability and uncertainty for a range of forecasting and modeling scenarios. Although specific climate change effects and outcomes cannot be predicted with accuracy and certainty, there are general attributes and trends in climate change that are reasonably expected to occur and can be considered in planning and conducting USMC activities. Some examples of USMC activities at installations which, indirectly or otherwise, support climate change adaptation efforts include: 1) wildfire preparation management; 2) water conservation; 3) hurricane preparedness; and 4) natural resources management.

- *Adaptation to Increased Risk of Wildfires.* Several climate change predictive modeling scenarios include an increase in the frequency and severity of wildfires in some geographic regions affected by climate change. In Southern California for example, after increased frequency and severity of wildfires over the past few years, the USMC has initiated replacement of all aboveground communications and utilities lines to underground as much as economically feasible, so that they are clear of any fire damage should they occur.

- *Adaptation to Increased Risk of Drought.* Under a changing climate, water resources in some areas will be less abundant and face increasing pressures for demand. We are specifically seeing the early stages of this event in Southern California, where frequent drought conditions coupled with ever increasing population growth has severely taxed clean water supplies. Consequently, the USMC is expanding our use of recycled water at our installations, primarily for irrigation and other non-potable water use requirements.

- *Adaptation to Increased Risk of Severe Storms.* The majority of USMC installations are located in coastal areas where amphibious landing and other mission critical training and operational exercises are conducted to directly support the USMC mission and our Naval mission. The forecasted increase in frequency and severity of hurricanes and tropical storms on the Eastern seaboard of the United States could directly impact this mission. Consequently, the USMC continues to consider hurricane damage vulnerability and base evacuation requirements in all facilities and operational planning.

- *Adaptation to Changing Ecosystems.* Characteristics of climate change include changing temperatures and precipitation patterns. These changes would undoubtedly alter wildlife and habitat patterns and distributions. Associated changes in ecosystems and land use decisions will also result to

varying degrees in some geographic regions. The USMC monitors ecosystem conditions and trends and has adopted an adaptive management strategy for implementing Integrated Natural Resource Management Plans (INRMP) for our installations. The USMC also actively participates in numerous broader, regional partnerships to better integrate conservation strategies throughout a given region of ecosystem.

- *Awareness of Existing Laws, Policies or Regulations That Hinder Adaptation Efforts.* The Services are unaware of existing laws, policies or regulations that hinder climate change adaptation efforts.

- *Awareness of Existing Laws, Policies or Regulations That Assist Adaptation Efforts.* The Services are unaware of existing laws, policies or regulations that assist climate change adaptation efforts."

U.S. Army Corps of Engineers

"Managing hydrologic extremes due to climate variability is an essential mission of water management agencies. The U.S. Army Corps of Engineers (USACE) has missions to help reduce risks from floods and to mitigate the impacts of drought. USACE must ensure that its systems and projects will remain adaptable and sustainable over time even if the frequency and severity of extreme hydrologic events may change.

Several climate change adaptation activities are planned as part of the USACE Actions for Change effort. The Actions for Change were developed from analyses of the performance of the Southeast Louisiana Hurricane Protection System during Hurricane Katrina and the decisions leading up to the disaster. The goal of Actions for Change (now known as the IPET/HPDC Lessons Learned and incorporated in the USACE Campaign Plan) is to effect fundamental change in the US Army Corps of Engineers by developing and implementing an integrated, comprehensive, systems-based, and risk-informed approach in the execution of all mission areas. The changes will incorporate anticipatory and adaptive management so that systems remain adaptable and sustainable over time. The changes will ensure that USACE can incorporate new information and knowledge throughout a system's life cycle to ensure satisfactory safety and performance.

The USACE climate change strategy involves working closely with other Federal agencies to develop consistent approaches with regard to policies related to climate change. USACE is also trying to coordinate climate change activities with state governments and others so approaches can be integrated.

Water Resources Management

USACE formed an interagency workgroup on climate change and water resources to evaluate how climate change considerations can be incorporated into activities

related to the Nation's water resources. This interagency team represented the two major water resources operating agencies – USACE and the Bureau of Reclamation – and the two major science agencies supporting water resources management – U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA, National Weather Service and Office of Atmospheric Research). The result was a February 2009 report on "Climate Change and Water Resources Management: A Federal Perspective" published as a USGS Circular (Available online at: http://pubs.usgs.gov/circ/1331/). It presents the best available science to help water managers prepare for and adapt to the effects of climate change on the nation's water resources.

USACE has formed a team of water managers to develop strategies for how water management can better adapt to a changing climate. This group and others from USACE are working with an interagency team, Climate Change and Water Working Group to prepare an assessment of required capabilities, current capabilities and gaps associated with incorporating climate change information into longer-term water resources planning. At workshops in California in spring 2007, water managers from Federal (USGS, Reclamation, NOAA), state, local and private agencies and organizations recommended more flexible reservoir operations, better use of forecasts, and more monitoring of real-time conditions in the watersheds. The USACE water managers are working on better implementing integrated water resources management, which the Intergovernmental Panel on Climate Change (IPCC) says should be the framework for climate change adaptation. They are considering ways to make water management more flexible and adaptable to changing conditions. Research and development activities in the USACE have included improvements to numerical models for reservoir simulation, studies of climate impacts to western USACE projects and systems, and development of a primer to guide use of downscaled climate models.

Coastal Management

The USACE has recently revised guidance on how to incorporate future sea-level change projections into planning and engineering design. The guidance was written with the active participation of USGS and NOAA's National Ocean Service (NOS). USACE has actually had a policy on sea level change since the late 1980s that was based on a 1987 National Research Council (NRC) study. The revised guidance uses a scenario approach to account for the uncertainty of future sea level change. USACE is currently working with USGS and NOS on a companion project assessing the vulnerability of existing USACE coastal projects to sea level change and other coastal processes such as erosion. USACE has formed an interagency team to write more detailed planning guidance for coastal management with a changing climate, while another team is dealing with engineering design for coastal structures. Future studies are being planned to evaluate climate change impacts, including sea level change, in Florida and California.

Great Lakes Studies

Climate change is being considered in two studies in the Great Lakes that the U.S. Army Corps of Engineers are supporting for the International Joint Commission (IJC). The objectives of the studies are to improve the management of Great Lakes water levels and outflows. The International Lake Ontario-St. Lawrence River Study studied how to regulate outflows from Lake Ontario. Numerous plan alternatives were developed that considered the multiple objectives that include hydropower, navigation, flood damage reduction, recreation, and the environment. To test the robustness of the options, various supply scenarios were used including historic (1900-2001), stochastic (generation of 50,000 years of supply sequences) and climate change. The climate change scenarios were based on four general circulation models from the IPCC Third Assessment Report that were considered "warm and wet", "not so warm and wet" (UK Hadley), "warm and dry" and "not so warm and dry" (Canadian Climate Centre) cases.

The International Upper Great Lakes Study (IUGLS) began in March 2007 to investigate the factors affecting the recent declining Great Lakes levels. The first phase of the Study is investigating whether historic changes in the St. Clair River which flows from Lake Michigan-Huron to Erie, such as dredging, are responsible for the declining levels or are a result of seasonal or short- or long-term climate variability. The second phase will consider Lake Superior outflow management improvements considering an array of supply scenarios including climate change. Climate scenarios will be considered based on the IPCC Fourth Assessment Report which refines previous scenarios.

Additional Update as of September 11, 2009

In July 2009, USACE released updated guidance on incorporation of sea-level change to its Civil Works projects. The guidance requires that all projects, whether in planning or engineering phases, or already constructed, be evaluated for sensitivity to sea-level change. Adaptation alternatives must be evaluated for projects that are sensitive to sea-level changes."

The U.S. Department of Energy (DOE) submitted information on its adaptation-related efforts on July 16, 2009. DOE was given the opportunity to review its initial submission and sent updated information on September 2, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to DOE.

U.S. Department of Energy

"DOE recognizes that energy production and use in the United States today, and over the next 100 years, will be significantly affected by actual and expected climate change impacts and vulnerabilities. DOE is expanding its climate change activities to achieve a balanced approach and address both mitigation and adaptation. This will ensure a comprehensive and effective strategy to address climate change and energy security.
The focus of this strategy is: (1) to ensure the expansion of the Nation's energy supply and protection of the energy infrastructure and operations from climate change; (2) to harness its technical expertise, assets and resources to assist and provide guidance/information to federal, state, regional and local decision-makers and effected parties in addressing climate change impacts and vulnerabilities; and (3) to protect DOE's infrastructure (e.g., National Laboratories, Strategic Petroleum Reserves, etc.,) and operations from climate change impacts.

Climate-related changes have already been observed globally and in the United States, and will have direct and indirect impacts on this nation's ability to produce, deliver and store energy as well as how energy is used. DOE is in the process of assessing these impacts and identifying adaptation strategies. For example, warming will increase demand for cooling energy in the US resulting in increases in electricity use and peak demand in most regions. Energy production will be constrained by rising temperatures and limited water supplies. Proposed energy technology mitigation solutions will increase water demand (e.g. coal fired power plants with CCS, biomass, hydro and nuclear energy). Energy production and delivery systems will be exposed to sea-level rise and extreme weather events (e.g., oil and gas operations, and Strategic Petroleum Reserve). Increased variability of wind patterns and cloud cover will impact wind and solar technology performance. Concerns about impacts could influence perceptions and valuations of energy technology alternatives and shape energy production and consumption in the US.

Many of the challenges of adaptation have been identified but little in-depth analysis or research has been conducted by DOE or the Federal government on the scope, scale, and timing of these impacts. This has significant bearing on U.S. energy security as well as the near term ability to make informed policy and program design decisions. DOE believes that a proactive approach by the Federal Government can enhance resilience and reduce severity and cost of climate change impacts regardless of the nature of these impacts (i.e. energy or human

health, natural resources, agriculture, forestry, etc). DOE recognizes that many of the impacts (i.e. water scarcity) are crosscutting and will require a coordinated approach across the Federal government. In addition, DOE's assets (National Labs, super-computers, etc.) can serve as the nation's leading service providers to the impacted and vulnerable communities.

DOE is focusing its expertise and resources in several areas related to climate change adaptation, including research: (1) to improve the capability to forecast climate change on a regional/local scale and to conduct vulnerability assessments; (2) to understand the risks and impacts of climate change on existing energy sector infrastructure, and potential low carbon-clean energy technologies; and (3) to identify options and develop technologies and practices for reducing and recovering from climate change impacts including reducing water requirements, increasing efficiency of energy use, saving cooling energy and reducing electrical peak load.

DOE implementation of specific climate change adaptation projects is expanding. In addition, many of the current Departmental activities address aspects of climate change adaptation, but were not implemented with adaptation in mind. Illustrative examples of DOE activities and initiatives relevant to climate change adaptation include:

(1) Ensure the expansion of the Nation's energy supply and protection of the energy infrastructure and operations from climate change.

- DOE has played a leadership role in the U.S. Climate Change Technology Program to strengthen the Federal research portfolio on climate change technology development and to coordinate and prioritize related investments. CCTP's mission is to accelerate the development and deployment of advanced technologies that reduce, avoid, capture or sequester greenhouse gas emissions.

- DOE has been proactive in strengthening the connection between the U.S. Climate Change Technology Program and supporting basic research, both in-house and between the U.S. Climate Change Technology Program and the U.S. Climate Change Science Program (now referred to as the US Global Change Research Program (USGCRP). DOE has played a key role in coordinating and integrating climate research, observations, decision support, and communication. Results from these efforts have provided the scientific basis for the current international and domestic understanding of climate change mitigation and adaptation.

    - Under the auspices of the USGCRP, DOE led the effort to analyze and report on the "Effects of Climate Change on Energy Production and Use in the United States" (Synthesis and Assessment Product 4.5). This report enhances the understanding of the effects of climate change on energy

systems in the United States and the need for developing effective adaptation strategies.

- DOE also supported the development of the USGCRP report: Global Change Scenarios – Their Development and Use. The report outlines the state of the art in scenario use, research needs, and emphasizes the connection between scenario development and both mitigation and adaptation planning.

- DOE's Office of Energy Efficiency and Renewable Energy/National Renewable Research Laboratory is enhancing state-of-the-art capabilities for geostatistical analysis of the impacts of weather on renewable energy generation and energy demand and developing enhanced resource forecasting techniques.

- DOE's Office of Energy Efficiency and Renewable Energy is pursuing energy efficiency programs and improvements to reduce the consumption of water, fuels and energy in homes, buildings, industry and transportation: all of which will have an impact on water usage and reducing the impact of climate change.

- DOE's Office of Electricity Delivery and Energy Reliability is working to ensure that the Nation's energy delivery system is secure, resilient and reliable. This includes efforts: to modernize the electric grid; enhance security and reliability of energy infrastructure including potential impacts of extreme weather events on energy infrastructure; and facilitate recovery from disruptions to energy supply.

- DOE is addressing a variety of water scarcity-related issues related to climate change adaptation and energy production and use, including:

  - The Office of Fossil Energy/National Energy Technology Laboratory (FE/NETL) has assessed the water requirements for existing and emerging thermoelectric plant technologies including carbon capture and storage. A key objective of the FE/NETL research and development program is to minimize the impact of mitigation technologies on water resources. This is being addressed under two key inter-related components of the R&D program – (1) the development of advanced CO2 capture technologies that require less cooling and (2) the development of advanced water management technologies that reduce water usage throughout the power plant.

  - Sandia National Laboratory has assessed major water issues related to electrical generation and fuels production, and identified approaches that could reduce freshwater use in the energy sector, and opportunities for further research and development to address questions that decision-makers will need to resolve to effectively manage the energy/water issues.

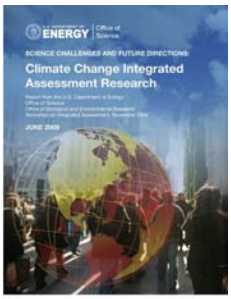
- DOE Fossil Energy has conducted over 100 projects on various aspects of water management related to oil and natural gas development. For example, projects have examined the use of produced water from oil and natural gas production as a potential water resource for agriculture and other beneficial uses, rather than a waste, as the availability of useable water becomes more scarce in certain regions with climate change.

- The Office of Energy Efficiency and Renewable Energy's (EERE) Biomass Program has funded several National Laboratories to assess water consumption and water quality impacts for biofuels production. In addition EERE analyzed water use by concentrated solar photovoltaic (CSP) plants and approaches for reducing water consumption.

(2) Harness DOE's technical expertise, assets and resources to assist and provide guidance/information to federal, state, regional and local decision-makers and effected parties in addressing climate change impacts and vulnerabilities.

- The Office of Science's Integrated Assessment Research Program (IARP) supports research on models and tools for integrated analysis of both the drivers and consequences of climate change. Past work has focused on drivers, specifically sources of greenhouse gas emissions within a common, most often economic, modeling framework. Resources are now being devoted to modeling the interactive effects of impacts and adaptation, and go beyond a national focus to better inform regional integrated planning. Efforts will include broad-based vulnerability analyses spanning multiple, interactive stressors; analysis of the role of science and technology in both mitigation and adaptation; analyses of the combined economic effects of different response strategies and policies; and explore key intersecting systems and their interdependencies, such as found at the energy, water, and land nexus. Efforts also include:

  - Development underway of impacts, adaptation, and vulnerability data base. Establishment of a climate change impact and adaptation component, led by the Oak Ridge National Laboratory to develop a comprehensive data base on climate change impact research and science, scoping and to develop a comprehensive data base on climate change adaptation processes and management practices.



Source: Department of Energy.

- Workshop Report illuminates research needs and challenges in impacts and adaptations for Integrated Assessments. The Integrated Assessment (IA) Research Program recently completed a major report that identifies the research needs in impacts, adaptation, and vulnerability (IAV) modeling as a grand challenge for integrated assessment research. The report, found at: http://www.sc.doe.gov/ober/IA%20Workshop_06-25-09.pdf , represents the discussions and findings of a major workshop to identify the future research needs in the field of climate change integrated assessment (IA) and represents the synthesis of supporting focused workshops; meetings; white papers; and other venues for critical thinking.
- Targeted university solicitations on the modeling of climate change impacts and adaptations. DOE recently funded several university grants that would improve the fundamental knowledge and methodologies for analysis of climate change impacts and adaptations within integrated assessment frameworks, including innovative general approaches to modeling impacts and adaptation, development of different measures of impacts, techniques for accommodating thresholds and tipping points, concepts and approaches for addressing probabilities and uncertainties, and methods for addressing data limitations. Funded grants spanned the range from core modeling in water resource impacts for energy systems, to energy system vulnerabilities from extreme weather events, and ultimately to long-term offshore wind energy resources.
- DOE main sponsor for annual international workshop on integrated assessment. DOE's Office of Science is sponsoring workshops on adaptation to build understanding and research collaborations, including a three-day workshop session on Urban Impacts, Adaptation, and Vulnerabilities in July 2009 with technical experts from the public and private sector and academia. The workshop explores sectoral, cross-cutting, and interaction issues (e.g., simultaneous mitigation and adaptation, interacting stressors and multiple adaptations) within common analytic frameworks, such as Integrated Assessment Models.
- New computation equipment for dedicated Integrated Assessment Research responds to the needs of impacts and adaptation analysis. DOE supports core research in Integrated Assessment and provides support for two (MIT and the Joint Global Change Research Institute) of the three main U.S. modeling teams that model, at high detail and complexity, the human – natural systems interactions surrounding climate change. In addition, DOE will use funds from the America Recovery and Reinvestment Act to acquire a supercomputer for Pacific Northwest National Laboratory for research and development of Integrated Assessment models for climate change impacts and adaptation that require finer scale modeling and demand greater computational horsepower.

- DOE's Oak Ridge National Laboratory (ORNL) is using its technology, expertise, and capability to provide world class computational resources needed to tackle climate challenges. ORNL's super-computing resources offer a Massive Peta-Scale computational tool for running climate models and forecasting climate change on a regional/local scale. ORNL's climate modeling tools use satellite data, regional inputs, land and water use data, policy standards, or any other variety of informational points, giving modelers the potential to extract a wide range of potential scenarios. For example, ORNL has the modeling ability to assess financial impact of temperature change, anticipate extreme events, and predict risk from climate change effects (e.g., water availability) on a regional/local basis.
- DOE's Office of Energy Efficiency and Renewable Energy/National Renewable Research Laboratory has three ongoing activities that are relevant to the analysis of climate change impacts and adaptation strategies. These include: (1) a study to assess the status of knowledge about the potential role of renewable energy and energy efficiency to support climate change adaptation and vulnerability reduction and clarify relationships to related issues, such as energy reliability, energy security, emergency response, infrastructure development, and economic development. (2) Launching with NREL and MIT a comprehensive multi-client analysis of the environmental, economic, and technical issues associated with large-scale deployment of renewable energy. Included within this study, is an assessment of the potential impacts of climate change on renewable energy generation. (3) NREL is also enhancing state-of-the-art capabilities at the lab for geostatistical analysis of the impacts of weather on renewable energy generation and energy demand and developing enhanced resource forecasting techniques.

(3) Protect DOE's infrastructure (e.g., National Laboratories, Strategic Petroleum Reserves, etc.,) and operations from climate change impacts.

- DOE's Office of Fossil Energy is assessing the impact of climate change, including sea level rise, subsidence and increased frequency and severity of hurricanes on oil storage and delivery infrastructure and operations, including current and future response capabilities of the Nation's Strategic Petroleum Reserve along the Gulf Coast.
- DOE's National Environmental Policy Act (NEPA) Program is developing guidance on consideration of climate change in the NEPA process. Integrating climate change considerations into DOE's planning process under NEPA would provide decision makers and the public with information about potential environmental impacts of DOE proposed actions and alternatives resulting from greenhouse gas emissions, and may also inform about how climate change may affect proposed DOE actions."

The U.S. Department of Health and Human Services (HHS) submitted information on its adaptation-related efforts on March 19, 2009. HHS was given the opportunity to review its initial submission and sent updated information on September 11, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to HHS.

U.S. Department of Health and Human Services

Centers for Disease Control and Prevention

"*Evaluating Models of Heat Vulnerability & Heat Island Impact in NYC* – Collaboration between CDC and Columbia University

The study looks at the relationships between social and physical vulnerability measures to heat waves in New York City from 1997 to 2006. The data will provide an understanding of how vulnerability to such events changed over time and how it varied among New York City's neighborhoods and demographic groups

Developing a Modular Web-based Preparedness Modeling Tool for Heat Waves - Collaboration between CDC and Arizona State University

The project develops a new research methodology that provides local and regional governments with a new set of skills and tools in prevention and emergency response planning for acute and chronic urban climate impacts, including heat waves.

Urban Heat Island (UHI) and Human Mortality during Heat Waves: The Role of Remote Sensing - Collaboration between CDC and Indiana University

This study determines the association between urban thermal characteristics and deaths associated with extreme heat events through remote sensing instruments. The research will provide detail on the association between the UHI and morbidity related to heat wave events and the creation of heat related risk maps in high risk urban areas.

Urban Sprawl and Excessive Heat Events in Large US Cities: 1956-2005 – Collaboration between CDC and Georgia Tech

The research studies the effect of urban sprawl on the incidence of extreme heat events. The study reviews extreme heat events over the last fifty years in association with indices of urban sprawl for a host of cities in the US, including Atlanta, and explores the components of urban form that drive the observed associations.

Extreme Heat Media Toolkit

The project creates a comprehensive communications campaign, which includes developing a toolkit of materials that can be easily downloaded, customized, to be used by cities across the US which have or are developing coordinated public health responses to extreme heat events.

Web-based training module for secondary school educators on "The Identification and Prevention of Heat-related Illness among Athletes"

This project will develop an accredited, web-based course and instructional materials to train coaches, athletic trainers, and other associated with athletic events at secondary schools, in the identification and prevention of exertion-related heat illness in student athletes

Local climate change and health indicators work- Austin Climate Protection Program.

The project will integrate environmental public health indicators associated with climate change into local climate mitigation plans to assess and support local policy decisions on climate change.

Expanding climate change research

CDC has funded intramural research awards, including research on topics such as vector-borne and zoonotic disease spread, analysis of climate change impacts on heat wave mortality, and evaluation of potential climate change adaptation strategies. Additionally, extramural research grants have been awarded to fund studies on a wide variety of health impacts of climate change.

Enhancing adaptive capacity at local health departments

Formalized partnerships have been developed with the National Association of County and City Health Officials (NACCHO) and the Association of State and Territorial Health Officials (ASTHO). Pilot programs have been initiated in five states and six local jurisdictions to conduct needs assessments and develop strategic plans to address weaknesses and bolster climate change capacity. The selected states are California, Minnesota, Florida, New Hampshire, and Massachusetts, and the selected local jurisdictions are Travis Co, Tx; Mercer Co, IL; Orange Co, FL; Thurston Co, WA; Hennepin Co, MN; and Imperial Co, CA.

Promoting workforce development

Postdoctoral and PhD dissertation awards in climate change and health adaptation research will help to fund projects while improving development of a

well-educated and experienced climate change workforce. They will also foster collaboration between CDC and academic institutions."

National Institutes of Health

"The NIH is currently supporting and conducting numerous and diverse research and training projects on climate and weather effects on health, including actual and potential impacts on infectious diseases, mental health, cardiovascular disease, toxic exposures, trauma, cancer, nutrition and substance abuse, among others. Projects include development of predictive models for disease impacts of weather and climate, new disaster management tools, individual and population responses to relevant medical and public health interventions, health workforce needs in the U.S. and abroad, and focused studies on populations that may be particularly vulnerable to climate-influenced health concerns. Currently, a relatively small subset of these projects is focused directly on the impacts of long term climate change using the rapidly advancing predictive tools of climate change science. More focused efforts are being contemplated and in development. As with current NIH projects, future research and training activities on climate change and health will be developed in partnership with U.S. universities, other federal agencies and expert private organizations through rigorously peer-reviewed science.

Trans-NIH Working Group on Climate Change and Health

A planning group has been convened at the NIH to assess the research questions in health and medicine that climate change presents. Sixteen NIH Institutes and Centers actively participate in the Trans-NIH Working Group on Climate Change and Health, with coordination from the Fogarty International Center (FIC) and including with the active participation of the National Institute of Environmental Health Sciences (NIEHS). The goals of the Working Group are to identify and describe relevant research and training activities currently supported by the NIH, engage the biomedical research community in discussions of the health effects of climate change, and identify research needs and priorities for an NIH research agenda for climate change and health, including the development and evaluation of clinical and public health strategies for climate change adaptation.

NIH Challenge Grants in Health and Science Research

The NIH has recently taken steps to increase support for research on the health effects of climate change. As part of the American Recovery and Reinvestment Act of 2009, NIH has developed a new initiative called the NIH Challenge Grants in Health and Science Research. Included in the range of Challenge Topics that the NIH plans to support is research that focuses on the development of models to predict the health effects of climate change. Quantitative and predictive models of effects of climate change on disease burden and health outcomes are needed to facilitate public health planning and inform adaptation strategies. Of particular

interest are studies that quantify the current impacts of climate on a diversity of communicable or non-communicable diseases, or studies project the impacts of different climate and socio-economic scenarios on health. Awards will be announced in October and November of 2009.

NIEHS-Wellcome Project

The National Institute of Environmental Health Sciences (NIEHS), NIH, is supporting a project to quantify the population health consequences (both positive and negative) of key policy choices aimed at climate change adaptation-mitigation in each of four sectors: energy, housing/built environment, transport, and food/agriculture. This aim is being accomplished by an international consortium of expert scientists convened by the London School of Hygiene & Tropical Medicine. The Consortium will: define the critical policy choices for mitigation arising in each of the four sectors in both high- and low-income countries, and the parameters within which those choices are constrained; delineate the critical pathways by which such choices have effects on population health, encompassing both direct and indirect mechanisms; and develop quantitative models of these health effects, and illustrate them by application to hypothetical populations representative of high- and low-income country settings."

The Federal Emergency Management Agency (FEMA) submitted information on its adaptation-related efforts on June 18, 2009. FEMA was given the opportunity to review its initial submission and sent updated information on August 25, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to FEMA.

U.S. Department of Homeland Security

Federal Emergency Management Agency

"As noted in the responses below, FEMA is currently conducting a study on the impact of climate change on the NFIP. The study was recommended by the GAO in a Spring, 2007 report (GAO-07-285, "Climate Change: Financial Risks to Federal and Private Insurers in Coming Decades are Potentially Significant"). We began the study in September, 2008 and it will be completed in March, 2010. Approximately one million dollars was allocated for this and a related study that investigates methods to improve coastal floodplain mapping through the NFIP.

(1) Question: What actions, if any, are federal, state, local, and international authorities taking to adapt to a changing climate?

Answer: FEMA's Mitigation Directorate (and predecessor Directorates) has a long history of investigating and planning for certain aspects of climate change with respect of the NFIP; specifically long-term coastal erosion, and to a lesser extent sea level rise.

For example, in 1991 FEMA completed a congressionally mandated study on the impact of sea level rise on the NFIP. The study concluded that the NFIP would not encounter problems adapting to various scenarios of future sea level rise. For example, the study notes that the NFIP would not be significantly impacted by a one-foot rise in sea level over the next hundred years, and that under a three-foot sea level rise scenario, the program would have ample opportunity to adapt and implement changes to the NFIP. This could be done by considering alternative approaches to NFIP loss control and insurance mechanisms.

The current GAO-recommended study, however, uses more current information and data than was available for the 1991 study; this includes reports prepared by the Intergovernmental Panel on Climate Change, and the Climate Change Science Program. Moreover, the current study also considers aspects of climate change beyond just sea level rise. For example the study considers climate-induced changes in frequency and intensity of coastal storms, and climate-induced changes in precipitation patterns (as such, the study considers impacts of climate change on both riverine and coastal areas). As part of this study effort, FEMA is involving representatives from other federal agencies (such as NOAA and the USGS), State agencies (such as Delaware and North Carolina), the private sector,

and academia. The results of this study will provide FEMA with recommendations and policy options on how to deal with the affects of climate change on the NFIP.

Mitigation's efforts to deal with long-term coastal erosion (which is a specific consequence of sea level rise) follow a long convoluted history, a discussion of which may provide insight into the current consideration of climate change impacts on the NFIP. This discussion is also relevant to my answer to Question number 3.

In the late 1980's there was recognition by various interest groups and other entities that long-term coastal erosion was an issue that needed to be studied and addressed under the NFIP. This resulted in a FEMA-commissioned National Research Council (NRC) report (titled "Managing Coastal Erosion"). The report was released in 1990 and recommended that long-term erosion mapping and land-use management requirements should be incorporated into the NFIP. The NRC report stimulated congressional interest on this issue, and in 1990 several bills were introduced that would have required FEMA to consider long-term coastal erosion through the NFIP (note that short-term, or event driven erosion, has long been considered by the NFIP). Opposition to these bills by various interest groups led Congress to abandon the proposed bills, but ultimately a compromise bill was formulated that directed FEMA to study the long-term erosion issue, rather than mandate immediate change to the NFIP. The compromise bill was inserted as Section 577 of the National Flood Insurance Reform Act of 1994, and it required that the Director of FEMA submit a report to Congress that evaluated the economic impact of erosion and erosion mapping on coastal communities and on the NFIP. Ultimately, the erosion study was conducted for FEMA by the H. John Heinz Center, and a report was released in 2000. The "Heinz Center" report made two recommendations. The first was that Congress should instruct FEMA to map coastal erosion hazard areas. The second was that Congress should require FEMA to include the cost of expected losses when setting flood insurance rates along the coast. After the release of the Heinz Center report, FEMA formed an internal workgroup to determine what actions could be taken to implement the recommendations contained in the report under the laws and regulations governing the NFIP. The workgroup concluded that, because of the politically sensitive nature of the erosion issue, the implementation of either of the Heinz Center recommendations would require direct authorization from Congress. To this date, Congress has not acted on these recommendations. However, under existing regulatory and statutory authority, FEMA has increased insurance rates for policies in V Zones close to 10 percent (the maximum allowed by current statutory law) most years between 2001 and 2008. A primary reason for this increase was in recognition of the results obtained by the Heinz Center study. In summary, FEMA has not mapped erosion hazard areas and has not used this information for rate setting because of its long-term politically sensitive nature, and because of Congressional indecision on this matter. Note that during the time (late 1980's though early 2000's) that long-term coastal erosion was being debated in Congress, FEMA funded several research studies and published numerous

papers in peer-reviewed scientific journals that investigated various aspects of the long-term coastal erosion problem.

Other actions taken by FEMA to adapt to climate change include actions related to FEMA's Coastal Construction Manual, and to the NFIP's Community Rating System. These actions are explained below.

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 published in 2000. This version (as with previous versions) contained limited information regarding the direct effects of sea level rise on coastal construction design and siting. However, the update did include substantive information regarding the hazards of long-term coastal erosion (again, a specific consequence of sea level rise), and provided recommendations concerning coastal construction siting and design standards that reflect this long-term hazard. Currently FEMA's Mitigation Directorate is in the preliminary stages of substantially revising the Coastal Construction Manual. This revision will include a new section (or subsection) that addresses climate change. It is anticipated that this section/subsection will summarize what is currently known about the effects of climate change on our coastal regions, and will make recommendations concerning coastal construction siting and design within the context of potential climate change impacts.

FEMA has a program component of the NFIP, 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% up 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, or requiring long-term coastal erosion-based setbacks that, while not described as specific to climate change, do mitigate aspects of sea level rise and concomitant long-term coastal erosion.

Nevertheless, it is likely that the next revision of the CRS manual (which will probably be issued in 2011) will contain new climate change-specific language describing certain CRS activity credits.

Finally, it should be noted that FEMA is providing a $5 million congressionally earmarked grant to the State of North Carolina to conduct a "Sea Level Rise Risk Management Study." The study will assess the long-term fiscal implications of

climate change as it affects the frequency and impacts of natural disasters. Although the study focuses only on the State of North Carolina, the results of this study will provide FEMA with additional findings and conclusions that should assist the Agency in formulating climate change adaptation strategies.

(2) Question: What challenges, if any, do federal, state, and local officials face in their efforts to adapt?

Answer: It is not yet clear as to the challenges facing the NFIP with respect to climate change adaptation. As an example, if the influences and impacts of climate change occur gradually, then the NFIP would be able to readily adapt by using procedures and methods currently used to administer the program. Thus, the NFIP would continue to: (1) annually adjust insurance rates based on the most recent data; (2) revise or remap Flood Insurance Rate Maps (FIRMs) under current mapping cycles, albeit expedite remapping where significant changes (climate-related or otherwise) in flooding or topography have been identified; and (3) recommend changes to building codes to better reflect current flood risks. If the influences and impacts of climate change occur more rapidly, then the NFIP might have to make fundamental changes to the NFIP in order to adapt. Nevertheless, we understand that there is scientific consensus that global warming is occurring and as such FEMA needs to be proactive in preparing for potential changes that could affect coastal and riverine flooding. Results from the forthcoming completion of the FEMA Climate Change study should provide relevant information regarding adaptation challenges.

(3) Question: What actions could the Congress and federal agencies take to help address these challenges?

Answer: As noted above, FEMA is currently conducting a study that will provide policy options and recommendations regarding the affects of climate change on the NFIP. Nonetheless, based on past history and experience with the erosion issue (as expounded upon, above), in the short-term, FEMA should continue to investigate and perhaps take actions that can be implemented under existing statutory and regulatory authorities. In the longer-term, Congress needs to provide legislative guidance or mandates where such statutory and regulatory authorities do not currently exist, or where identified actions are controversial or politically sensitive. In short, we believe that the degree of effectiveness of any actions is strongly dependent on Congressional willingness to mandate changes to the NFIP."

The U.S. Department of the Interior (DOI) submitted information on its adaptation-related efforts on May 22, 2009. DOI was given the opportunity to review its initial submission and sent updated information on September 18, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to DOI.

U.S. Department of the Interior

"The vision for moving the economy from recession to recovery and ultimately to prosperity involves investments in clean energy and combating global warming. DOI is a primary leader in the federal government's adaptation response to climate change via its expertise in climate change and adaptation science, adaptive management of our natural landscapes and resources, fish and wildlife, and ecosystem services, and biological carbon sequestration.

DOI initiatives will help mitigate climate change, adapt to a warming planet, and create green jobs, all of which will help give shape to the low-carbon US economy. In response to the need for fully integrated information to achieve these objectives, the Department of the Interior issued a new Secretarial Order (no. 3285) on March 11, 2009 that made the production and transmission of renewable energy on public lands a priority and also created new DOI Energy and Climate Change Task Force co-chaired by the Deputy Secretary and Counselor to the Secretary. Building upon this effort the Department of the Interior issued Secretarial Order 3289 on September 14, 2009 that established a Department-wide approach for applying scientific tools to increase understanding of climate change and to coordinate an effective response to its impacts on tribes and on the land, water, ocean, fish and wildlife, and culturally heritage resources that the Department manages.

To fulfill the vision for a clean energy economy, Interior is now managing America's public lands and oceans not just for balanced oil, natural gas, and coal development, but also-for the first time ever-to promote environmentally responsible renewable energy development. Sun, wind, biomass, and geothermal energy from our public lands is creating new jobs and will soon power millions of American homes.

The Department of the Interior is also on the front lines of protecting our country's water, land, marine, fish and wildlife, and cultural heritage resources from the dramatic effects of climate change we are witnessing-from the Arctic to the Everglades. The realities of climate change will require the Department to change how we manage the land, water, marine, fish and wildlife resources that we oversee. By way of example: .

- New water management imperatives associated with climate change may require the restoration of natural system and the building of new infrastructure to reduce new flood risks and/or to capture early run-off.

- Strategies to address sea level rise may require the acquisition of upland habitat, the creation of wetlands and other natural filters and barriers to protect against sea level rise and storm surges.
- Shifting wildlife and habitat populations may require investments in new wildlife corridors.
- New invasions of exotic species and new wildland fire threats due to longer fire seasons and more severe droughts will need to be fought.
- Certain iconic and culturally historic structures may need to be relocated.

Interior's 67,000 employees – with their scientific and natural and cultural resource management expertise – will be responsible for helping protect the nation from the impacts of climate change.

- Interior must adapt its water management strategies to address the possibility of shrinking water supplies and more frequent and extended droughts in order to continue to supply drinking water to more than 31 million people and irrigation water to 140,000 farmers.
- Interior manages millions of acres of marine-based parks, refuges and national monuments; 35,000 miles of coastline; and the 1.7 billion acres of the U.S. outer continental shelf.
- The Department has the primary national responsibility for the conservation and management of fish and wildlife resources, including over 800 native migratory bird species and nearly 2,000 federally listed threatened and endangered species.
- The Department must manage many cultural and archaeological resources and iconic structures as the climate changes.
- The Department must address, in particular, the impacts of climate change on American Indians and Alaska Natives, for whom the Department holds trust responsibilities on behalf of the federal government.
- The Department will continue to provide state-of-the art science to better understand the impacts of climate change and develop science-based adaptive management strategies for natural and cultural resource managers.
- Interior is identifying areas where carbon emissions can be stored underground, best management practices to increase the amount of carbon stored in our forests, wetlands, and grasslands, and ways to reduce the Department's carbon footprint.

To meet these current and future challenges Secretarial Order No. 3289 establishes a Climate Change Response Council within the Office of the Secretary that will execute a coordinated Department-wide strategy to increase scientific understanding of and development of effective adaptive management tools to address the impacts of climate change on our natural and cultural resources. The Council will help coordinate activities within and among the Department's agencies and bureaus to develop and implement an integrated strategy for responding to climate change impacts involving the resources managed by the Department. The Council will also coordinate its climate change activities with all

relevant Federal Departments and agencies including, but not limited to USGCRP participating agencies and the Council on Environmental Quality, the Office of Energy and Climate Change, and the National Science and Technology Council.

The Climate Change Response Council will implement Department-specific climate change activities through 1) Climate Change Response Planning Requirements in which each bureau and office of the Department will consider and analyze potential climate change impacts when planning exercises, setting priorities for scientific research, when developing management plans and when making major decision regarding the potential use of resources under the Department's purview; 2) DOI Regional Climate Change Response Centers that will ensure that management decisions in response to climate change impacts will be informed by science and will require that scientists work in tandem with those managers who are confronting climate change impacts and evaluating options to respond to such impacts; 3) Landscape Conservation Cooperatives which, guided by the Climate Response Council, will work interactively with the relevant DOI Regional Climate Change Response Centers to work with federal, state, tribal and local governments, universities, non-governmental organizations, and private landowner partners to develop landscape-level strategies for understanding and responding to climate change impacts and coordinate adaptation efforts in the region.

In addition Secretarial Order No. 3289 establishes the DOI Carbon Storage Projects and DOI Carbon Footprint Project to also be supported by the Climate Change Response Council. The USGS has the lead (pursuant to the Energy Independence and Security Act) to develop carbon sequestration methodologies for geological and biological carbon storage. The USGS will also take the lead in administering the Carbon Storage Project as it will be vital for successful domestic and global geological and biological carbon sequestration efforts. The DOI Carbon Footprint Project will develop a unified greenhouse gas emission reduction program, including setting a baseline and reduction goal for the Department's greenhouse gas emission and energy use.

Secretarial Order No. 3289 builds upon and further coordinates already existing ground-breaking adaptation projects being spearheaded by Interior bureaus and agencies. A truly comprehensive list of all existing projects involving climate change adaptation would be extensive and beyond the scope of time available for this data call. What follows are illustrative examples and descriptions of climate change adaptation activities across DOI.

DOI Adaptation Strategies in Practice: Collaborative Examples:

Rising Sea Level

As our globe warms, sea level has already risen and will continue to rise due to melting ice sheets and glaciers, as well as thermal expansion of our oceans.

Strong science is needed to understand the risks associated with the impacts of sea level rise. DOI through U.S. Geological Survey (USGS) is conducting a national risk assessment due to future sea-level rise for the U.S. Atlantic, Pacific, and Gulf of Mexico coasts. This includes work with the National Park Service (NPS) for coastal park units. In parallel, the DOI through the US Fish and Wildlife Service (USFWS) is working with partners to create and implement adaptation plans for specific coastal wildlife refuges. For example, forecasts suggest that without action, the North Carolina Albemarle Peninsula & Alligator River National Wildlife Refuge may lose 67% of swamp & 90% of dry land by 2100. In 2004, FWS created an adaptation plan with The Nature Conservancy, State of North Carolina, and Duke Power. Solutions articulated in the plan include the following elements:

- Restore Wetland Hydrology: restore damage caused by artificial ditches

- Reforest and Restore Shoreline: protect and restore existing natural coastal and inland habitat to facilitate species migration as sea level rises
- Oyster Reef Restoration: restore oyster reefs in Pamlico Sound to protect shorelines from storms and rising seas;
- Measuring and Monitoring Carbon Sequestration: monitor effects of management on soil carbon.

Invasive Species and Fire

Invasive annual grasses (e.g. cheatgrass) are increasing rapidly throughout the western U.S. These fire-tolerant species increase fire frequency, eliminating native plants, wildlife and livestock forage, and habitat. USGS is providing science in support of decision-making, including 1) mapping annual plant invasions (ground, aerial, satellite); 2) development of native plant restoration protocols; and 3) mapping of historic fires to understand causes. DOI's Bureau of Land Management (BLM) is responsible for managing much of the federal land affected by these issues. In response to these issues, BLM is developing adaptation plans to restoring native plant communities, reduce fire frequency, and "pre-adapt" for climate change – planting communities in anticipation of local changes due to a changing climate. Specifically, the BLM and its partners are conducting a natural habitat restoration effort for millions of acres in the Great Basin of Nevada, Oregon, Idaho, California, and Utah, and they are working with commercial seed producers to grow native seed for restoration. The end goals of the adaptation plan are to reduce invasive species, reduce severity of wildfire, assure the necessary presence of pollinators, and "pre-adapt" these lands to climate change.

Water Supply Predictability under Climate Change

Water supply forecasts drive water project operations for resources managed by DOI's Bureau of Reclamation (BOR), and climate warming could cause diminished snowpack in western U.S. basins, which in turn affects the timing, quantity, and quality of water supplies. In order to manage these critical resources effectively under a changing climate, it is essential to understand how climate

change will affect the reliability of snow-driven forecasts of spring-summer water supply and related Reclamation operations. Such information would inform adaptation planning, where studies of future operations capability require assumptions about the reliability of future water supply forecasts driving future operations. BOR has developed a process and is working together with four National Oceanographic and Atmospheric Administration National Weather Service (NOAA NWS) River Forecast Centers (RFCs) – Colorado Basin, Northwest, Missouri Basin, and California-Nevada – and the US Department of Agriculture Natural Resource Conservation Service (USDA NRCS) National Water and Climate Center, US Army Corps of Engineers (USACE) Portland District, and Bonneville Power Administration to understand and adapt to these expected changes.

The approach is to translate downscaled climate projections over eight western U.S. basins into runoff and snowpack projections, using hydrologic simulation models provided by collaborating RFCs. Within these runoff and snowpack projections, the team is implementing water supply forecast model development, application, and updating procedures from federal forecast producers (NRCS, RFCs). The forecast models reflect relations between fall-winter precipitation, winter snowpack and spring-summer runoff.

These models will be evaluated regarding how forecast reliability changes through time within the climate projections. If reliability decreases, BOR will explore mitigation options (e.g. new predictors or new forecast seasons of emphasis). At this point in time, the runoff and snowpack projections have been developed and forecast modeling has begun; the forecast reliability assessment is expected to be complete by Fall 2009. The results will be used to inform adaptive management decisions and planning in the west.

An additional approach to water supply predictability issues is illustrated through a collaborative program coordinated by the Climate Change and Western Water group (CCAWG). The CCAWG is a coordinated federal interagency R&D plan/workgroup to provide scientific collaboration in support of Western water management and adaptation strategies in part in response to climate change. Principal partners also include DOI's BOR and USGS. Other Federal Agencies include NOAA and USACE.

Practitioner Development: Pilot Training Program

With the array of potential climate change impacts on water resources, a key question is how to build capacity among the planning practitioners at BOR and other western water agencies, so that they are fully able to scope and conduct water resources planning evaluations and design adaptation strategies in a changing climate. A variety of methods exist that could be applied to support such studies, and new methods continue to emerge. Yet there is immediate need among western water management agencies to incorporate climate change information into longer-term planning, and the need is growing (e.g., Secure Water Act 2009).

To help fill that need, on September 18, 2009 the BOR announced the implementation of a new Basin Study Program that will better define options for future water management of Western river basins where climate change, record drought, population increases and environmental needs have heightened competition for scarce water supplies. The Basin Study will incorporate the latest science, engineering technology, climate models and innovative approaches to water management. The program will serve as a part of Water Conservation Initiative and a key element in implementing the Secure Water Act. Reclamation will partner with key stakeholders and provide a 50% cost share contribution to state, local and tribal partners to implement the studies.

In addition DOI's Bureau of Reclamation Research and Development Office and an array of partners (including six NOAA-RISAs; the Alaska Center for Climate Assessment and Policy; the Southern Climate Impacts Planning Program; USACE, USGS, EPA, and USDA) are working together to:

- Develop and provide a Climate Change Integration Technical Training Program for western water practitioners, planners, technical specialists and/or decision makers.

- Develop a "living curriculum" that (a) orients practitioners on established methods, and (b) exposes practitioners to emerging methods as they become available.

- Conduct first-phase, classroom, pilot training course to develop information that guide development of higher-capacity online course, and provide a sense of demand and fees necessary to make the course self-sustaining.

Preliminary discussions on program structure and curriculum have been held, and the goal is to develop the pilot course during FY2009 and serve the course during FY2010.

National and Regional Groundwater Evaluations

The depletion of groundwater at a variety of scales and the compounding effects of recent droughts emphasize the need for an updated status on the availability of the Nation's groundwater resources. Assessments of the current state of the highest stressed groundwater flow systems are necessary tools for characterizing the availability of groundwater. The USGS Ground Water Research Program is taking advantage of the quantitative work previously conducted by the Regional Aquifer-System Analysis (RASA) Program and information available from other USGS programs, DOI Bureaus, including BOR, NPS, and BLM, other Federal agencies such as EPA and NOAA, States, Tribes, and local governments to provide an updated quantitative assessment of groundwater availability in areas of critical importance. Those assessments that are currently underway and continuing into 2010 and beyond will: 1) document the effects of human activities on water levels,

groundwater storage, and discharge to streams and other surface-water bodies; 2) explore climate variability impacts on the regional water budget, and 3) evaluate the adequacy of data networks to assess impacts at a regional scale.

Climate Change Impact Data Collection and Monitoring

Responding to global climate change and its impacts requires an unprecedented integration of information from multiple science disciplines and the full range of temporal and spatial scales. DOI is a lead in the collection and the assessment of data, and the dissemination of new data inventories for the better understanding of the causes and effects of climate change. Below are examples of USGS-and NPS-led efforts:

DOI National Climate Effects Network

The USGS leads DOI's effort to build a Department of the Interior Climate Effects Network focused on the monitoring and understanding of causes and impacts of climate change and variability on physical and biological resources. With this effort, USGS is working toward implementation of a comprehensive plan that will combine new and existing monitoring information from multiple sources to provide more effective and timely science information on climate change and related impacts for resource management and policy decision-making. This integrated monitoring and research program will provide the nation with a system for early detection and management/adaptation to changes before they become chronic or catastrophic. Data from the DOI Climate Effects Network will be used for creating scientifically-sound decision-support tools to accelerate and improve responsiveness to resource management and policy needs. The prototype for this effort is underway in the Yukon River Basin, as a partnership among the USGS, USFS, the Department resource management agencies, the University of Alaska, the Yukon River Inter-Tribal Watershed Council, and several other partners. The prototype integrates air, water, soil, and forest information across the Yukon River Basin to track and understand regional changes in carbon flux and storage to inform management decisions.

Vital Signs Program

The National Park Service's Vital Signs Program is the steward of long-term legacy monitoring data, plus new data inventories that have provided timely examples of the possible effects of climate change now visible in parks. The goal of Vital Signs is to help parks acquire the information they need to make informed decisions and to employ adaptive management in the face of climate change. Vital Signs also includes baseline documentation, including condition assessments of its cultural resources and ethnographic studies that include data on natural resources utilized and monitored by native groups.

Decision Support for Designing Adaptation Strategies

A fundamental element of DOI's climate change strategy is providing resource managers and policymakers with timely and responsive science information, in a useful format, for empowering more effective decision-making. Some examples of the tools and applications developed at DOI include:

Adaptive Management Tools and Techniques

Adaptive Management is a structured approach to resource management. Through this iterative process, managers and scientists team together to improve resource management over time by learning from management outcomes. The DOI Adaptive Management entails a multi-step process:

1. Considering various actions to meet management objectives;
2. Predicting the outcomes of these management actions based on what is currently known;
3. Implementing management actions;
4. Monitoring to observe the results of those actions; and
5. Using the results to update knowledge and adjust future management actions accordingly.

By repeating this cycle and increasing to the body of knowledge about the system in question, managers are able to refine their prescriptions to more closely meet the original objectives.

DOI develops strategies and tools for science-based adaptive management and implements them in practice. The DOI Adaptive Management Technical Guide, issued March 2007, provides technical guidance for using adaptive management in decision making. The guide includes case studies, such as the Bureau of Reclamation's management of Glen Canyon Dam and the FWS' determination of annual waterfowl harvests, to demonstrate how adaptive management can be applied.

Structured Decision Making

Structured Decision Making is an organized approach to identifying and evaluating management options and making choices in complex, multivariate decision environments. The USGS and FWS have partnered to develop a series of workshops, training exercises and short courses intended to educate both scientists and managers in the principles of a structured decision making process, including:

- The use of consistent and robust methods for evaluating physical and biological science information for use in decision-making
- Methods for facilitating the integration of the science and management communities with stakeholder involvement
- Identification of methods for empowering more effective decision-making in an open and transparent manner

- Tools for integrating different kinds of quantitative and qualitative information including value-based information

Climate Change Scenario Planning Workshops

The National Park Service conducts Climate Change Scenario Planning Workshops. In the workshops, specific park units are used as case studies for exploring methodology and training. The workshops include participation by multiple agencies, with the goal of developing a series of guidelines for how scenario planning can be used for incorporating climate change into park planning processes.

Carbon Sequestration

The USGS is charged with the conduct of geological and biological carbon sequestration research, including starting a national assessment of the geological storage capacity for carbon sequestration (using a methodology developed by USGS), and developing a methodology for national assessment of biological carbon sequestration. These activities were authorized in the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140), which calls for comprehensive assessment of geologic and biologic carbon sequestration to enable decision-makers to evaluate the full range of sequestration options. USGS has begun the national assessment of the Nation's resources for geologic sequestration of carbon dioxide (CO2) in saline formations and oil and gas reservoirs (physical traps), including coordination with BLM and other Federal and State agencies who are working with USGS on the national assessment, and USGS is also conducting research on technical issues and data gaps that impact uncertainties in the ability to assess CO2 storage resources. This effort will be closely coordinated with BLM and the Department of Energy.

Similarly, USGS is also beginning the development of a methodology for assessment of the Nation's resources for biological carbon sequestration, including the establishment of consultative mechanisms and research on data gaps and uncertainties that will also incorporate DOI's numerous adaptation activities.

An example of the linkage between sequestration and adaptation is the California Carbon Capture Project. This project is a 14-acre pilot, begun in the mid-1990s, on Twitchell Island in the western Sacramento-San Joaquin River Delta, about 40 miles south of Sacramento. The research is being led by USGS with funding and assistance from the California Department of Water Resources. Other research partners include the University of California, Davis, UC Berkeley and the University of New Hampshire. Carbon-capture farming works as CO2 is taken out of the air by plants such as tules and cattails. As the plants die and decompose, they create new peat soil, building the land surface over time. The Carbon Capture Program shows promise as a way to rebuild Delta islands that have "subsided," or sunk, below the level of surrounding waterways by building new peat soils. Preliminary results show significant accretion rates f peat soils much greater than the local rate of subsidence. This net increase in island elevation will help to shore up delta levees which protect water delivered to 23 million Californians. In addition, by taking CO2 out of the atmosphere, "carbon-capture" farming could combat

climate change by sequestering a major greenhouse gas. Another co-benefit relates to the establishment of native vegetation that will also restore nursery, breeding and forage habitat for fish and migratory waterfowl populations. Thus, outcomes and methodologies developed by this study may have substantial transfer value to together locations across the Nation related to sequestration, ecosystem restoration and wildlife conservation.

Climate Change and Drought on Navajo Tribal Lands

USGS scientists work with communities on the Navajo Nation to conduct geologic mapping and establish relations of land use and climate change to changes in the landscape. The landscape of the Navajo Nation is characterized by streams that have incised easily eroded fine-grained valley-fill, and highly erodible soft bedrock units. Conventional geologic mapping from this study provides crucial information for planning urban development and infrastructure such as highways, buildings, bridges, and domestic septic and landfill systems. Surficial maps that show temporal changes also provide information on geologic hazards, such as sand and dust storms and flood vulnerability, to provide a better understanding of ecosystem responses to land use and global warming. Sand dune mobility brought on by drought, climate change, or land use practices, has serious consequences on human and animal populations, agriculture, grazing, and infrastructure. Dune mobility is inundating housing and causing transportation problems. It may also contribute to a loss of rare and endangered native plants and grazing land, and lower air quality from periodic dust storms. The USGS staff and their Navajo Nation partners are combining mapping efforts with remotely sensed data and meteorological data to provide information necessary to more effectively mitigate these impacts. This project includes a significant traditional ecological knowledge component. Recent research is showing that erosion rates are highest, and most sensitive to climatic changes, in semiarid regions including the Navajo Tribal lands. Geologic mapping is highlighting those areas most susceptible to minor climatic changes, and when combined with precipitation and land use data, can identify those areas where land use sustainability is at greatest risk, and which threatens the livelihood and culture of local residents.

Alaska Native Health and Ecosystem Studies

The Alaska native community has an inseparable nexus to their surrounding natural resources that supports both nutritional and spiritual health. Alaska's fish, wildlife, plants, and waters are also critical subsistence resources for Alaskan Natives. No more clearly than in Alaska are public health threats affected by the relationship between people and their surrounding natural physical, chemical, and biological environment. Public health problems caused by environmental contamination (both natural and anthropogenic) and insect or wildlife transmission of emerging diseases are a growing concern, with some being directly related those resources being used by Alaska Natives. These may include bio-accumulated, naturally occurring contaminants in the food chain, diseases transmitted by the bite of insects or animals, and environmental threats to public health from airborne hazards such as volcanic ash. The USGS is working closely with a number of Federal, State, and local native organizations in assessing the potential interconnections between naturally occurring minerals, ecosystem health, wildlife

health, and human health. In 2009, the USGS produced maps of arsenic in soil and water from regional databases and known cases of diabetes in and around native communities. These data were also related to arsenic obtained from drinking water samples from those same communities. This information is used to support organizations such as the Alaska Native Tribal Health Consortium, which is interested in better understanding how climate change and Alaska's heavily mineralized environment (e.g. mercury, asbestos, arsenic) and wildlife patterns will relate to subsistence food safety and key health changes.

Everglades Restoration Program

The Everglades Restoration Program is critical to the restoration, preservation, and protection of Federal interest lands in South Florida. The National Park Service is a major partner in the combined State and Federal effort to restore Florida's Everglades. The south Florida NPS units are among the collaborating entities implementing major water resources projects such as the Modified Water Deliveries and the regional Comprehensive Everglades Restoration Plan (CERP). The CERP is a $10.5 billion program of large-scale modifications to the water management infrastructure of south Florida, with a targeted completion date of 2038. Projects affecting NPS lands and waters occur in phases through the end of CERP implementation. The NPS works with the Fish and Wildlife Service (FWS) and the U.S. Geological Survey (USGS) to support CERP projects through the development of restoration performance measures and quantitative evaluations of the environmental benefits of proposed actions. Long-term monitoring and assessment plans that are critical for adaptive management are developed and implemented through the Critical Ecosystems Studies Initiative (CESI), while the South Florida Ecosystem Restoration Task Force provides assistance in coordinating this multi-agency effort.

Coral Reef Protection

Coral reefs worldwide are in decline, and DOI has responsibility for more than 3.5 million acres of submerged habitat. In addition to shallow reef habitat, Interior also has responsibility for ocean areas where deep reef habitat exists. USGS research is informing States and Territories in the development of Local Action Strategies in response to Coral Reef Task Force resolutions to address coral reef degradation, conservation, and restoration in State and Federal waters (e.g., Hawaii, Florida, and the Caribbean). The USGS research is also providing information on reef health and status to resource managers and the scientific community to enable them to develop management strategies to address climate change effects on coral communities. USGS is working with the Minerals Management Service (MMS) on the structure, diversity and extent of deep reefs under Department responsibility. Resource managers with the NPS, FWS, MMS, NOAA, and coastal States have called upon USGS to help them understand the processes involved in reef decline so that local-scale stressors can be mitigated or removed, and reef recovery encouraged. USGS products are being and will continue to be used by members of the Coral Reef Task Force as they implement the various Local Action Strategies and the coral reef community as a whole.

Restoration of Mined Lands

In 2004, DOI's Office of Surface Mining (OSM), in cooperation with several states and other partners, initiated the Appalachian Regional Reforestation Initiative (ARRI) to address the technical, legal, and cultural barriers to effective reforestation as a part of mined land reclamation. There are enormous environmental, cultural, and economic benefits to restoring trees to those areas that were forested before mining. These include:

- Increased carbon sequestration in plants and soils,
- increased land values and economic productivity for mined lands,
- reduction in peak storm flows that reduce flooding potential,
- restoration of habitat for threatened or endangered species, and
- improved water quality.

Through ARRI, OSM has worked with states and others to remove the barriers to effective reforestation of mined land. Currently, ARRI has fostered partnerships enlisting 226 individuals from 118 different organizations who share its objectives. In FY 2009, OSM will continue this effort and promote reforestation in other areas where appropriate.

Wyoming Landscape Conservation Initiative (WLCI)

The WLCI is a long-term science based effort to assess and enhance aquatic and terrestrial habitats at a landscape scale in Southwest Wyoming, while facilitating responsible development through local collaboration and partnerships. Wyoming encompasses some of the highest quality wildlife habitats in the Intermountain West.

Sagebrush, mountain shrub, aspen, and riparian communities provide crucial habitat for deer, elk, pronghorn antelope, greater sage-grouse, and a variety of non-game species.

This region's vast open spaces support and are maintained by an important livestock industry and provide essential corridors for migratory wildlife. Lands and water in Southwest Wyoming also offer some of the country's most sought-after recreational opportunities and provide an important economic asset by attracting anglers, hunters, and other visitors seeking outdoor recreation in pristine settings. For many small rural communities, money spent by anglers and hunters is essential for long-term economic stability. At the same time, this region is an active source of natural gas, producing enough natural gas annually to heat 4 million homes.

The estimated 83 trillion cubic feet of recoverable natural gas in Southwest Wyoming will continue to account for one of the largest sources of natural gas in the U.S. WLCI Partners include the DOI's Bureau of Land Management, Fish and Wildlife Service, Geological Survey, National Park Service, the Bureau of Reclamation, the Wyoming Department of Agriculture, USDA Forest Service, the Wyoming Game and Fish Department, local conservation districts, and local counties, who work together to conduct efficient science-based species monitoring and habitat enhancement; facilitate

best reclamation and mitigation practices for areas impacted by development; integrate existing data with new knowledge and technologies to forecast future development of energy resources and assist in habitat conservation planning; and conduct habitat enhancement in all habitat types with a special focus on the sagebrush, mountain shrub, aspen, and riparian communities. The WLCI provides a mechanism for the exchange of information, data, and research findings among partners, industry, and stakeholders to improve habitat conditions and long-term viability of species at a landscape scale. These efforts complement existing habitat reclamation and mitigation efforts, broaden our understanding of the valuable Green River Basin ecosystem, and ensure that grazing management practices support a viable livestock industry and associated open spaces.

Conservation Planning Assistance (CPA)

Conservation Planning Assistance (CPA - formerly Project Planning) plays a vital role in conserving America's natural resources by helping advance energy, transportation, and land and water projects that simultaneously meet economic development needs and conserve fish and wildlife habitat for the benefit of the American people. The early recommendations to avoid or minimize project impacts saves design costs for projects proponents and makes later environmental reviews shorter and less costly.

Environmental changes are occurring today in ways fundamentally different than at any other time in history. For example, sea-level rise, habitat loss, and climate change due to the growing scale of human activities have become prominent conservation challenges. DOI's Fish and Wildlife Service proposes to reposition the CPA program to better address contemporary and emerging conservation issues, consistent with its mission and planned implementation of the new 2008 Strategic Plan for this program. The new plan has CPA employing strategic habitat conservation principles to conserve and restore native species and their habitats, and maintain the ecological processes and structure crucial for ecosystem integrity.

Consensus-based, landscape-level planning approaches provide a framework to guide land use decisions necessitated by expanding population growth and land development. The resulting plans for key focal areas will protect human health and safety, as well as preserve community assets and sustainable ecosystems for fish, wildlife, and people.

Wildlife Without Borders

Wildlife Without Borders projects (created and maintained by DOI's Fish and Wildlife Service) will continue to create viable long-term solutions to conservation efforts in undeveloped countries by building the capacity of local indigenous people to understand the purpose of conservation and species management and take action as a result. The Service will continue to fulfill the conservation commitments of the United States outlined in international treaties and statutorily mandated by Section 8 of the Endangered Species Act. Significant activities in 2008 and 2009 include:

- Continuing support of the Mexican campesino community which maintains the world's only winter habitat reserve of the Monarch butterfly, by integrating local

people into conservation efforts and reconciling their local land use practices with butterfly survival in indigenous forests;
- Continuing facilitation of international cooperation related to the U.S./Canada/Mexico Trilateral Committee; international wetlands activities; the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere; the Commission for Environmental Cooperation the Ramsar Convention on Wetlands of International Importance; the Western Hemisphere Migratory Species Initiative; and other bi-national and multi-lateral initiatives.
- Continuing support of academic and technical programs related to protected areas management training in the Western Hemisphere
- Continuing support for training initiatives aimed at building capacity of African wildlife managers to address threats from extractive industries, climate change, human/wildlife conflict, wildlife disease, and the illegal bushmeat trade.

The Outer Continental Shelf

DOI's Minerals Management Service (MMS) is a regulatory agency that oversees energy production from oil and gas and renewable resources on the Outer Continental Shelf. As part of this responsibility, the MMS must evaluate the potential environmental impact from these activities within the context of the existing marine environment. In describing the environment in which these activities occur, the MMS requires information about changes to that environment from global climate change, including shifting patterns of species distribution and changing habitats due to alterations in ice distribution. The MMS must also evaluate the cumulative effects of energy production activities in an environment that is stressed as a result of climate change. In response to shifting weather patterns, the MMS must ensure that structures placed in the ocean are designed to withstand increased storm activity and intensity.

With a large portion of OCS production located in an active hurricane corridor, many changes in industry requirements have taken place due to the recent damages and curtailment associated with Hurricanes Ivan, Katrina, Rita, and Ike. Most notably, the MMS meteorological and oceanographic conditions criteria used to design offshore infrastructure has been revised since the 2005 hurricane season. Besides upgrades in structure design, the MMS has recommended the installation of Global Positioning System locators and black box information storage systems on Mobile Offshore Drilling Units, which will continue to monitor on-site conditions after evacuation of personnel as well as track the location of the unit should it drift from its position.

Additional guidance has been developed or made available to assess vulnerabilities for existing structures; applying modifications to minimize damage; identifying the best seafloor and soil conditions for jack-up rigs; and determining where and when a particular jack-up rig can be used during Hurricane Season. In addition, MMS has adopted a requirement that drilling contractors upgrade their mooring systems for mobile drilling units. This requirement involved an increase in the number of mooring lines from 8 to 12 to 16, and additional requirements for the type and strength of anchors and mooring lines used by mobile drilling units. A mandatory detailed checklist is used to assess the safety of a mooring system.

The MMS is continuing efforts with industry workgroups to address hurricane-related issues, manage risk, and minimize damages associated with future storms that enter the OCS of the Gulf of Mexico. This enhanced scientific information will provide a better basis for evaluating meteorological hazards and requirements for engineering design of offshore energy infrastructure."

The U.S. Agency for International Development (USAID) submitted information on its adaptation-related efforts—and those pertaining to the U.S. Department of State— on May 07, 2009. USAID was given the opportunity to review its initial submission and did not send us any changes or updates for this e-supplement. Any questions should be directed to the USAID.

U.S. Department of State and **U.S. Agency for International Development**

"U.S. Government Activities Directly Supporting Adaptation to Climate Change in Developing Countries

USAID is one of the main U.S. Government agencies funding direct climate change activities in partner developing countries, although a number of other U.S. Government agencies also address adaptation needs. USAID has broadened its climate change portfolio to include activities aimed at strengthening the ability of developing and transition countries to respond to the challenges posed by climate-related impacts and risks. USAID seeks to strengthen the capabilities of program managers, host-country institutions, project implementers, and sectoral experts to assess relative vulnerabilities to climate change and to evaluate and implement adaptation options for agriculture, water, forest and coastal zone management projects within USAID's development assistance portfolio. Adapting to climate change requires a hierarchy of linked efforts. USAID is linking information from observation systems to stakeholders lacking such information, improving their understanding of current climate, climate variability and future climate change. USAID is working to make Earth observation information readily applicable to development decisions, including creating innovative applications and appropriate tools to then communicate that information to stakeholders and decision makers. Through interaction with local partners and new tools, USAID can better understand how environmental changes may impact sectors critical for development. Once those impacts are understood, stakeholders need to assess and agree on preferred adaptation options. Then, on-the-ground actions are implemented to build the resilience of projects designed to promote economic development. Adaptation actions will vary depending upon the sector, and can include activities ranging from improving the use of weather forecasts, to changing planting dates or seed varieties, to modifying water harvesting approaches or key infrastructure.

USAID has developed several tools and programs and is leveraging the efforts of many other U.S. Government agencies to facilitate international adaptation. USAID funding for these direct adaptation activities (four USAID projects detailed immediately below – Adaptation Guidance Manual, Coastal Zone Adaptation Manual, Climate Mapper, and FEWSNET) was $14M in FY07, and approximately $13M in FY08, with some additional funding from NASA. Of the USAID funding, most of that supports the Famine & Malaria Early Warning Systems (funding for FY06-08, approximately $13.2M/yr). In addition, NOAA supports adaptation activities through the International Research Institute for Climate and Society (IRI) and co-designed and provides technical support to the GEF/CARICOM Mainstreaming Adaptation to Climate Change (MACC) Project.

USAID Climate Change Adaptation Guidance Manual

To facilitate the process of adapting development projects, USAID has developed a Climate Change Adaptation Guidance Manual to provide USAID staff, other donor organizations, and developing country planners with the tools to understand how climate change may affect their projects. The manual draws on lessons learned in four pilot projects that assessed impacts and vulnerability to climate variability and change, and developed adaptation implementation plans for: flood planning and coastal resources in Honduras, water resource planning and natural resource management in South Africa, rainfed agriculture and food security in Mali, and sustainable livelihoods and water management in shared river basins in Thailand. These pilot projects and the guidance manual are helping to improve the resilience and sustainability of USAID's development efforts by integrating climate change adaptation into project planning. The Adaptation Guidance Manual provides a step wise process for evaluation of climate change impacts applicable in the field, including a primer on climate-related risks, a framework for determining if a specific project is vulnerable, and guidance on interventions to increase project resilience. Training courses for USAID staff and partners are being developed, and have been requested by other donors. The Adaptation Guidance Manual has been enthusiastically received by the international development community, and has been disseminated by the U.S. Climate Change Science Program (CCSP), Columbia's IRI, and a variety of climate change and development list serves. It is referenced in the OECD Guidelines on Integrating Climate Change Adaptation into Development Cooperation, and outside groups, including in Nigeria and Pakistan, are using it in their own training activities.

USAID Guidebook on Adapting to Climate Change in the Coastal Zone

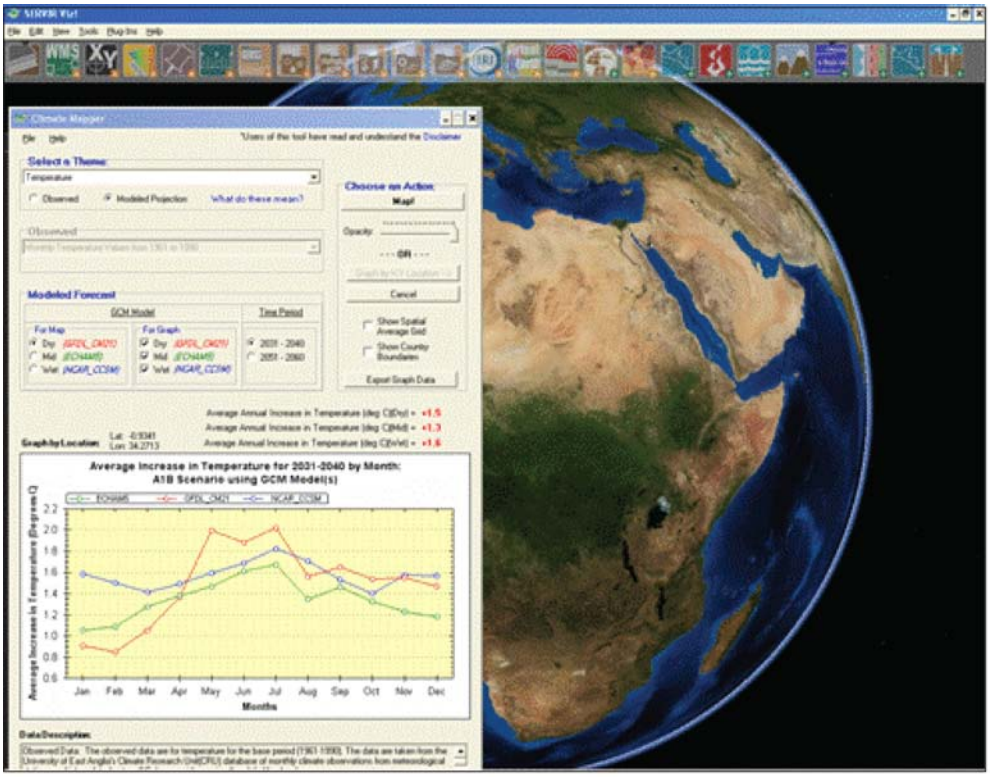
Recognizing a need to provide sector-specific guidance to USAID staff and host country partners, USAID is finalizing a Guidebook that draws lessons learned in coastal zone management and in the tsunami recovery effort and places them in the context of building resilience to climate change. USAID and its partners led an initial seminar on climate change and coastal management at the 4th Global Conference on Oceans, Coasts, and Islands in April, 2008. The Guidebook will be released in Fall 2008. A pilot project is planned in the Pacific.

Climate Mapper for SERVIR Viz (NASA, USAID)

USAID, NASA, the Institute for the Application of Geospatial Technology (IAGT), the University of Colorado, and the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) released in May 2008 the Climate Mapper tool. Climate Mapper is part of a larger program, called SERVIR – the Regional Visualization and Monitoring System, which is detailed in the next section. The Climate Mapper makes historical weather data and the results of climate change models accessible to a broad user community via the Internet. With the Climate Mapper, users can assess climate change projections for the 2030s and 2050s against 3D visualizations of landscape (Figure 6). By making climate change model results easily accessible and

understandable, vulnerability assessments will be enhanced and development planners can consider improved adaptation strategies for projects. The Climate Mapper data are currently available for Africa at ½ degree latitude by ½ degree longitude areas, or roughly 50km x 50km areas near the equator; it will soon expand to cover the entire globe. The Climate Mapper also presents historical temperature and precipitation for the base period (1961-1990), which were taken from the University of East Anglia's Climate Research Unit (CRU) database of monthly climate observations from meteorological stations. As additional climate model scenarios are produced, they can be easily imported into the Climate Mapper and made available to the general public. Funding: FY07 - USAID $90K.

Screen-shot of Climate Mapper for SERVIR Viz.



Source: USAID.

Famine Early Warning Systems Network – FEWSNET & Malaria Early Warning System – MEWS (USAID, NASA, DOI/USGS, USDA, NOAA)

USAID, NASA, the Department of the Interior U.S. Geological Survey (DOI/USGS), the U.S. Department of Agriculture (USDA), and NOAA are collaborating with local, regional, and international partners to provide early-warning and vulnerability information on emerging or evolving food security and malaria issues, including information relating to variability and changes in regional climate conditions. A primary goal of the Famine Early Warning Systems Network (FEWS NET) program is to produce high-quality information for disaster and crisis prediction. FEWS NET provides demand-driven information products that pinpoint and assess emerging or evolving food security problems. Program professionals in the United States and Africa monitor data and information—including remotely sensed as well as ground-based data on meteorological, crop, and rangeland conditions—for early indications of potential threats to food security. The program also works to strengthen African early-warning and response networks by increasing local technical capacity, building and strengthening networks, developing policy-relevant information, and forming consensus about food security problems and solutions. Additional accomplishments include the development of capacity to prepare seasonal food security outlook scenarios from consensus forecasts of Regional Climate Outlook Forums, as well as analysis of food security implications of IPCC climate change scenarios for East and Southern Africa. The FEWS-NET Web site serves as a gateway of information about threats and updates on response measures.

The Malaria Early Warning System (MEWS) is part of the FEWSNET project. Malaria is a high priority infectious disease target for domestic and international health agencies. Malaria kills an estimated 3 million people yearly worldwide, many of whom are children. In addition, malaria costs African nations approximately $12 billion per year in economic productivity. Both FEWSNET and MEWS enhance USAID humanitarian programs by integrating NASA Earth observation and modeling results to improve famine and malaria early warning in sub-Saharan Africa. The project utilizes NASA Earth Science satellite observations of vegetation density, precipitation, and relative humidity. Recent accomplishments of MEWS include the analysis of rainfall patterns in sub-Saharan Africa using meteorological station data, rainfall estimated from satellite images, and malaria incidence. The analysis indicated strong links between clinical malaria incidence and rainfall patterns across Eritrea, with malaria incidence peaks lagging behind rainfall peaks by 2 to 3 months. Funding: USAID ($13.2M/yr, as noted above); NASA FY07 $467K.

Information, Communication, and Decision Support Tools for Adaptation

SERVIR and SERVIR extension (NASA, USAID)

NASA and USAID are developing tools that apply space-based assets to development assistance. SERVIR is a U.S. led high-tech regional satellite visualization and monitoring system for Central America that supports decision-making in the areas of climate change adaptation, environmental management, and early warning for disasters, among others,

providing historical data, information on current environmental and weather conditions, forecasts and future scenarios. In operation since 2005, SERVIR consists of a regional hub in Central America and a suite of web-based tools, providing access to information products in a variety of formats and tailored to the range of decision makers, from scientists to the general public. Products available via SERVIR include high resolution climate change scenario database, climate change maps indicating impacts on Central America's biodiversity, a fire/smoke mapping and warning system, red tide alerts, and weather alerts. The SERVIR regional hub has enabled the training and capacity building of hundreds of Central American scientists, technicians, and government employees. Based on the successful SERVIR program, the U.S. Government is developing regional hubs in Africa and beyond to apply remotely sensed information to help track and combat wildfire, improve land use and agricultural practices, and help local officials respond faster to natural disasters. The first expansion of SERVIR is in East Africa where a hub is being established at the Regional Centre for Mapping of Resources for Development in Nairobi, Kenya. This SERVIR expansion to East Africa will link available data streams to new applications, develop tools, and build local human and institutional capacity to use this information. Funding: USAID $1.254M for FY07, $924.5K for FY08; NASA -Mesoamerica $1,021K in FY07 and $897K in FY08, Africa $439K in FY08.

RANET Program (NOAA, USAID)

USAID and NOAA are working with a range of humanitarian and meteorological organizations to provide useful weather and climate information to rural communities. The RANET program (Radio and Internet for the Communication of Hydro-Meteorological and Climate-Related Information for Development) uses reserve capacity on the WorldSpace digital satellite system to transmit forecasts, bulletins, imagery, seasonal assessments, and data to remote areas. The goal of the program is to provide environmental information that assists governments and populations in coping with hydro-meteorological hazards and environmental fluctuations. The program provides vulnerable communities with access to hydro-meteorological information, which in turn strengthens day-to-day decision-making to reduce vulnerability to potential hazards. RANET also supports the formation of community groups and associations that are instrumental in disseminating information and extending the network to new communities. Since its inception in 2000, RANET has expanded to 16 African countries, with ongoing pilot activities in Asia and the Pacific. The program operates in Africa, South and Southeast Asia, and the Western Pacific. Funding: FY07 and FYO8, $619,925 (two-year total). Average annual direct funding ranges from $400 -$700K per year. The program also receives significant in-kinds in the form of satellite broadcast capacity and personnel time of foreign weather services. USAID/OFDA is the primary funder of RANET, with contributions from other donors made on a project-by-project basis. RANET began in 1998.

Inter-Governmental Authority on Development Climate Prediction and Application Center (USAID)

Together with the WMO, the Inter-Governmental Authority on Development Climate Prediction and Application Center (ICPAC) has implemented seasonal climate prediction systems in several regions in ten Horn of Africa countries. In targeted countries, the project has improved climate monitoring, prediction, and applications, for early warning for weather-related hazards. Funding: FY07 $200,000 and FY08 $200,000.

Climate Forecast Applications (USAID)

As a follow up to the Extreme Climate Events program implemented by the Asian Disaster Preparedness Center (ADPC), in 1998, this project strengthens the national capabilities of Indonesia, the Philippines, and Timor-Leste to manage and reduce the impacts of climate fluctuations through targeted demonstration projects and community participation. The project makes climate forecasting information available to farmers and local communities, and helps them utilize the data for planting and other decision making purposes. Funding: FY07 $250,000; FY08 $79,413.

Hydrometeorological Technical Assistance (USAID, NOAA)

Through an interagency agreement funded by USAID/OFDA, NOAA provides access to weather, climate, and hydrometeorology experts and information to build the capacity of national, international, and regional response bodies in reducing vulnerability to extreme hydrometeorological events. Funding: FY07 $830,075; FY08 $1,000,000.

Activities Indirectly Supporting Adaptation (Non-Forest)

A number of U.S. Government activities constitute good adaptation practice and contribute to enhanced climate resilience in developing countries, but were not implemented expressly for the purpose of addressing climate change. These activities are being evaluated for their applicability as climate adaptation responses and will be applied more broadly as appropriate. Funding information is not provided for all the activities in this section, as it was not possible to separate out an adaptation-specific funding component and would have been misleading relative to direct funding of adaptation activities. Any funding amounts listed are for the program as a whole and should not be taken to indicate funding specific to adaptation.

The Consultative Group on International Agricultural Research (USAID)

USAID is a major donor to the Consultative Group on International Agriculture Research (the CG system), which is developing heat and drought tolerant varieties of cereal crops and improving natural resource management and soil protection in agriculture ecosystems through conservation agriculture and agroforestry. Examples include:

- Drought tolerant maize and rice through biotechnology and breeding. Such technologies hold enormous promise for achieving economic growth and insulation from shocks (e.g., droughts, floods) in developing countries in South

Asia and Africa.

- Mitigating impacts of agriculture on tropical forests & biodiversity: 13% of the CG supports biodiversity, providing alternatives to clearing tropical forests.

- Achieving transformation in high-population Middle East countries through drought and salinity tolerant crops and more strategic management of land and water resources in countries such as Sudan, Syria, Iraq, Pakistan, Afghanistan and Yemen.

Global Conservation Program (USAID)

The Global Conservation Program is supporting the development and application of nature-based strategies to adapt to climate change in four large marine ecoregions – the Meso-American Reef in Central America; Wakatobi National Park and Raja Ampat in Indonesia; and Kimbe Bay in Papua New Guinea. Climate change poses a major threat to tropical marine ecosystems by increasing sea temperatures, sea level, storm intensity, and the acidity of the ocean. Nature-based adaptation strategies can help people and communities deal with climate change impacts by protecting natural systems and the benefits they provide – shoreline protection, erosion control, as well as food from fisheries, jobs and income.

Capacity Building for Flash Floods Management and Sustainable Development in the Himalayas (USAID)

The IPCC Fourth Assessment states that climate change-related melting of glaciers could seriously affect half a billion people in the Himalaya-Hindu Kush region and a quarter of a billion people in China who depend on glacial melt for their water supplies. USAID/OFDA has supported technical assessments and forums for decision-makers and technical personnel from the Himalaya-Hindu Kush region to strengthen capacities on flash flood management, promote collaboration, and develop regional approaches to flood management, flood early warning systems, and broader transboundary water issues. These forums convey information about climate impacts as well as strategies and lessons about how to effectively cope with climate change, and thus are part of our strategy for impacting policy development and implementation in these countries. A regional organization based in Nepal, the International Center for Integrated Mountain Development hosts the forums, which include participants from Afghanistan, Bangladesh, Bhutan, Burma, China, India, Nepal, and Pakistan. Funding: FY07 $125,000.

Flood Early Warning Systems (USAID)

USAID/OFDA has engaged in flood early warning systems in a number of regions and countries; changing precipitation patterns and increased extreme events are recognized as significant climate change impacts in developing countries. For example, in January 2003, USAID/OFDA and the Mekong River Commission, an inter-governmental river basin organization based in Laos, began an innovative demonstration project to strengthen warnings to communities most at risk to floods. The five-year program

developed appropriate flood information to enable the most vulnerable communities in Cambodia to effectively prepare for floods. In Mozambique USAID/OFDA has contributed to the Mozambique Integrated Information Network for Decision-Making (MIND) project, part of USAID's FEWS NET. The MIND FEWSNET system indicates storm severity (based on wind speed) and the expected amount of time until storm landfall. MIND has strengthened early warning systems for cyclones and flooding and helped improve disaster management and contingency planning in the Limpopo River Basin. The project includes flood risk mapping, community flood education, planning and preparedness, and establishment of RANET stations to inform communities about storm risk in highly vulnerable remote locations. Funding: FY07 $102,257.

Flood Proofing for Households in the Mekong Delta, Vietnam (USAID)

USAID/OFDA is supporting the flood proofing of homes in the poorest flood-prone villages in the Mekong Delta. In collaboration with the Government of Vietnam's Ministry of Agriculture and Rural Development, the program is also training officials and the affected populations on the use of flood mapping to reduce loss of life, economic consequences, and disruption of livelihoods. The program is implementing river flood alert systems and a television and radio flood disaster warning system in three provinces and at the national level. USAID/OFDA provided $180,250 to support the flood proofing of homes in the poorest flood-prone villages in the Mekong Delta from September 2005 through March 2008. This was a follow-on program to the USAID/OFDA-funded U.N. Development Program (UNDP) initiative to implement a comprehensive flood preparedness program in seven provinces of central Vietnam from June 2000 through December 2004. A coastal storm early warning system implemented by the Government of Vietnam with support from USAID/OFDA and UNDP helped mitigate the impact of storms such as Typhoon Damrey in September 2005, and Typhoon Durian in December 2006. Since FY 2001, USAID/OFDA funding for flood and storm preparedness in Vietnam, including flood early warning, coastal storm early warning, and flood proofing of households totals $2,834,250.

Asia Flood Network (USAID, DOI/USGS, NOAA)

The Asia Flood Network (AFN) aims to strengthen the climate, weather, and hydrological forecasting capacity of regional and national hydro-meteorological institutions with the goal of reducing the vulnerability of at-risk communities. USAID/OFDA, NOAA, and the U.S. Geological Survey (USGS) are jointly implementing AFN in the Mekong river basin in Cambodia, China, Laos, Thailand, and Vietnam as well as in the Ganges-Brahmaputra–Megna river basin in Afghanistan, Bangladesh, Bhutan, Burma, China, India, Nepal, and Pakistan. Funding: FY07 $500,000 and FY08 $250,000.

Development of Hurricane Hazard Maps for the Caribbean (USAID)

Development of accurate baseline data related to climate and environmental conditions is critical to understanding the extent to which climate is changing. Without understanding the present in the context of historical norms it is impossible to plan appropriate adaptation activities. In FY 2007, USAID/OFDA supported the Pan American

Health Organization (PAHO) to develop wind hazard maps for the Caribbean basin, including all of the islands of the Caribbean and the Caribbean coastlines of South and Central America. The program will incorporate over 20 years of the region's data to improve the quality of currently available wind hazard information. The proposed maps will enable wind hazard experts, government authorities, and the engineering and architectural communities to obtain better wind hazard guidance for structural design of new hospitals and other relevant facilities. Funding: FY07 $126,560.

Program for Hydrometeorological Risk Mitigation in Asian Cities (USAID)

The IPCC Fourth Assessment reports that amplification in storm-surge heights, along with high reported rates of recent sea level rise, could result in an enhanced risk of coastal disasters along the coastal regions of East, South and South-East Asian countries. Implemented by the Asian Disaster Preparedness Center (ADPC), this program promotes hydrometeorological disaster preparedness through demonstration projects to improve community preparedness and reduce vulnerability to climate sensitive disasters in six highly vulnerable secondary urban centers in Bangladesh, Pakistan, the Philippines, Sri Lanka, Vietnam, and Indonesia. Funding: FY07 $855,285.

Drought Preparedness (USAID)

Climate variability in the form of drought significantly impacts developing countries. These impacts are projected to be exacerbated by climate change. USAID/OFDA has implemented drought preparedness programs in a number of drought-prone areas. For example, the NGO CARE is implementing drought preparedness activities in Cambodia, Vietnam, and Timor-Leste. Also, NGO partner Catholic Relief Services is implementing a three-year project to improve resilience to drought among communities in Rajasthan, India, and Sindh, Pakistan. In partnership with International Relief and Development, USAID/OFDA is strengthening food security through a community-based drought mitigation program in Shiselweni and Lubombo districts in Swaziland. These programs promote community-based drought preparedness planning while also developing expertise in effective low-cost and innovative drought mitigation and preparedness technologies, such as promoting water harvesting and water storage practices and techniques, agroforestry, water conservation, and dry season cultivation. Through the program, vulnerable communities will be better able to harvest and store rainwater for domestic and agricultural use, adopt water-efficient agricultural practices, improve land-use techniques for agriculture and livestock, and better engage with local government and other actors. Funding: FY07 $1,099,963.

Land Cover Change and Biodiversity in Africa (DOS/USGS, USAID)

The DOI's USGS is completing projects that integrate remote sensing to assess land cover and land use change with biogeochemical modeling to quantify carbon status and evaluate both climate mitigation and adaptation options. This activity, funded by USAID, is focused on the Sahel and some countries, especially Senegal and Ghana, in West Africa and incorporates local capacity building. A related project has completed a land cover change project for the Sahel with country reports for management and policy guidance in both French and English soon to be released. In cooperation with host country partners,

USGS has used remote sensing and site validation to describe some exemplary village level interventions to improve economic livelihoods and likely carbon sequestration. The work has resulted in products for several major watersheds, utilizing data from the NASA Shuttle Radar Topography Mission (SRTM) at resolution of 30m, a Rapid Land Cover Mapper (RLCM), and a capability to secure time series of remotely sensed images. New project activities will assist the monitoring of resources, including areas for forest protection and management, in transboundary areas. Training in the new tools and products will be provided to regional centers.

National Health Accounts (USAID)

Research suggests that climate change could have a variety of impacts on human health, for instance by changing the frequency and distribution of disease vectors. Tracking financial information will help countries understand the extent to which the health sector in different countries is directing funds towards climate change based concerns. In partnership with the World Health Organization (WHO) and the World Bank, the U.S. Agency for International Development (USAID) created and introduced a tool for comprehensively mapping public and private funding sources and how funds are used for health sector activities. This approach, known as national health accounts (NHAs), is being applied in more than 65 developing countries to strengthen national health policy and decision-making processes.

Drinking water and sanitation services (USAID)

Safe and reliable access to drinking water and sanitation services are critical to developing country health. Water supplies are also highly sensitive to climate variability. USAID is developing guidance on technologies and techniques for managing water supplies as climate changes. Many water program managers and implementers recognize that their work is closely tied to adapting to climate variability and change.

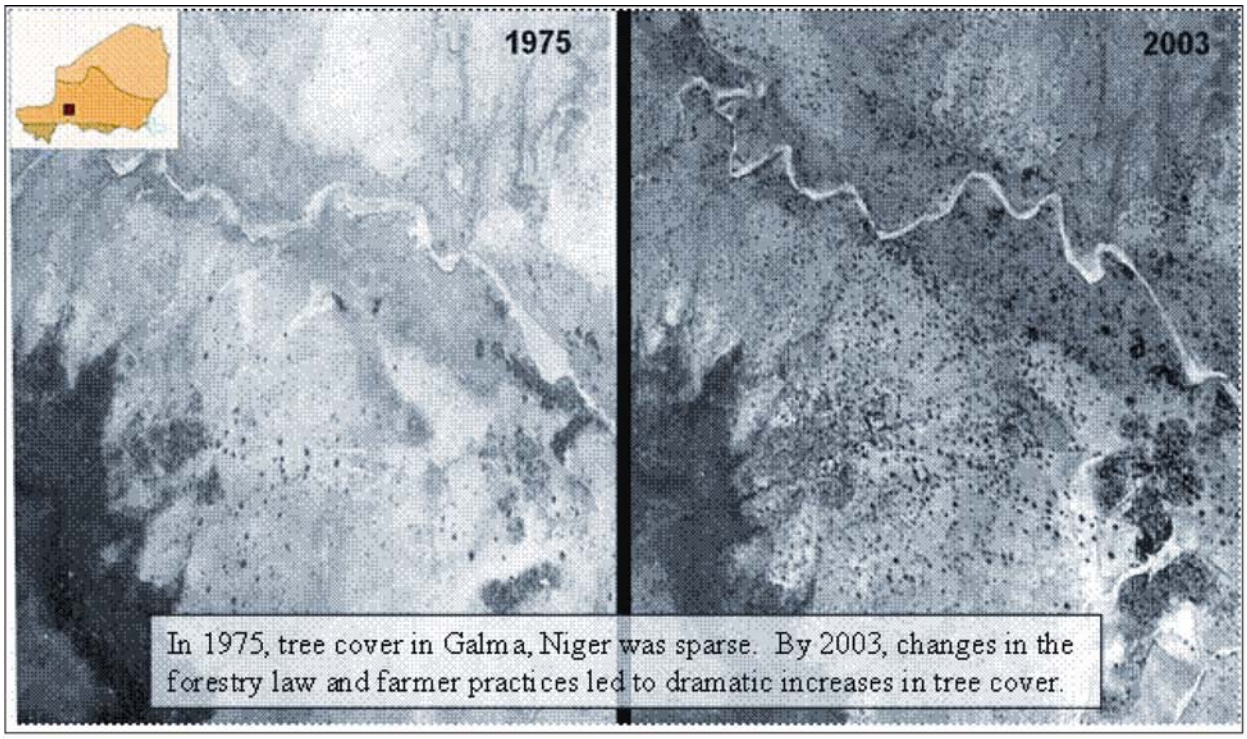
Activities Indirectly Supporting Adaptation (Forest-Related)

Well-managed forests provide climate mitigation and carbon sequestration benefits, as well as resources to communities and natural services that help reduce the impacts of, and enhance resilience to, climate change. For example, sustainable forest management facilitates communities' resilience to changing temperature and precipitation regimes – providing buffers against flooding and helping to maintain water table levels. The U.S. Government supports a number of international initiatives and programs to promote the conservation and sustainable management of existing forests, as well as to increase forest cover and enhance the health of forest ecosystems. A number of U.S. international forest initiatives offer co-benefits for both climate change mitigation and adaptation. Examples of U.S. Government forest activities that can have adaptation benefits are provided below.

Farmer Managed Natural Regeneration (USAID)

Through a series of successive projects, USAID has led efforts in Niger to change the forestry code and encourage farmers to allow trees to grow up on their land. Three to six million ha of tree cover have been added in the past 30 years. In addition to sequestering carbon, the effort has resulted in better soil condition, water infiltration, reduced wind damage, and more resilient livelihoods. New businesses have arisen around the availability of wood and fodder for animals. Women have particularly benefited from the effort, gaining access to and rehabilitating infertile land, and starting small businesses for fattening animals (using seed pods from the trees for feed) and selling wood and food products.

Changes to tree cover in Galma, Niger, 1975-2003 (aerial photographs).



Source: U.S. AID.

Technical Assistance to Address Deforestation and Forest Degradation (USDA/USFS, USAID)

Under its International Programs, the U.S. Forest Service is currently collaborating with other governments, nongovernmental organizations and the private sector on climate change and avoided deforestation through policy engagement and technical cooperation. By slowing deforestation rates, curbing land degradation, increasing carbon storage, and using forests as an alternative and sustainable energy source, greenhouse gas emissions can be mitigated and reduced. The Forest Service works with

a number of countries on these issues, including Brazil, Indonesia, Liberia, Mexico, and Peru.

Tropical Forest Conservation Act (DOS, Treasury, USAID)

The Tropical Forest Conservation Act (TFCA) was enacted in 1998 to offer eligible developing countries options to relieve certain official debt owed to the United States, while at the same time generating funds to support local tropical forest conservation activities. As of July 2008, TFCA debt-for-nature programs are being implemented in Bangladesh, Belize, Botswana, Colombia, Costa Rica, El Salvador, Guatemala, Jamaica, Panama (two programs), Paraguay, Peru, and the Philippines. These 13 programs will together generate more than $163 million to conserve tropical forests over the life of the programs. Additional funds will be generated through returns on investments and matching funds.

Congo Basin Forest Partnership (USAID, DOS, DOI/FWS, USDA/FS)

The Congo Basin Forest Partnership (CBFP), which includes more than 35 governments, international organizations, private sector and civil society representatives, is working to strengthen the sustainable management of the world's second largest tropical forest. The partnership promotes economic development, poverty alleviation, and improved local governance through natural resource management across 13 landscapes in six Central African countries. The United States has invested more than $82 million from 2002-2007 in a wide range of programs that support sustainable forest management, development of alternative livelihoods for forest-dependent communities, control of illegal logging and wildlife poaching, governance, and capacity building for natural resource conservation. Secretary Powell and other partners launched the CBFP at the World Summit on Sustainable Development in Johannesburg in 2002. If successful over the long-term, CBFP programs could have significant climate benefits through conservation of the forest biomass.

Initiative for Conservation in the Andean Amazon (USAID)

The Initiative for Conservation in the Andean Amazon (ICAA) is a 5-year program (2006-2011), supported by USAID and partner funds, that brings together the efforts of 20 public and private organizations working in the Amazon regions of Bolivia, Colombia, Ecuador, and Peru. ICAA's goal is to build constituencies that promote the sustainable use and conservation of biodiversity and environmental services of the region. In promoting a regional vision of conservation that is able to address the growing array of challenges and threats to biodiversity, ICAA focuses in particular on supporting the management of indigenous territories and strengthening indigenous organizations for enhanced conservation and development. ICAA builds on and complements the successful current portfolio of conservation efforts supported by USAID in the region by the bilateral Mission programs in Brazil, Bolivia, Colombia, Ecuador and Peru."

The U.S. Department of Transportation (DOT) submitted information on its adaptation-related efforts on March 19, 2009. DOT was given the opportunity to review its initial submission and sent updated information on September 4, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to the DOT.

U.S. Department of Transportation

"*Recent Accomplishments*

Gulf Coast Study, Phase 1, (2008)

Phase 1 of the Gulf Coast Study studied how changes in climate over the next 50 to 100 years could affect transportation systems in the U.S. central Gulf Coast region and discussed how to account for potential impacts in transportation planning. A case study approach was selected that generated useful research methodologies for application in other locations. http://www.climatescience.gov/Library/sap/sap4-7/final-report/

The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure—Atlantic Coast Study, (2008)

The study uses multiple data sources to identify the potential impact of sea level rise on land and transportation infrastructure along the Atlantic coast, from Florida to New York. The study (1) creates maps of land and transportation infrastructure that, without protection, could be inundated regularly by the ocean or be at risk of periodic inundation due to storm surge under a range of sea level rise scenarios; and, (2) provides statistics to demonstrate the potential extent of land areas and transportation infrastructure affected. http://climate.dot.gov/impacts-adaptations/forcasts.html#potentialImpacts

Integrating Climate Change into the Transportation Planning Process, June 2008.

The final report summarizes a review of the state-of-the-practice in State DOTs and Metropolitan Planning Organizations (MPOs), including statutes and regulations, and interviews with several planning agencies. Report includes both mitigation and adaptation. (Report completed June 2008)
http://www.fhwa.dot.gov/hep/climatechange/index.htm

Peer Workshop on Adaptation to Climate Change Impacts, December 2008 (Report Pending).

Peer Exchange conducted (with support from the American Association of State Highway Transportation Officials (AASHTO)) on adaptation of transportation infrastructure to climate change impacts. Participants in the workshop included leaders from FHWA and 11 State DOTs.

Initiated or Ongoing Activities

FHWA Adaptation Working Group

FHWA has formed a multi-disciplinary internal working group to coordinate policy and program activities to address climate change impacts to transportation infrastructure.
Status: first meeting: December 2008, meetings ongoing

FHWA Strategy to Address Adaptation to Climate Change Effects

The Strategy is being developed by the FHWA Adaptation Working Group. The Strategy will include the relevance of impacts/adaptation to FHWA program areas, identify program vulnerabilities, and discuss ongoing, planned activities by FHWA. The Strategy will provide FHWA with a common strategic framework as the agency addresses climate change impacts through policies, regulations, and programmatic activities.
Status: Currently drafting
Timeframe: Late 2009

Interim Framework on Conducting Assessments of Transportation Infrastructure Vulnerable to GCC Effects

The project's first phase will address what can reasonably be assumed by practitioners with regard to climate change impacts, its effects differentiated by geographic area**,** and data to be used in conducting assessments (including data gaps). The Framework itself will include criteria to be considered, recommended categories for existing and planned infrastructure, and methods to assess importance, redundancy and scale. HEP and HIF are requesting additional research funds to pilot the "Framework" in up to 5 States.
Status: Proposals are currently being reviewed
Timeframe: Summer 2010

NCHRP 20-83(05): Climate Change and Highway Infrastructure: Impacts and Adaptation Approaches

This is a $1 million project identified by the Transportation Research Board (TRB) executive committee as priority research. FHWA is providing technical assistance to the panel and coordination with other FHWA and DOT activities to prevent duplicative effort. The anticipated product will be guidebooks for transportation practitioners and outreach materials.
Status: Initial panel meeting held, RFP being drafted
Timeframe: 2-3 years

Guidelines for Consideration of GCC Impacts and Adaptation in Project Development and Environmental Review

These guidelines will include discussions of how to consider climate change impacts as part of the project development, preliminary engineering, and NEPA analysis (including scoping, environmental context, and alternatives screening and analysis)
Status: Initiating activity
Timeframe: Fall 2009/Spring 2010

Second peer workshop on Adaptation to Climate change, under development for fall 2009

FAA Approach to Address Adaptation for Aviation Navigation Systems Brought by Climate Change: Induced Perturbation in Weather Patterns

More frequent adverse weather brought on by climate change will potentially impact aviation operations and air space management. Presently, the FAA is researching approaches to better use predictive weather capabilities to adapt flight routes to minimize weather related impacts. Though these efforts are largely not driven by climate change, they can provide an adaptation strategy for potential climate change impacts.

Future activities – Medium to Long-term

Gulf Coast Study – Phase 2

The ultimate goal of the "Impacts of Climate Change Variability on Transportation Systems and Infrastructure: Gulf Coast Study" research is to provide decision-makers with more capacity to adapt to the long-term impacts of climate change on the transportation system. This will be achieved by providing knowledge and tools that will enable transportation planners and managers to better understand the risks, adaptation strategies, and tradeoffs involved in planning, investment, design, and operational decisions for all modes of transportation. The objective of Phase 2 research is to build on the findings of Phase 1 to develop more definitive information about multimodal impacts at the local level. This study will focus on a detailed analysis in one area within the Gulf Coast region.
Lead: Robert Ritter
Status: RFP drafted
Timeframe: 3 years

Update of the FHWA Floodplain regulations (23 CFR 650, Subpart A)

This revision of the floodplain regulations is anticipated to better reflect more recent flood risk assessment and management approaches/opportunities, clarify requirements vis-à-vis NEPA, FEMA, and other floodplain processes and stakeholders, incorporate consideration of climate change effects as appropriate.
Status: Pending
Timeframe: Several years (rulemaking process)"

Additional Update as of September 4, 2009

The Department of Transportation (DOT) Center for Climate Change and Environmental Forecasting

The Center fosters comprehensive and multi-modal approaches through technical expertise, research, policy analysis, partnerships, and outreach to reduce transportation-related greenhouse gases and mitigate the effects of global climate change on the transportation network. The Center's Transportation and Climate Change Clearinghouse (http://climate.dot.gov) is intended for use by the transportation community as a one-stop source of information on transportation and climate change issues, including adaptation."

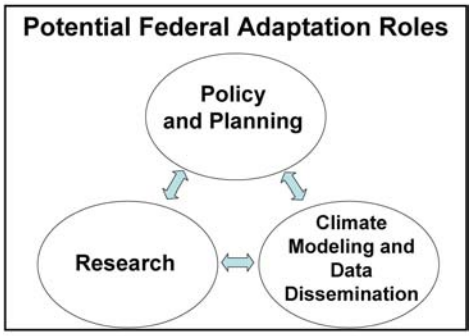
The U.S. Environmental Protection Agency (EPA) submitted the following examples as illustrative of its adaptation-related efforts on July 2, 2009. EPA was given the opportunity to review its initial submission and sent updated information on September 3, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to EPA.

U.S. Environmental Protection Agency

"*Information on EPA's Ongoing Adaptation Efforts: A perspective on the role of the federal government in adaptation*

Climate change will have far-reaching impacts across many federal agencies. We believe that federal adaptation efforts can be categorized into three relatively distinct but interactive roles:

1. *Research*. Includes all research to inform climate change adaptation, such as adaptive options for natural and human systems; the tradeoffs, costs, and benefits inherent in those options; and the necessary basis for implementation.



Source: EPA.

2. *Climate Modeling and Data Dissemination*. Compiling, analyzing, and distributing information related to climate variability and change, including future climate projections and associated impacts (e.g., downscaled climate projections), the characteristics and tradeoffs of various adaptation options, and other important data and research down to the local level.

3. *Policy and Planning*. The programmatic-oriented implementation of adaptation. Recognizing that *specific adaptation actions will generally occur at the local level*, this role involves actions at the federal level to inform and enable adaptation policy, management, and planning. Examples of such actions include: compiling and distributing lessons learned, providing expert knowledge on adaptation, and programmatic efforts to enable encourage and inform adaptation. These efforts will utilize existing information and build upon existing infrastructure and relationships between the federal, regional, state, local, and tribal communities.

EPA's relative expertise and work lies generally in the first and third of these roles: research and policy and planning. In general, EPA considers itself a "client" or user of data and climate modeling referred to in #2 above with regard to adaptation efforts. Below are examples of ongoing EPA work within these two roles.

Examples of EPA adaptation research efforts

- *Climate Change Science Program Synthesis and Assessment Products (SAPs) (ORD).*[2] ORD produced two SAPs entitled: *Synthesis and Assessment Product 4.4: Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources* and *Synthesis and Assessment Product 4.6: Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems.*

    - *Climate Change Science Program Working Group on Adaptation (ORD).* ORD is currently the co-chair of this effort.
    - *Climate Change and Air Quality (ORD).* In collaboration with OAR, ORD is conducting a major assessment of the sensitivity of air quality to climate change. The final assessment will be completed in 2012.
    - *Climate Change Impacts on Water Quality and Aquatic Ecosystems (ORD).* In collaboration with OW, the Global Program is conducting a major assessment of the sensitivity to climate change of goals articulated in the Clean Water Act and the Safe Drinking Water Act, and opportunities for adaptation to the anticipated impacts. This assessment will be completed in 2013.
    - *Climate Change and Human Health (ORD).* ORD is working with other CCSP agencies (particularly CDC, NIEHS, and NOAA) to support the public health communities' efforts to develop strategies for adapting to a changing climate.

Examples of EPA program office initiatives to enhance adaptation planning efforts

Program office adaptation efforts are focused on the third role described above: the programmatic informing and enabling of adaptation policy, management, and planning. Examples of current and future work include:

- *Planning for Air Quality Management in a Changing Climate (OAR).* IPCC (2007) and CCSP (2008) reports indicate with "virtual certainty" declining air quality in urban areas as a result of climate change. To better understand and address the effects of climate change on air quality, OAR, in collaboration with the Office of Research and Development, is undertaking modeling studies and impacts analyses, and updating our analytical tools, to assist urban areas, states and regions to integrate climate change into their air quality planning. These analyses will also help answer questions such as: Which air pollution control scenarios are clear "winners"—i.e., worth pursuing regardless of the uncertainties surrounding future climate? What additional air pollution mitigation efforts may be necessary as people alter behavior in response to future climate conditions (e.g., higher air conditioning use)? What control strategies can reduce air pollutants and climate pollutants simultaneously and

[2] EPA Offices referred to in this document:
ORD – Office of Research and Development
OAR – Office of Air and Radiation
OW – Office of Water

cost-effectively? Answers to these questions will help EPA, along with our regional and state partners, integrate air quality management planning with climate change and to develop multipollutant emission standards for sources of air pollution and GHGs.

- *National Water Program Strategy: Response to Climate Change* (OW). This September 2008 strategy document, and the effort behind it, broadly represents the Office of Water's recognition that adaptation is necessary for a significant number of national water programs. The strategy identifies 44 specific actions that the National Water Program planned to take in 2008/2009 to respond to climate change. The majority of the proposed actions involve adjustments to program management to reflect a better understanding of impacts of climate change in several key areas: drinking water, water quality and effluent standards; watershed protection; National Pollutant Discharge Elimination System permits; water infrastructure; and wetlands protection. The Office of Water has significant actions currently underway to implement this strategy. In addition, efforts are now underway to update and revise the Strategy. More information can be found at http://www.epa.gov/ow/climatechange/strategy.html.

- *Climate Ready Estuaries (Joint OAR-OW)*. The Climate Ready Estuaries (CRE) program is a partnership between EPA and the National Estuary Programs (NEPs) to address climate change in coastal areas. In its second year, this effort is building additional capacity in coastal communities as they prepare to adapt to the effects of climate change. Climate Ready Estuaries is supporting NEPs and coastal communities in becoming "climate ready" by providing tools and assistance to:
  - Assess climate change vulnerabilities
  - Engage and educate stakeholders
  - Develop and implement adaptation strategies
  - Share lessons learned with other coastal managers

  More information can be found at http://www.epa.gov/cre/.

- *Planning for Heat Health-Related Climate Change Impacts in American Cities (OAR)*. Heat is presently the #1 weather-related killer in the U.S. and heat waves are projected to increase in frequency, intensity, and duration in a warming climate. Building on past EPA heat health-related work, this developing effort is designed to assist American cities with understanding and planning for the public health impacts of climate change, focusing mainly on extreme heat events.

- *Scoping Adaptation Planning and Management Options for the U.S. Southeast (Joint OAR-OW)*. This initiative is a joint project of the Office of Air and Radiation, the Office of Water, and Region 4 (composed of 8 Southeastern states). The purpose is to help begin to create the conditions for success for the U.S. Southeast on climate change adaptation with regard to scoping adaptation planning and management options based upon an understanding of climate change impacts, and bringing together practitioners and principals to assess and develop these options.

- *Water-focused Adaptation Programs and Activities (OW).* Other Office of Water efforts include:
  - Forming a FACA subcommittee on Climate Ready Water Utilities to address both water and wastewater utility adaptation;
  - Creating a State/Tribal Climate Change Workgroup to work with and inform OW on water program adaptation;
- Developing a Climate Vulnerability Assessment tool to complement the security VA tool already existing for water utilities;
  - Developing a decision framework for vulnerability assessments; and
  - Held a joint OW/ORD expert and stakeholder workshop on water infrastructure sustainability and adaptation to climate change.

- *U.S. Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region* (OAR). This Synthesis and Assessment Product (SAP), developed as part of the U.S. Climate Change Science Program, examines potential effects of sea-level rise from climate change with a focus on the mid-Atlantic coast of the United States. The SAP describes the physical environments; potential changes to coastal environments, wetlands, and vulnerable species; societal impacts and implications of sea-level rise; decisions that may be sensitive to sea-level rise; opportunities for adaptation; and institutional barriers to adaptation. SAP 4.1 was released in January as a joint product of EPA, USGS, and NOAA with EPA as the lead agency. More information can be found at http://www.epa.gov/climatechange/effects/coastal/sap4-1.html or http://www.climatescience.gov/Library/sap/sap4-1/final-report/default.htm.

Additional Examples of EPA Regional Efforts

Numerous adaptation efforts are occurring in many of the 10 EPA Regions. As examples, some of the activities being undertaken in two Regions are highlighted below.

- *Region 1 (New England).* Adaptation work that is being undertaken by this Region includes:
  - involvement of four of the Region's six NEPs in the Climate Ready Estuaries program;
  - working with the EPA-funded New England Environmental Finance Center to develop tools for coastal communities to identify sea-level rise and coastal storm vulnerabilities to make informed adaptation planning and zoning decisions, coupled with economic impact assessments;
  - conducting a multi-stakeholder meeting on adaptation research and planning in June 2008 at the University of New Hampshire;
  - conducting a multi-day inter-agency meeting on adaptation research and planning for ocean and coastal resources and watersheds in June 2009, in Gloucester, MA, with participation by 12 federal agencies; and
  - participating on taskforces for regional and statewide adaptation planning in New England states.

More information about Region 1 activities can be found at http://www.epa.gov/region1/climatechange/

- *Region 10 (Northwest).* This Region has produced its own climate change strategy that incorporates many adaptation-related activities. Examples of such activities include:
    - personnel support to Alaska Department of Environmental Conservation adaptation activities;
    - using existing grant programs to encourage incorporating considerations of climate change impacts into funded work, such as IGAP, Tribal Air Grants, and Western Estuary Initiative grants; and
    - organizing workshops for state, local, and tribal governments on considering climate change impacts and adaptation strategies.

More information about Region 10 activities can be found at http://yosemite.epa.gov/R10/ECOCOMM.NSF/climate+change/cc."

The National Aeronautics and Space Administration (NASA) submitted information on its adaptation-related efforts on July 2, 2009. NASA was given the opportunity to review its initial submission and did not send us any changes or updates for this e-supplement. GAO did not assess the validity of this submission. Any questions should be directed to NASA.

National Aeronautics and Space Administration

"The National Aeronautics and Space Administration (NASA) makes global measurements of climate forcing and Earth system responses from advanced satellite missions; conducts cutting-edge research utilizing data from spaceborne, airborne, and in-situ systems to produce more accurate Earth system models; and works with both NASA and external organizations to provide tailored, efficient Earth system predictions that are an essential basis for adaptation.

NASA's 15 operating Earth research satellite missions acquire high-resolution, frequent, stable, accurate, *global* measurements of key quantities including solar irradiance and Earth radiation budget, atmospheric composition and dynamics, aerosols, precipitation, land and sea ice cover, ocean surface winds, sea level, ocean surface temperature and color, land cover and vegetation type, time-varying gravity, and space weather. Most of the research satellites provide near-real-time data, thus contributing to improved short-term environmental forecasts produced by NOAA, DoD, and international meteorological organizations. A further 7 NASA Earth-observing research missions are in formulation and development for launch before 2013, and the 2007 Earth Science and Applications Decadal Survey identified 13 additional Earth-observing missions to be developed and demonstrated by NASA over the coming 10-20 years.

NASA's Earth data and information systems generate, archive, and make broadly available the full suite of NASA Earth observation products, including notable multi-decadal, multi-mission, consistently processed climate data records such as the 27+ year time series of calibrated solar irradiance, the 30-year time global series of multi-spectral land images (Landsat), and the 17-year time series of global precision ocean topography.

NASA's Earth science research activities – comprising approximately half of the NASA Earth Science Division (ESD) budget – focus on advancing Earth System Science and related applications, and defining the set of highest priority, yet tractable, questions for the next generation of spaceborne missions. NASA-funded research combines theory with measurements (often from multiple satellite missions as well as in-situ and airborne campaigns) to increase understanding of the Earth as an integrated system. The resulting quantitative knowledge of the interactions between Earth processes – as well as the characteristics of individual processes – is codified in models which can be used for predictions when combined with a continuing stream of input measurements. Much of this work is carried out with significant involvement of the scientific research community through competitive solicitations; at present, ESD funds some 1700 grants.

The scientific results provide a rigorous basis for scientific assessment, especially with respect to multiple stressors that affect Earth today and in the future.

In addition to providing the underpinning for adaptation studies—the data and models needed to enable forecasting of climate impacts—NASA works directly with the organizations that have management and policy responsibilities to develop and carry out adaptation strategies. NASA's Applied Sciences Program helps to leverage the nation's investment in Earth observations and research by demonstrating their use for practical decision making. These demonstrations are carried out in partnership with resource managers, policy makers and other end-users. For example, the Applied Sciences Program is working in 31 states and has developed mature partnerships with other Federal agencies and their regional offices. Federal partners currently include 7 USDA agencies, 4 DOI agencies, 6 branches of NOAA, USAID, EPA and the Departments of Energy, Transportation (FAA) and Homeland Security.

As one illustration of the integrative nature of our Earth system science research, NASA researchers have developed the *Terrestrial Observation and Prediction System (TOPS)* to forecast ecological impacts of climate change by combining surface, satellite, and climate data with ecosystem models (Nemani et al., 2009). TOPS has been used extensively by both the research and applications community for nearly a decade. Example applications include: forecasting stream temperatures for NOAA managers responsible for managing Chinook salmon populations in the Sacramento River system; predicting water flow regimes and subsequent fire risk in Yosemite National Park; building species distribution models for the U.S. Fish and Wildlife Service; forecasting projecting bark beetle outbreaks in the Western U.S.; supporting the state of California's Encephalitis Virus Intervention Decision Support Systems; and developing a Viticultural Information System for vineyards throughout California. Now, TOPS is providing the basis for the development of an integrated information system that incorporates climate impact data to improve water management in the agriculture sector. This tool, to be demonstrated in California's drought-ridden San Joaquin Valley, will assimilate satellite data and meteorological observations into models parameterized for specific crop types to produce forecasts of soil moisture, evapotranspiration (ET), and irrigation demand for multiple crops (e.g., corn, soy, vegetable row crops, orchards, vineyards) for enhanced irrigation efficiency. It will also provide snow water equivalent (SWE) forecasting to improve the ability of state and local agencies to estimate water availability and annual water budgets, and forecast flood risk information.

NASA, in collaboration with USAID, is also providing environmental information products and portals to developing regions of the world, where predictions and resources for adaptation are scarce. The Regional Monitoring and Visualization System, called SERVIR, is a web-based information system that utilizes imagery and data from numerous satellites and other data sources for environmental management and disaster early warning. SERVIR was developed in Mesoamerica by NASA in partnership with USAID and Central American environmental management organizations. Today, SERVIR is routinely used in Central America to plan for and respond to hurricanes and other natural hazards. Recently, USAID and NASA expanded SERVIR to East Africa. SERVIR Africa is already providing data and information to first responders to the recent severe

floods in that region. A next step will be to develop flood-potential maps and Rift Valley Fever maps for East Africa area based on vegetation indices, precipitation and other climate variables to enable better planning. SERVIR provides a platform upon which to build and serve to policy makers and the general public an array of information tools and is thus an important (and sometimes, the primary) environmental decision support system within these regions as they plan for and respond to climate change impacts (http://www.servir.net/).

Internally, NASA is also planning for adapting to climate impacts on our own physical installations, several of which are unique national facilities located in climatically and ecologically sensitive locations. Kennedy Space Center, Wallops Flight Facility, Stennis Space Center, and the Michoud Assembly Facility are all coastal installations exquisitely susceptible to sea-level rise and with large exposure to storm damage from hurricanes (as is Johnson Space Center). The Marshall Space Flight Center is subject to severe thunderstorms and tornadoes, while the centers in California – Ames Research Center, Dryden Flight Research Center, and Jet Propulsion Laboratory - are vulnerable to future water stress and fire.

NASA ESD and NASA's Environmental Management Division (EMD) in the Office of Infrastructure are collaborating to ensure that knowledge of climate trajectories and their implications developed by ESD are accounted for in long-term facilities planning by the NASA centers. As the next step in this collaboration, ESD and EMD are planning a joint workshop to be held in the summer of 2009, to define any additional NASA research studies required to address key center-specific issues, and to identify specific information products required to best apply NASA's scientific capabilities to the agency's need for long-term facilities planning that fully recognizes and responds to the impacts of a changing climate.

References:

Nemani, R.R., H. Hashimoto, P. Votava, F. Melton, L. Mutch, W. Wang, C. Milesi, S. Hiatt and M. White, 2009: Monitoring and forecasting ecosystem dynamics using the Terrestrial Observation and Prediction System. *Remote Sensing of the Environment*, doi:10.1016/j.rse.2008.06.017."

The National Science Foundation (NSF) submitted information on its adaptation-related efforts on April 10, 2009. NSF was given the opportunity to review its initial submission and sent updated information on September 3, 2009. GAO did not assess the validity of these submissions. Any questions should be directed to NSF.

National Science Foundation

"As an agency charged with supporting basic research, the National Science Foundation (NSF) in general is not involved in the implementation of adaptation measures; rather NSF-supported projects are aimed at providing a strong scientific basis for rational decisions regarding potential adaptation strategies and identification of potential unintended consequences of choices. There are some exceptions, most often, at some of our specialized research centers where engagement of stakeholders dealing with adaptation questions may be a critical component of the project. NSF recognizes that the "science of adaptation" will have to expand to meet national needs and we are actively exploring how NSF can most effectively contribute to the overall federal effort. With respect to GAO's three specific questions, NSF primarily will be involved in helping authorities and the public adapt to a changing climate by providing new insights into the issues and helping to develop new tools for predicting the effects of adaptation choices. Our research portfolio will include projects to help identify the challenges involved in implementing adaptation strategies.

Four science directorates within NSF are involved with climate change and adaptation issues: Biological Sciences, Engineering, Geosciences, and the Social, Behavioral, and Economic Sciences. In addition, the Office of Polar Programs funds activities that span many disciplines, but are regionally focused. NSF has several research programs that are cross-directorate in nature and support. The key activities related to adaptation in each of these organizations are described below.

As noted above, research focused on climate adaptation issues will increase in the coming years, as our scientific understanding is not mature enough to form a solid underpinning for policy action. NSF recognizes and is responding to the need for compressed timelines of discovery, understanding, and education on key concepts.

Additional information on specific NSF programs and awards can be found on our website: http://www.nsf.gov

Directorate for Biological Sciences

The living world is tightly coupled with Earth's climate; the biosphere responds and adapts to changes, but it also produces important drivers and feedbacks that transform the climate. Adaptation planning requires that managers and policy-makers account for the potential and likely outcomes of climate change for the biosphere. The Directorate for Biological Sciences (BIO) participates in the Federal response to climate change

adaptation needs by supporting fundamental disciplinary and interdisciplinary research that relates to resilience and limits to adaptation; system dynamics governing responses and feedbacks; and transformations and tipping points in biophysical systems. Our research is discovering answers to fundamental questions about how the living world adapts to and transforms Earth's climate.

Biological science projects provide an understanding of the factors that underlie vulnerability, resilience and robustness to change across levels of organization from the molecule to the ecosystem. Studies in ecology and evolution are helping to determine how organisms may respond to rapidly and continuously changing environments through behavioral changes and genetic responses. Research at the nano- and molecular-scale is elucidating biophysical phenomena that underlie mechanisms of rapid stress response and other adaptive strategies. We are supporting the use of powerful genomic tools in research that reveals the secrets encoded in the genomes of microbes and other organisms that control ecosystem function and enable adaptation to environmental change.

Researchers supported by the BIO are helping to develop next-generation climate models that better represent the dynamics of biosphere, carbon, water and nutrient cycles, and more tightly integrate biophysical and social sciences. Our support of sites in long-term ecological research and centers for biological synthesis provide crucial information to validate models and understand adaptation phenomena that are undetectable or poorly understood at short time scales. We have begun an effort to determine the unknown dimensions of biodiversity within a decade that will enable better understanding of the relationships between biodiversity, ecosystem services, and human systems. And, BIO is supporting research that investigates the ecology of infectious disease and the biology of invasion by exotic species, biological impacts of climate change with direct bearing on human well-being.

Climate change will disproportionately affect developing nations, tropical and dry regions, and alpine, tundra, and coastal systems. Biophysical patterns and processes will change, as well as the ecosystem services that are elemental to sustainable development and human health and well-being. BIO-supported research helps to inform adaptation efforts that account for the dynamic relationship between humans, the living world, and the Earth's climate.

The Directorate for Engineering

The Directorate for Engineering (ENG) has no programs specifically focused on implementation of adaptation measures, but a number of programs involve research on related topics. In particular, ENG supports research in areas such as preparing cities for climate change, whereby international comparative assessments of urban adaptation planning are conducted and quantify adaptation strategies in the face of uncertain climate change impacts to conserve or reuse water, manage storm-water, and/or reduce energy demands. Research is also supported to translate climate change predictions and uncertainties into useful information for drought preparedness planning in order to

address the critical question: What does possible climate change imply for drought hazards, and how should society respond? Projects focused on understanding renewable energy resource applications and adaptation to climate change impacts; creating a national capability to better predict and manage the behavior of water-and its nutrients, contaminants, and sediments-everywhere in the U.S.; and electronic systems to sense and detect environmental changes have been awarded.

Researchers supported by ENG contribute significantly to the knowledge base for major components of the U.S. economy, including chemicals, pharmaceuticals, medical devices, forest products, metals, petroleum, food, textiles, utilities, sensing systems, and microelectronics.

Several programs also support research related to impacts of extreme events or changing climate (e.g., sea level rise) on infrastructure, water resources and infrastructure, and alternative fuels.

Directorate for Geosciences

The Directorate for Geosciences (GEO) supports the adaptation process at the front end by sponsoring research that aims to provide information about future climate on decadal and shorter time scales and at regional resolution. Such information serves to inform decisions made by the public and policy makers for adaptation strategies.

The starting point for adaptation to climate change is a credible climate forecast, with a reliable estimate of its uncertainty. Planning for adaptation is done on time horizons at which anthropogenic climate change is convolved with natural variability of the climate system. Climate scientists supported by GEO seek to advance prediction on these timescales through their collective strengths in the mathematical theory of prediction and predictability, through their innovative uses of peta-scale computing, through development of new techniques of initializing the key long-memory components of the climate system (the ocean and land surface) and through their development of novel multi-model ensemble methods for climate forecasting.

The availability and fate of water resources will be a key issue for consideration in adapting to climate change. GEO, along with ENG, is working closely with the research community to expand capabilities to improve understanding of how the overall water cycle functions, how it will be affected regionally with climate change and the implications for future water resources management.

NSF provides significant support for research that is exploring the impacts of climate change on marine ecosystems, including fisheries, with obvious connections to the global and regional approaches to ensuring adequate food supplies.

Directorate for Social, Behavioral, & Economic Sciences

For purposes of this report, the Social, Behavioral, and Economics Sciences (SBE) interprets “climate change adaptation” research as addressing how humans can adapt to

climate change. The research is not about how to reduce the amount of global warming by reducing greenhouse gas emissions (we interpret that as "mitigation"). Adaptation research includes work on resilience and vulnerability to expected climate change (e.g., more frequent and more severe storms, more droughts in some regions, more flood in other regions, rising ocean levels, melting permafrost, urban heat island effects, longer growing seasons in some regions, etc.).

SBE is involved in three key interdisciplinary activities that have a significant component of adaptation research. These include:

1) Decision Making Under Uncertainty Centers/Collaborative Groups (DMUU). All five existing DMUU Centers and Teams do adaptation research. For example, the Decision Center for a Desert City at Arizona State has developed a water use simulation that projects adaptation options.

2) Dynamics of Coupled Natural and Human Systems (CNH). This BIO, GEO, SBE collaborative effort funds several adaptation projects on how species and humans are responding to climate change.

3) Environment, Society, and Economics (ESE). This SBE/GEO collaboration encourages submission of interdisciplinary proposals for joint review and co-funding by existing programs within the two directorates. Many aspects of climate change adaptation are topics appropriate for this activity.

The SBE programs (which span the social sciences from economics and political science to social psychology and anthropology) support a wide variety of projects that are relevant to climate change adaptation. Research topics include adaptive environmental management, as well as climate change adaptation as a "commons" problem. In addition, projects are funded on how people understand climate change and adaptation options as well as adaptation costs and opportunities. Response to vulnerabilities is a leading research theme. SBE also supports many projects examining why some civilizations failed to adapt to climate change (or did successfully adapt) and how societies reacted to climate changes.

Some of the SBE-supported research is relevant to, but does not directly address, adaptation. For example, SBE supports projects related to land-use in response to rising tides, as well as such topics as planning and zoning, vulnerability and class. Other research topics that can contribute to the development of successful adaptation strategies include treaties for adaptation, game theory, politics of land-use and intergovernmental relations. In addition, projects to investigate the role of media treatment of adaptation issues, how policy makers have treated the science of adaptation, organizational treatment of climate change information, and ethical issues in adaptation are being and have been supported. Finally SBE funds basic social psychology studies on how people respond to new information, which will be a crucial component in developing successful adaptation pathways.

Office of Polar Programs

The Office of Polar Programs (OPP) does not have a program dedicated to adaptation, but supports research focused on the polar regions, which can include biological, physical, chemical, and the social sciences - and combinations thereof. The poles are expected to experience climate change of greater magnitude and at a more rapid rate than other parts of the globe and, indeed, already there is significant evidence for this, particularly in the Arctic. Within the existing programs, OPP invests in both Arctic climate change as well as Arctic social science. One program, the Bering Sea Ecosystem Study, will serve as a baseline for understanding ecosystem and fisheries changes in response to climate change. A significant portion of the Arctic social science research portfolio focuses on cultural adaptation to rapid climate change. Work in these areas will continue to be encouraged. OPP also supports research in the Antarctic to understand the response of organisms and ecosystems to climate change. A number of these programs are accomplished in collaboration with the Biology Directorate (e.g., the two Antarctic Long Term Ecological Research sites). Such studies in the Antarctic Peninsula are particularly important because of the significant warming seen in that region, which has led to changes in sea ice extent as well as to collapse of significant ice shelf areas. These in turn have significant effects on ecosystems.

Finally, OPP supports the NSF Science and Technology Center for Remote Sensing of Ice Sheets. A principal goal of this Center is to advance understanding of the contribution of the polar ice sheets (both Arctic and Antarctic) to sea level rise. The question of how ice sheets are contributing now to sea level rise and how they will contribute to sea level rise in the future is a major source of uncertainty in the IPCC projections of climate change. In addition to the obvious global effects of sea level rise on coastal communities, improving IPCC models is of major importance to environmental policy worldwide."

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