DEPARTMENT OF THE INTERIOR
TASK FORCE ON CLIMATE CHANGE

REPORT OF THE SUBCOMMITTEE ON SCIENCE

An Integrated DOI Science Plan
For Addressing the Effects of Climate Change on Natural Systems

Table of Contents

Preface

Last year, Secretary of the Interior Dirk Kempthorne established the DOI Climate Change Task Force, chaired by Deputy Secretary Lynn Scarlett. It was composed of a Steering Committee and three subcommittees. The Assistant Secretaries, Bureau and Service Directors, the Special Advisor for Alaska, and the Solicitor were members of the Steering Committee. The three subcommittees were made up of land managers, biologists, economists, climatologists, lawyers, policy analysts, and many others (approximately 100 employees in all). The tasks of the subcommittees were identified as follows:

> (1) The Land & Water Management Subcommittee was to identify issues and challenges that may be facing the Department of the Interior (DOI) as a consequence of predicted climate change and to suggest possible options for addressing them.
>
> (2) The Law & Policy Subcommittee to identify the legal and policy issues facing DOI and to suggest possible options for addressing them.
>
> (3) The Science Subcommittee to identify the science and information needed to assist DOI in addressing potential consequences of climate change and to suggest possible options for developing, coordinating, acquiring, and analyzing any additional scientific information that would be helpful for that purpose.

The objective was for the Task Force to canvas the existing information and expertise within the Department and suggest options for the Secretary to consider in ongoing management of the Department. By the nature of the process, these draft reports do not contain budget proposals, set priorities or policies, nor provide legal advice. Any such subsequent activities would be undertaken pursuant to Secretarial direction and be subject to the regular policy procedures, budgetary proposals, solicitor reviews, interagency coordination, and administration priorities. The three Draft DOI Climate Change Task Force subcommittee reports provide an organized means to collect views within the agency and highlight a series of questions and potential options for addressing them.

As drafted, the reports do not represent either Administration or Departmental positions on the issues discussed. But it is hoped that they will begin an informed process for the coordinated consideration of various climate change issues facing the Department and how to address them.

These reports are the product of brainstorming sessions presented in a fashion to organize the material while maintaining the dynamics of subcommittee participation. As such, the drafts do not attempt to prioritize the information presented either by the order of presentation or the length of the discussion associated with any particular issue, option, or grouping of information.

While it would have been consistent with standard operating protocols for the drafts to go to the Secretary without external consideration, it was felt that the Secretary and the decision-making process would be best served if the broader public had an opportunity to consider this information and have an opportunity to weigh in on the issues. Although the Department uses various processes to involve the public, such as public comment on regulations, Advance Notice of Proposed Rulemaking, and agency scoping meetings, the posting of these documents on the web does not fall into any of these or other existing categories. This is an informal process to provide knowledgeable members of the public an opportunity to provide additional insights into a subject of general concern.

The subject of climate change is being addressed in a wide variety of venues throughout the federal government. These reports are written in the context of that environment and with an acknowledgement that all comments in the reports are made with a strong realization that many efforts discussed therein are related both to activities already conducted by DOI and to actions being taken by other agencies.

For instance, fire management has long been a major focus for DOI in the western states. If future climate change is associated with extending or intensifying the fire season, the issues raised in these reports are an attempt to anticipate trends and adjust our readiness to respond to those threats. Options in the reports on such matters do not constitute new programs; they offer options for possible adjustments and improvements in existing programs to meet new conditions.

Likewise, although carbon sequestration is of major interest to DOI, and the reports highlight important options the Secretary may want to pursue, such programs also relate to the missions of the Department of Energy, the Environmental Protection Agency, the Forest Service, and the Department of Commerce. All options proposed in the DOI reports are in the context of coordination with the responsibilities of each of those agencies, where appropriate, and a desire to maximize the efficiency with which the government addresses the emerging issues.

Finally, the effort to address climate change is being organized and managed through various Administration organizations, including the Climate Change Science Program, the Council on Environmental Quality, and the National Economic Council. Congress is also placing an increasing focus on the issue with new committees, hearings, and legislation. The options presented in the draft subcommittee reports range from those which DOI can implement directly to those requiring Administration action or Congressional enactment. Some options would require coordination and leadership from state, local and private initiatives. Consequently, the reports discuss issues and propose options that are important to the Department but which may require many other stakeholders for effective implementation. The hope is that, by raising these issues and potential options in a timely manner, better solutions will be adopted.

Executive Summary

In order to deal with the impacts of climate change, the Department of the Interior (DOI) needs scientific information not only on the effects of climate change on DOI lands and resources, but also on the effects of adaptation and mitigation actions. This document describes a collaborative strategy that DOI could use to meet the needs for this information. The strategy builds on and leverages existing resources within DOI, as well as many other partners, and includes four components: (1) an inventory and evaluation of climate-related issues and existing capabilities for collecting and analyzing data; (2) field-based observations that support our understanding of the effects of climate change on resources and hazards; (3) support for making decisions, including modeling to forecast future conditions, climate change related impacts, and the effectiveness of potential adaptation or mitigation actions; and (4) development of capabilities to manage, analyze, and disseminate information. We have presented options for implementing these components, and the appendices show varying scenarios based on the availability of funds, the scope of the program, and the timeframes for implementation. We have emphasized the design and implementation of a national strategy for early detection and tracking of environmental changes caused by climate change. This strategy could proceed incrementally, beginning with regions where climate change effects are most rapid and the need for decision support is most pressing. Together, these components comprise a coherent plan to identify critical needs and address them over short-to-long time periods and local-to-national scales. The plan should lead to better management of at-risk DOI assets and resources, more efficient and effective use of climate change information for managers and the public, and improved forecasting of the consequences of climate change for our environment, our society, and our natural resources.

Introduction

The Challenge of Climate Change

The effects of recent climate change present potentially significant stress to infrastructure, natural resources, human health, and ecological stability. Coping with these stressors is a critical issue for DOI, the United States, and the world. Over the past 20 years, environmental research has shown that air, land, water, living resources, and human activities all interact in a complex mosaic to make up our world (Figure 1). Changes in one or more of these components can have a ripple effect that impacts each of the others. Recent climate change is significantly affecting these interactions. It is altering how ecosystems function, destabilizing societal infrastructure, and challenging the sustainability of subsistence cultures. There are large uncertainties in the projections of how fast these changes are occurring, what the full extent of the changes will be, and how our ecosystems will be permanently altered.

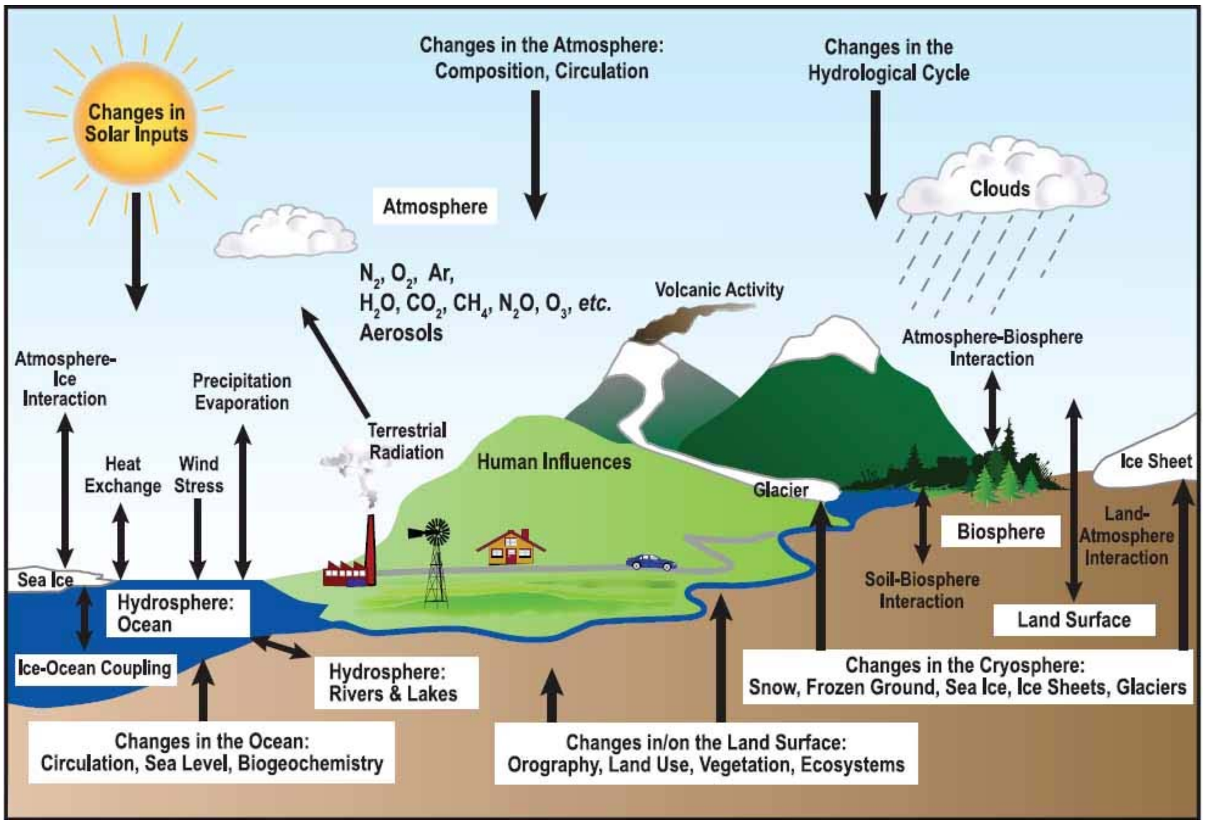

Figure 1. Earth is made up of a complex mosaic of interactions between air, land, water, living resources, and human activities. Changes in one component can have a ripple effect, impacting each of the other components. Climate change is significantly altering these interactions.

What is certain is that the effects of climate change will cross jurisdictional boundaries and the degree to which these effects will be felt across different landscapes will vary, in some places improving and other places exacerbating existing environmental stresses and societal issues. In order to develop effective solutions for coping with climate change, DOI will need to take this variability into account and engage in deliberate, ongoing collaboration across jurisdictions.

While DOI's current science capabilities can contribute significantly toward understanding the most vulnerable habitats and systems, our existing programs were not designed to measure the complex interactions that influence and are influenced by climate change. Additionally, the information generated by our existing programs is not widely available in a form that managers and decision makers can understand and use.

Local, regional, and national systems for anticipating environmental degradation from a changing climate and developing cost-effective adaptation and mitigation strategies are imperative. In this report, the Science Subcommittee of the DOI Climate Change Task Force describes a framework for developing a climate effects research and monitoring network for DOI. The framework would integrate into and build upon our current data-collection capabilities and create an early warning system for detecting and anticipating environmental change caused by climate change.

Informing a Management Response to Climate Change

DOI has extensive responsibilities for managing, tracking, and reporting on resources, many of which already are or soon could be impacted by climate change. These responsibilities include managing unique natural resources within our national parks and reserves; stewardship of Federal lands, mineral and oil resources, and federally protected species; and monitoring nationally significant resources and hazards (i.e., floods, volcanoes, earthquakes, etc.). The infrastructure that DOI agencies oversee is extensive, consisting of buildings, roads, dams, and other structures. DOI is responsible for both near-term decisions to maintain existing resources and planning future activities that accommodate changing social values in a changing environment. Recognizing the complexity of this responsibility, DOI adopted a 2007 policy supporting adaptive management, a framework in which monitoring and research are integral components of the decision-making and management processes (Figure 2).[1] The adaptive management approach considers the complex connections between the many components of Earth's systems. It uses a cycle of learning and action in which there are continuous feedbacks among science, management, and policy.

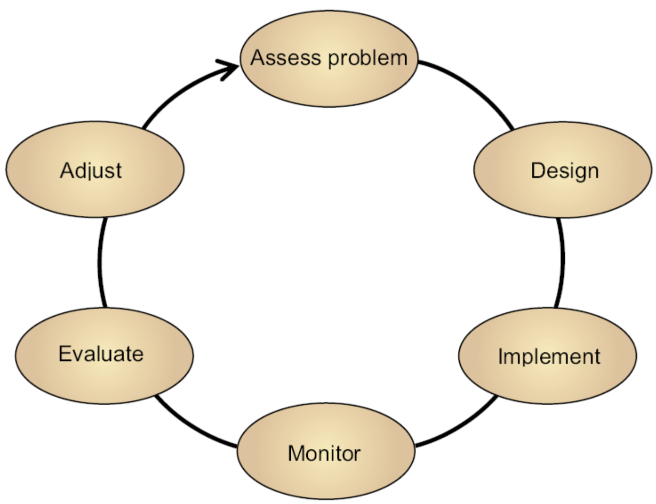

Figure 2. Adaptive management cycle from the adaptive management technical guide

Climate change could affect virtually every aspect of DOI's management, and DOI will have to consider both the direct and indirect effects of climate change. Some of the most challenging aspects of climate change will relate to the interactive and cumulative effects of many factors, including invasive species, disease, pollutants, water, and altered disturbance regimes (e.g., fire, storms, floods, and permafrost degradation). Several bureaus within DOI have long-standing histories of studying climate change and its effects on ecosystems and society. DOI already has significant capabilities for collecting environmental data and has established long-term records of environmental condition in some locations. These records could help assess environmental trends. DOI is unique in its ability to provide the environmental observation necessary for assessing climate change, including basic environmental research, monitoring, and modeling across multiple scientific disciplines, a wide variety of spatial scales (including satellite-based observations), hundreds of thousands of years of Earth history (for both short- and long-term climate cycles), and short- and long-term processes (e.g., from weather to climate change). This capacity enables DOI to take a national leadership role within the climate science community, including the U.S. Climate Change Science Program. In order to assume this role, however, DOI should consider how to effectively organize and implement its management, budgetary, and scientific assets along a common set of strategic goals formulated across all bureaus within DOI. To meet the challenge, DOI should consider how to develop a coherent science strategy that addresses all elements in the adaptive management cycle and enables DOI managers to address complex climate-related issues at national and local scales.

DOI Science Strategy for Climate Change

Goals and Objectives

The overarching goal of a DOI science strategy for dealing with the impacts of climate change could be to provide accurate, relevant, understandable, and timely information about environmental conditions that helps land and resource managers develop effective mitigation and adaptation strategies to reduce management costs, resource degradation, negative economic impacts, and human hazards associated with climate change. To cost-effectively and rapidly address this national challenge, DOI should consider how to strategically enhance existing capabilities. At the Departmental level, a science strategy could be created with the following objectives:

- to assess and monitor selected indicators to determine the status and trends of ecosystem and resource conditions and to provide an early warning of abnormal conditions;
- to better understand the dynamic nature of climate-induced changes to species, ecosystems, and resources and determine how climate change may dampen or exacerbate the effects of other stressors (e.g., pollution, human water use, and changing land use);
- to improve the capacity for DOI managers to access research and monitoring results and apply those results toward resource decisions, whether at a national, regional, or local level;

---

[1] DOI Secretarial Order 3270, 9 March 2007; mandate for 'Ecosystem Management of Federal Lands,' GAO, 1995

- to provide data to meet climate-related legal and Congressional mandates, such as those related to protecting natural resources and infrastructure and DOI's trust responsibilities; and
- to provide a way to measure progress towards management or policy goals.

Organization and Rationale

Existing Climate Change Science

Through the USGS, DOI is already conducting a significant amount of climate change science across the Nation and throughout the world. This science provides critical research, monitoring, and predictive modeling of information related to our changing climate and its effects on the Nation's landscapes and resources. The knowledge that results from this effort will help policymakers, resource managers, and citizens to make informed decisions about the management of the landscapes for which they have responsibility and on which they live. Current climate models and scenarios do not provide information that most stakeholders need for effective resource or hazard management, and they do not provide information in ways that are accessible to the managers that need that information. While local and regional studies are essential for understanding the processes of physical and biological systems and their responses to climate change, it is cost-prohibitive to conduct rigorous, detailed studies of this type for every square mile of the Nation. A better approach is to monitor and measure changes at a broader scale, and then to relate those observations to the results of detailed, regional-scale studies in a rigorous, reproducible way.

Existing research elements include ongoing work on current and past climate and climate variability. This research uses both direct evidence and proxies in the geologic, cryospheric, and biotic records (i.e., ice cores, tree rings, fossils, sediments, phenology, and other data) to better understand the natural variability of climate and better account for that variability in climate models. Other ongoing research includes analyzing monitoring systems and archives of remotely sensed data to research the magnitudes, rates, and effects of natural and human-induced changes to Earth's surface and systems and to separate and quantify human-induced versus natural change in Earth surface processes. Studies of the carbon cycle, sedimentation rates, and terrestrial and geologic sequestration potential help us develop methods for managing carbon dioxide, a significant greenhouse gas, and this work is continuing in 2008.

Additional USGS activities implemented in FY 2008 include studies aimed at both assessing the processes and cycles among the hydrosphere, cryosphere, biosphere, and geosphere across a wide range of spatial and temporal scales and at measuring and reducing uncertainty in the rates of change in the earth's past climate and past climate variability.

Some elements of a national monitoring network are already in place. These include nationally based monitoring efforts and analysis of trends and change. Ongoing studies in FY 2008 are aimed at understanding ecological and biogeochemical processes in the context of the hydrologic cycle and understanding process responses to small changes in the system. These studies will help to discriminate between natural and human-induced changes; to ensure effective water availability, water quality, and ecosystem management; and to support managers in making informed and effective decisions about water management. Also in 2008, the USGS is developing improved computer models of the global climate system and using regional models to improve understanding of conditions that lead to climatic extremes, the hydrologic hazards that result from those extremes, and regional and global climatic precursors of hydrologic events and hazards.

Land cover is both a driver and a consequence of climate change. It is heavily influenced not only by climate, but also by human activities. Understanding the overall distribution of various types of land cover through time (e.g., forest, agriculture, rangeland, and urban) provides a unique look at the human footprint on the land surface. National-scale work that is continuing through 2008 includes a systematic effort to characterize and quantify the status of the land surface and trends in its changes. This will provide a framework for understanding patterns and processes of change from local to global scales. This work includes the continued development of a national assessment of changes in land cover for the lower 48 States over the past 30 years, using Landsat satellite imagery as the basis for assessing rates, trends, causes, and consequences of change and to define future scenarios of change.

Adapting Climate Change Science to Meet Management Needs

Recent climate models of the ocean and atmosphere predict that in this century there will be pronounced warming of most continental areas, a poleward expansion of the subtropical highs, and a poleward expansion and strengthening of the mid-latitude westerly flow and associated storm tracks. In North America, the warming is projected to be greatest at high latitudes, and except for the southwestern U.S., greatest during the winter season. In conjunction with the projected circulation changes, precipitation is likely to increase in the northeastern U.S. and to decrease in the southwest. The frequency and magnitude of extreme events is expected to change through an intensified hydrologic cycle.

However, the models available have a number of limitations for land and resource managers who need to adapt their management plans for anticipated environmental changes to the areas they manage. The global models are unable to depict the spatial distribution of temperature, precipitation, wind, and clouds in regions with complex topography, complex coastlines, small irregular landmasses, or mixed land use. Therefore, the models are unable to adequately represent important regional- and local-scale atmospheric circulations. Processes that take place in short timeframes, such as the frequency and intensity of precipitation and variability of wind speed, are not well represented. Because of these deficiencies, local climatic changes may be significantly different from the large-area changes. In some cases, local changes may even be in the opposite direction. In short, the models, while robust in many ways, are not adequate to inform DOI resource managers in their efforts to anticipate and adapt for change.

Much of the land managed by DOI is located in complex terrain where climatic parameters (e.g., temperature, precipitation, wind, and radiation) vary rapidly over short distances. There are many issues that are likely to be sensitive to climate change, including coastal erosion, inundation of coastal areas by storm surges, severity and frequency of floods, fluvial erosion, severity and frequency of droughts, insect outbreaks, severity and extent of fires, eolian erosion and frequency of dust storms, air quality, depth and duration of snow pack in mountain areas, stream flow and lake levels, ground-water dynamics, permafrost degradation, melting of glaciers, mass wasting, shifting vegetation patterns, and wildlife migration patterns and range shifts.

To understand the effects of climate change on DOI lands, we need a better understanding not only of the potential changes for various climate parameters at local-to-regional scales, but also of how these projected changes are likely to interact with other important factors affecting physical and biological systems at these scales.

The Components of the DOI Climate Change Science Strategy

In order to meet the DOI Climate Change objectives articulated above, a climate change science strategy could be designed around four major, strongly connected components:

1. **Evaluating Climate-Related Issues and Existing Capacity.** As a first step, fundamental to all other activities, a comprehensive inventory, evaluation, and reorganization of DOI's existing capacity for collecting and interpreting data could be conducted with regard to specific DOI objectives related to climate change. The combined knowledge of the Science Subcommittee members and several recent reports could provide a strong foundation for initiating this activity.
2. **Researching and Monitoring Climate Change Effects.** A nationally integrated program for collecting data could be initiated to establish long-term tracking of climate effects and ecosystem responses to adaptation or mitigation actions. A climate change monitoring network could promote collaborative research, monitoring, and development of science applications for the Nation and could be linked to similar efforts by other nations around the world. The network could provide observational data and interpretive products and could improve our scientific understanding of the rates of climate change and the effects of these changes on natural resources and human infrastructure.
3. **Developing Science Applications and Decision-Support Tools.** Advanced forecasting and downscaled models, applications of science to address specific resource questions (e.g., the vulnerability of species and their habitats), and assessments of model uncertainties would help decision makers to effectively use information, data products, and knowledge.
4. **Integrating, Interpreting, and Disseminating Information**. Decision makers could benefit from a decision-support "roadmap" that would help them (1) access the best scientific data and information, (2) interpret that information, (3) assess those interpretations with on-the-ground knowledge for specific landscapes or resources, and (4) apply the accumulated knowledge toward resource management plans and decisions.

These represent the major components of a strategy that could be used for science-informed planning and decision making, regardless of the topic. The following sections of this report provide a deeper look at each of these strategy components in terms of climate change. For each component, there are three levels of options for implementation, showing how the strategy could be applied depending on the urgency for information and the funds available. In general, Option 1 implements the strategy as quickly as possible nationwide, providing the most comprehensive information and decision-support; Option 2 implements the strategy quickly in a few regions of known climate sensitivity, allowing for implementation on a larger scale over a longer period of time; and Option 3 implements the strategy quickly in ecosystems of immediate concern, allowing for implementation on a larger scale over a longer period of time.

It is important to note that the components are strongly connected, and the options chosen for the earlier components will affect what is possible in the later components. For example, the option chosen for Evaluating Climate-Related Issues and Existing Capacity can limit the choices that can be made (cost-effectively) on all of the proceeding components, and the option chosen for Researching and Monitoring Climate Change Effects will affect the data available for creating decision-support tools.

Role of other Federal Agencies

Many Federal agencies have a role to play in providing climate-related services. The agencies include (but are not limited to) NOAA, NASA, the NSF, and the USDA. NOAA plays a significant role in providing atmospheric, climate, and weather prediction information for regional and other downscaled climate effects studies used by DOI and other agencies. NASA provides significant remotely sensed observations about the status and changes to the atmosphere, hydrosphere, biosphere, and geosphere. The NSF conducts basic, fundamental research and observation that complement the specific monitoring and process-level research conducted by DOI. The USDA also conducts assessments and inventories of its trust forest resources. This work complements the work done by DOI on its areas of responsibility by providing critical information about the way forests respond to climate change and several related forces, including plant disease and insect infestations.

The DOI Climate Change Taskforce will coordinate with these and other Federal and State entities to ensure that the work conducted in climate change science at DOI is complementary to—and not redundant to—the work conducted by other agencies.

Component 1: Evaluating Climate-Related Issues and Existing Capacity

Statement of the Issue

Resource managers and policymakers need information to anticipate and address the effects of climate change, but no single data collection program or method can provide the complete suite of information they need. Before DOI can combine the capabilities of multiple programs, however, it needs a systematic assessment of what each existing program measures, how and when those measurements are made, and whether the measurements of each program can be meaningfully compared to the others.

Description of the Issue

DOI agencies have a long history in which they have built significant expertise and infrastructure for tracking, understanding, and managing the effects of climate change on DOI resources and responsibilities. This legacy, and DOI's experience in providing the Nation with real-time information on natural hazards, gives DOI a strong starting point for building a national network for climate change research. A history of successful partnerships with other Federal agencies, States, academic institutions, and non-profit organizations could be leveraged to further expand on existing capabilities. However, DOI could benefit from a better understanding of existing resources and capabilities for studying and responding to climate change, as well as an assessment of where existing capabilities may be insufficient to meet research, monitoring, or management objectives.

The Land and Water Management and Legal and Policy Subcommittees of the DOI Climate Change Task Force have developed lists of specific science needs of resource managers and policymakers. These needs are fundamental to the creation of new research and monitoring objectives and could be used as benchmarks for assessing existing capabilities and deciding which gaps in capability need to be filled.

A hierarchical framework for categorizing types of data collection programs was devised in the mid-1990s that can both define existing capabilities and reveal what new capabilities are needed to address specific issues. The same conceptual design was developed by several monitoring programs over the past 20 years, but was never fully implemented because of funding constraints. Establishing the complete framework would help to address the multi-scale, multi-process complexity of climate change effects. A detailed description of this Collaborative Observation and REsearch (CORE) framework is presented in Appendix 1.

Evaluating existing capacities and objectives is a critical first step in designing and implementing options for the following three components in a cost-effective manner. It is important to note that the option chosen for this component can effect the options available for the other components.

Options for Implementation

Option 1: Conduct a National Inventory. Conduct a national inventory of climate change research sites and monitoring stations and associated data and data products. Analyze data gaps for addressing significant climate effects questions.

Option 2: Conduct Multiple Regional Inventories. Conduct multiple regional inventories of climate change research sites and monitoring stations and associated data and data products. Analyze data gaps for addressing significant climate effects questions.

Option 3: Conduct Inventories at Ecosystems of Immediate Concern. Focus on ecosystems of immediate concern to conduct inventories and analyze data gaps for addressing significant climate effects questions.

Analysis of the Options

Option 1: Conduct a National Inventory. DOI could conduct a national inventory of climate change research sites and monitoring stations and associated data and data products, and then analyze gaps in data for addressing significant climate effects questions. A national inventory would provide a national assessment of infrastructure and ecosystem vulnerabilities, existing data archives, collection capabilities, and dissemination services, allowing for a complete analysis of gaps in DOI's national capabilities.

This assessment could include the following steps:

- Analyze current DOI and other Federal agencies' capabilities for collecting and assessing scientific data related to a changing climate. This step could include an assessment of what adjustments would be necessary to facilitate the integration of data with that of other programs to address specific climate-related issues.
- Analyze capability for gathering data on anticipated key indicators of climate effects (e.g., air and water temperature, sea-ice thickness and extent, forest health, and species distribution and population levels) that DOI observation and research programs could focus on for sampling and measurement. These indicators could be categorized as first-order indicators measured at all DOI sampling and measurement stations (e.g., temperature), second-order indicators measured at least at all high-priority research areas (e.g., streamflow), and third-order indicators measured to address unique local issues at specific locations (e.g., active layer thickness in permafrost). Information on a framework for determining key indicators is provided in Appendix 1.
- Analyze database management capabilities within and outside of DOI for compiling and interpreting information on the effects of climate change, and for easily disseminating that information to scientists, resource managers, policymakers, and the public.
- Inventory the decision-support systems and tools that are being used or developed across DOI, other agencies, and academia, as well as the efforts and strategies being used to quantify and communicate the uncertainties within observational datasets. This inventory would include an assessment of the quality and usefulness of the uncertainty assessment methods being used. Assessing the usefulness of such tools in addressing DOI management and policymaker needs should be performed immediately.
- Complete a gap analysis to determine what observation and research capabilities are missing from existing DOI programs that could help DOI address climate change issues. This analysis could be used to determine where DOI could enhance existing programs for collecting and analyzing data, where DOI could benefit from collaborative partnerships, and/or where DOI could establish new programs to fully implement a DOI climate change research and monitoring network. As part of this step, DOI could analyze resource management and policy issues potentially affected by climate change and determine locations where change appears to be rapid and significant but our understanding of the effects on resources, ecosystems, and socio-economics is poorly developed. This analysis could serve as a roadmap for the initial development of a DOI climate change research and monitoring network.

Conducting a national inventory could serve as crucial ground work for cost-effective implementation of a national research and monitoring network (Component 2), a national capacity for science applications and decision support (Component 3), or a national capacity for integrating, interpreting, and disseminating information (Component 4).

Option 2: Conduct Multiple Regional Inventories. DOI could conduct multiple regional inventories to develop an understanding of our capabilities. The national assessment could then be completed incrementally over time. Regional inventories would provide an assessment of the vulnerabilities, capabilities, and services of specific regions of known climate sensitivity. However, DOI capabilities outside of the chosen regions would remain undocumented and could result in more costly adaptation or mitigation of climate change effects.

Option 3: Conduct Inventories at Ecosystems of Immediate Concern. DOI could focus on a few discrete locations of interest, ecosystems of immediate concern, rather than undertaking a complete national assessment of DOI capabilities. These local inventories would provide an assessment of the vulnerabilities, capabilities, and services in locations where climate change is known to be rapidly impacting the ecosystem. The tradeoff of this option is that it would overlook important existing capacity that is not present in the locations assessed and in the long run could lead to a greater start-up expense than could otherwise be achieved. Additionally, this would not support decision making outside of the inventoried areas, it could be difficult or impossible to cost-effectively implement the other components beyond the inventoried areas, and it could result in more costly adaptation or mitigation of climate change effects.

An overview of the options for all four components is presented in Table 1 on page 22.

Component 2: Researching and Monitoring Climate Change Effects

Statement of the Issue

DOI land and resource managers need on-the-ground and up-to-date information about the effects of climate change that they can relate to the units they manage. In order to develop a complete picture of how climate change is affecting our ecosystems, resources, and infrastructure, DOI needs data at both local and national scales. A multi-scale observation and research network could be designed and implemented for tracking, understanding, and responding to the effects of climate change on the Nation's natural resources and ecosystems. Through collaborations among Federal, State, and international data collection programs, such an integrated monitoring and research program could provide the Nation with an early-detection system for addressing changes before they become chronic or catastrophic conditions.

Description of the Issue

In designing a network for researching and monitoring the effects of climate change, it is important to consider the many resource-management and policy issues raised by the task force subcommittees on Land and Water Management and Legal and Policy and the science objectives required to address those issues. Climate change poses many questions to land and water managers:

- How, and in what proportion, are climate-related and non-climate-related factors determining sea-level rise and the salinity of coastal salt marshes, and how are the observed salinity changes altering the ability of marsh vegetation to protect shorelines and near-shore infrastructure from erosion?
- How is climate change affecting the distribution of permafrost in areas critical to sustaining northern ecosystems, resources, and human infrastructure?
- How is climate change influencing forest structure and forest fire dynamics in the western mountains? How well, and with what accuracy, can regional and finer scale climate models account for observed changes in weather patterns and associated ecological responses?

- How are key indicator species responding to environmental stressors, including climate change, and what do these responses imply about DOI's ability to meet legal mandates to manage trust resources?

DOI would benefit from a systematic way to provide managers with the science to address such questions.

To effectively address the effects of climate on the Nation's resources, existing and new data collection capabilities would need to be integrated into a national system. This integration could be initiated incrementally, beginning in regions with the most urgent need for baseline information, and then expanding to a national scale.

A DOI Climate Effects Network (CEN) for collaborative, long-term investigation, monitoring, and applications testing for climate effects could be created to build a national capacity for researching and monitoring the effects of climate change. Such a network could bring together the following:

- a few focus areas in which multidisciplinary studies and monitoring would be used to determine the key factors that control how resources or ecosystems respond to shifts in climate;
- more numerous study sites designed to assess these responses across climatic gradients (e.g., warm to cold, wet to dry);
- regional and national surveys (multiple, widely-distributed measurement sites) of environmental conditions to link the understanding developed in the focus areas to the issues being addressed at local, regional, and national levels;
- new remote-sensing tools for cost-effective tracking of environmental change from space; and
- models of ecosystem processes for interpreting these integrated, multi-scale, and multi-component datasets and for providing scientifically defendable management decision tools that both accelerate and improve our ability to respond to resource management and policy needs (see Component 3).

This network, the chosen sites, and the key indicators measured could be designed according to the Collaborative Observation and REsearch (CORE) strategy outlined in Appendix 1.

Options for Implementation

Option 1: Create a National Climate Effects Network (CEN). Create a multi-scale, multi-disciplinary monitoring and research network including 6 to 10 CORE watersheds, multiple surveys, and remote-sensing tools that provide a national synthesis of climate impact information needed for effective adaptation and mitigation actions.

Option 2: Create a Regionally Focused National Climate Effects Network. Create a monitoring and research network including three to six CORE watersheds, multiple surveys, and remote-sensing tools that provide regional synthesis of climate impact information needed for effective adaptation and mitigation actions.

Option 3: Create a National Climate Effects Network Focused on Ecosystems of Immediate Concern. Create a monitoring and research network including two CORE watersheds, multiple surveys, and remote-sensing tools that provide sub-regional climate impacts information needed for effective adaptation and mitigation actions in ecosystems of immediate concern.

Analysis of the Options

Option 1: Create a National Climate Effects Network (CEN). The following set of actions could be used to establish a robust scientific analysis and early warning system for assessing climate effects on DOI lands, resources, and responsibilities:

- Establish focus areas in 6 to 10 medium- to large-scale watersheds that represent major ecosystem types in the United States. These watersheds could be selected where multidisciplinary data collection could take place to determine the key factors controlling how the ecosystems respond to climate change. The study area boundaries of these Collaborative Observation and Research (CORE) Watersheds would likely be delineated along watershed divides as a common geographic frame of reference so that measured exchanges of energy (e.g., solar energy input and heat released back from the land), water (e.g., precipitation input and runoff and evaporation output), and chemical (e.g., carbon uptake by plants and carbon export from soil erosion) can be used to test ecosystem model results.

  For example, the United States can be conceptually divided into 13 ecoregions (i.e., 13 different areas where ecosystem processes might be influenced by climate change in different ways). In establishing at least six CORE watersheds that represent the ecoregions with the greatest potential for change, each CORE watershed would likely include more than one ecoregion. This also assumes that some ecoregions will not be fully represented within the network; the scientific assumption is that the processes observed at the CORE sites would be sufficiently similar to those in the unrepresented ecoregions that data from the survey monitoring would be adequate to represent changes in those areas.

- Develop partnerships and protocols for integrating existing research stations to serve as indicator sites that represent a gradient of conditions (e.g., warm to cold, wet to dry) for specific high-priority climate change issues. These gradient study sites (CORE gradient) would likely measure a subset of the CORE watershed variables that are pertinent to the specific issue.

- Integrate and enhance existing regional-, national-, and continental-scale surveys and inventories of climate effects. A subset of the indicator variables measured in the CORE watersheds and CORE gradient sites could be measured at the survey and inventory sites. By using the extensive datasets (CORE surveys) developed through these measurements, the understanding developed at the CORE sites could be extrapolated to the scales where policy and management decisions are made.

- Develop and integrate remote-sensing capabilities for key indicators of climate effects (CORE imagery) through collaborations within and outside of DOI. Improving existing tools and creating new tools through use of the CEN observation stations could serve as a rigorous and consistent ground-truthing network for remotely-sensed data.

See Appendix 1 for more information on establishing the CORE framework.

The challenge for the DOI would be to determine how to build upon, more effectively use, and enhance existing networks and programs to better meet national and regional requirements for environmental information. Collaboration would be the most cost-effective strategy for building the CEN. In each of these steps, DOI could engage existing stakeholders (e.g., the public, other Federal agencies, and the scientific community). In developing models, DOI could seek to capitalize on existing efforts to monitor climate change, expand efforts as needed to set parameters and discriminate among climate change models, and facilitate the synthesis and exchange of data among land management agencies, policymakers, and the scientific community.

Option 2: Create a Regionally Focused National Climate Effects Network. DOI could initiate the CEN at key regional sites and enhance its climate change research and monitoring capabilities in areas of known climate sensitivity. Three to six watersheds could be used to represent northern, mountain and desert west, and coastal and tropical systems. By initiating the network with a focus on studying regions of known climate sensitivity, DOI could gather a range of data that could be sufficiently similar to inform decisions in similar areas. A full national capacity, with a more expansive representation of ecosystems, could be developed over time.

The tradeoff for initiating the network with a regional focus would be a greater potential for not observing and preparing for a change until it has become a significant hazard or chronic resource disturbance. Among the science community, it is generally accepted that anticipated climate changes will have at least some effect on ecosystem function, resource sustainability, and natural hazards. The primary tradeoff in reducing the scope of observation and research would, therefore, be that resource managers and policy makers may experience a larger number of circumstances in which reactive management is required, the period available for response is shorter, and the basic understanding required to differentiate between effective and non-effective management options is less developed.

Option 3: Create a National Climate Effects Network Focused on Ecosystems of Immediate Concern. DOI could initiate a monitoring and research network with two CORE watersheds, multiple surveys, and remote-sensing tools that provide sub-regional climate impacts information needed for effective adaptation and mitigation actions where climate change impacts are rapidly affecting the ecosystem.

This option would allow DOI to test the national network concept and gather data on ecosystems of immediate concern. Additional capacity could be developed over time.

Additional Considerations for Implementation

DOI could also reduce the costs of implementation by decreasing the number of indicators measured in CORE surveys or CORE imagery or by decreasing the resolution (number of samples or pixels) in those datasets. Optimizing the number of sampling points could be achieved after analyses of the initial surveys and imagery are completed under the chosen plan.

Whichever implementation option is chosen, the initial CORE watershed could be the Yukon River Basin, where rapid climate-related changes are occurring now and our capacity to describe and prepare for those changes requires immediate attention. For example, Interior Alaska could be considered an ecosystem of immediate concern for the following reasons:

- Permafrost in interior Alaska and Canada is near 0^{o}C (32^{o}F) and is already thawing and collapsing in many locations, dramatically altering fish, bird, and ungulate (hoofed mammal) habitat.
- Interior Alaska contains large carbon stores that are vulnerable to being emitted to the atmosphere or exported to the Bering Sea if thawing or erosion occur.
- The occurrence and size of fires in the Yukon River Basin appear to be intensifying, consequently accelerating carbon release, permafrost thaw, and habitat disturbance.
- Both fire and permafrost thaw will cause significant disturbance to regional ecosystems and challenge the sustainability of indigenous cultures.
- The sensitivity of the Polar Regions' frozen soil organic matter to decomposition upon thawing is poorly understood, yet that decomposition could significantly alter global climate models.
- Eight Wildlife Refuges, three National Parks, and numerous BLM land holdings in this area are changing rapidly as warming continues, and no adaptation strategies have been developed.

The remaining sites, and an amendment of the Yukon CORE watershed to include the Alaskan North Slope, could be phased in over a multi-year period depending on the availability of funds and the priority for data collection. Selection of the remaining CORE watersheds could be completed in the first year by a scientific task force.

An overview of the options for all four components is presented in Table 1 on page 22.

Component 3: Developing Science Applications and Decision-Support Tools

Statement of the Issue

DOI managers need science that applies to their management units and the decisions they have to make. Assessing the regional or local effects of climate change requires advances in forecasting climate change effects and downscaling global models to the regional or finer scale; the ability to assess which species, habitats, ecosystems, etc., are most vulnerable to rapid and long-term change; and understanding and applying estimates of uncertainty to planning and decision making. A Department-wide, systematic approach to developing science applications and decision-support tools could help to ensure that resource decisions are informed by the best available methods for forecasting and analyzing the effects of climate change.

Description of the Issue

In making decisions related to climate change, applied science could be critical in helping DOI managers accomplish the following:

- identify trends in ecosystem, resource, or hazard conditions;
- identify existing, emerging, and future problems, preferably with sufficient time and accuracy to manage them;
- define critical interactions between and dependencies among ecosystem parameters and species;
- separate the probable from the possible;
- quantify, characterize, and communicate the uncertainties in model results and the risks for greater disturbance to an ecosystem if specific threshold conditions are exceeded;
- separate the impacts of climate change from, and place them in the context of, other human-induced factors and natural variability;
- identify gaps in science, data, and information; and
- estimate the value of waiting (or not waiting) for additional research results in order to reduce the risk and uncertainty of adaptation or mitigation actions.

In order to build DOI's capacity for supporting decisions with science, observational monitoring needs to be integrated with the results of science research (i.e., data, interpretations, model projections, and information). For example, a DOI capacity for developing science applications and decision-support tools could include the following:

- **Improved climate forecasting.** DOI could improve climate forecasting, hindcasting (i.e., testing of models using past events), and data analysis methods, and then incorporate these improvements into the methods that DOI managers use to monitor and manage resource health. The most common tools for analyzing climate are global climate models and models that predict future climate variation by applying climate scenarios from historical or paleo-climate records.
- **Downscaled models.** DOI could scale climate models down to levels that are useful for managing resources. Complementary research could examine the uncertainties of the downscaled models and how these uncertainties could affect the decision-making process.
- **Assessing vulnerabilities.** DOI could identify, through vulnerability analysis, those areas where forecasting of future climate conditions is most critical, and then invest the necessary resources to identify and use the best available projections for decision making.
- **Analyzing risks and uncertainty and impacts on decision making.** DOI could strengthen its efforts to characterize uncertainty in its models of climate and environmental changes that result from natural and human-caused stresses on ecosystems.

- **Developing standards.** Standard methods for quantifying uncertainties of data and models could be required and tested. For observational data, methods published by the National Institute of Standards and Technology are accepted throughout the science community and should be used, where available and appropriate, for research undertaken by DOI.
- **Developing options.** DOI could develop options for scientific, economic, and social adaptation and/or mitigation strategies for DOI and other resource managers to apply in the protection of trust resources, infrastructure, and ecosystem or cultural sustainability. To ensure that the scientific products are ultimately pertinent to the end-user, instruction on how to use the decision-support tools could be provided and scientists, resource managers, and policymakers could continue to discuss and transfer information about the tools. Even when the likelihood of adverse changes is uncertain, many types of management actions are still appropriate and warranted. DOI could develop guidance for making decisions under conditions of uncertainty.
- **Examining scenario analysis as a decision-support tool.** The Department of Energy, as part of their leadership of the Nation's Climate Change Technology Program, has developed a robust Scenario Analysis Decision Support Tool for looking at the impact of climate change on energy resources over 100-year time scales. There has been significant research already completed on the adequacy of Scenario Analysis and its usefulness in supporting decisions. DOI could examine what has been accomplished by this program and recommend to managers and researchers how this may or may not be useful in their decision-making process. There is also a significant body of research funded through the National Science Foundation on the application and adequacy of Scenario Analysis as a decision-support tool. This information could be synthesized and communicated to managers and researchers at all levels of DOI.

The systems engineering framework (Figure 3), an adaptive management approach, has been used successfully by other Federal agencies to apply science and develop decision-support tools.[2] This structured approach may not be flexible enough for the many agencies that make up DOI, but it provides a conceptual view of the transition from the research to the application of science for societal benefits.

[2] See http://aiwg.gsfc.nasa.gov for more information on this systems engineering framework approach, the approach being used by NASA's Earth Science Division in the Applied Sciences Program for transitioning research results to the mission of partner operational agencies.

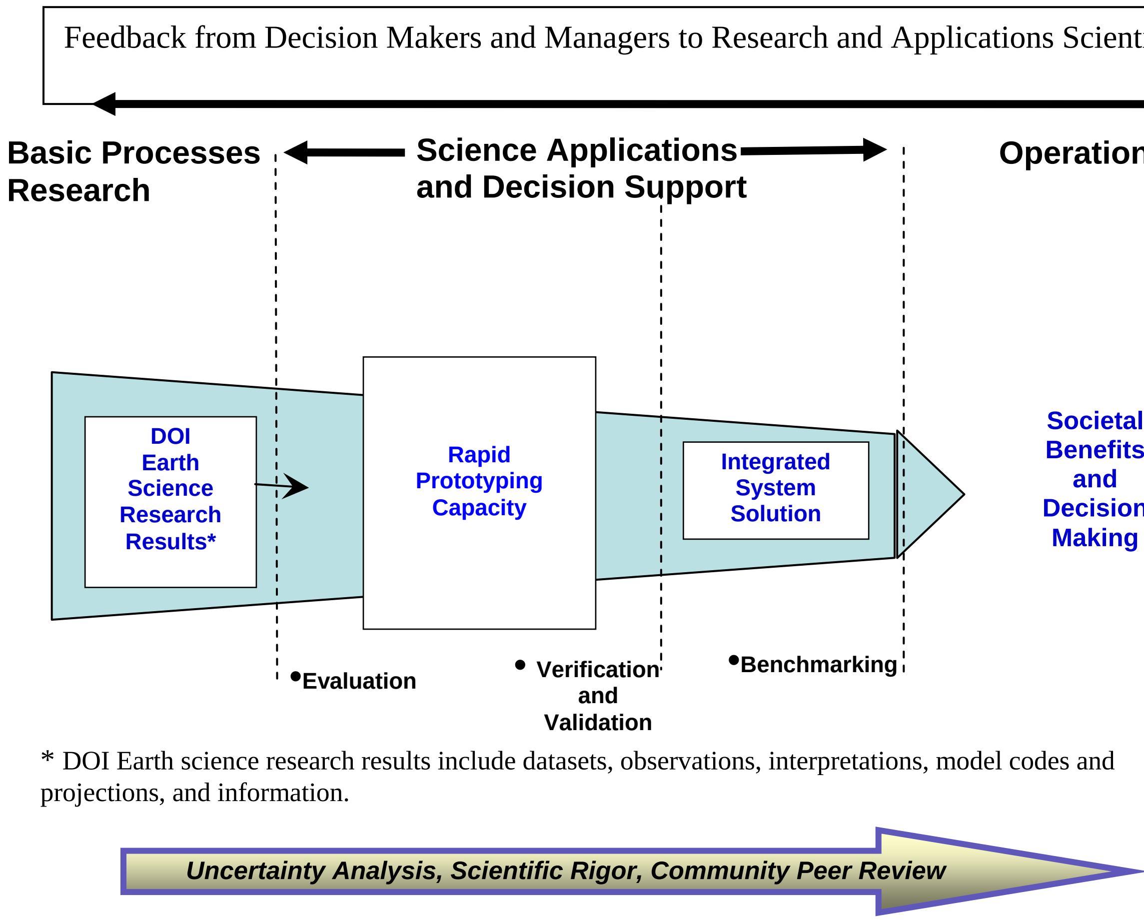

Figure 3. Diagram for moving from research results to operations that support decisions.

The credibility and effectiveness of the decisions made in response to climate change will depend not only upon development of quality datasets, but also upon vigilance in validating and improving models, quantifying the uncertainty of the projections, and adjusting the decision-support tools and recommendations in light of changing conditions. As DOI works to advance forecasting capabilities and deal with the uncertainties of climate change, it would benefit from a robust system for testing the validity of scientific results and the effectiveness of management decisions. As science applications and decision-support tools are developed, there are many questions that such a system could address:

- How can DOI build confidence in the results of the science and the applications it feeds?
- How do we ensure that ineffective or costly decisions can be corrected in light of future research results, data trends, science information, and decision-support tools?
- Can a set of criteria be established for determining the benefits of waiting for additional data, information, and research results in order to make more robust decisions?
- How are future conditions forecast to support planning for climate change?

The potential scope of science applications and decision-support tools will be limited by the options chosen to implement Components 1 and 2. For example, the applicability of models, forecasts, and other tools will be limited to areas that are sufficiently similar to the locations where climate change data is collected.

Options for Implementation

Option 1: Develop a DOI National Science Applications and Decision-Support Team. Create a Science Applications and Decision-Support team with modeling experts and social and economic scientists that would be on-call for managers. Create and implement a decision-support toolkit tailored to managers' needs with customized strategies, tactics, and methods for mitigation and adaptation responses. Include in-house and on-site delivery mechanisms. Provide national decision-support tools based on the scientific data collected in the observational network, data and interpretations, and application of research results.

Option 2: Develop National Science Applications and Decision-Support Capacity. Create and implement a decision-support team that relies heavily on partnerships to develop social and economic science capabilities. Provide a toolkit tailored to meet managers' needs and provide decision-support tools.

Option 3: Develop Science Applications and Decision-Support Tools for Ecosystems of Immediate Concern. Provide decision-support tools for ecosystems of immediate concern on an ad-hoc basis.

Analysis of Options

Option 1: Develop a DOI National Science Applications and Decision-Support Team. DOI could create a Science Applications and Decision-Support team with modeling experts and social and economic scientists that would be on-call for managers at all levels as a resource for making decisions. This team could begin to identify both those areas where we are not meeting the needs of decision makers and priority areas for developing science application models and tools to meet management and policy requirements.

This team could help in validating and improving models, quantifying the uncertainty of the projections, and adjusting the decision-support tools and recommendations in light of changing conditions. Significant progress in this realm has been accomplished by applications teams outside of DOI, and to minimize cost, the DOI team could collaborate with and leverage existing efforts and resources.

This team could prioritize and expand the climate change research and science applications that DOI is funding and participating in, especially those that examine the impacts and consequences of climate and environmental change and the implications those changes could have for policy and decisions. As an example, DOI does not currently fund any projects that concentrate on characterizing, communicating, and applying uncertainty from research results to support decisions.

This team could also coordinate the transition of science research results to actions, with a focus on developing decision-support tools. This development would include, but not be limited to, computer-based tools that link datasets, interpretations, model projections, and real-time observations within user-friendly decision-support software. It would be critical to include the decision makers and managers in all stages of developing these tools.

Establishing a team for developing science applications and decision-support tools could be an important component of turning research results into actions that managers can take to deal with the effects of a changing climate.

Option 2: Develop National Science Applications and Decision-Support Capacity. DOI could create a decision-support team that relies heavily on partnerships to develop social and economic science capabilities. As this team helps to create and implement a decision-support toolkit tailored to meet managers' needs and provide decision-support tools, it could initially focus on regions of known climate sensitivity. For areas covered by the Climate Effects Network, the team could provide customized strategies, tactics, and methods for mitigation and adaptation responses. Generic strategies, tactics, and methods could be created to help those outside of study areas to apply and use climate change information.

Option 3: Develop Science Applications and Decision-Support Capacity for Ecosystems of Immediate Concern. DOI could initially focus on providing science applications and decision-support tools for the ecosystems of immediate concern. Generic strategies, tactics, and methods could be created to help those outside of the study areas apply and use climate change information.

An overview of the options for all four components is presented in Table 1 on page 22.

Component 4: Integrating, Interpreting, and Disseminating Information

Statement of the Issue

Dealing with the effects of climate change is a broad issue that crosses jurisdictional boundaries. To develop the most efficient and effective adaptation and mitigation solutions, on-the-ground information will need to go up, global modeling will need to be scaled down, and information at all levels will need to be integrated, interpreted, and disseminated.

Description of the Issue

DOI could use a core capacity for disseminating climate change information across the bureaus. While current science on the effects of climate change can give us some idea of the most vulnerable habitats and systems, this information is not widely available in a form that decision makers can understand and use. And, as in all aspects of resource management, our knowledge is incomplete. Since the impacts of climate change will be seen across landscapes and jurisdictional boundaries, to preserve the essential elements and services of the systems DOI is charged to protect, effective resource management should go beyond conservation of individual jurisdictions.

Decision makers could benefit from a decision-support “roadmap” that would help them access the best scientific data and information, interpret that information, assess those interpretations with on-the-ground knowledge for specific landscapes or resources, and apply the accumulated knowledge toward resource management plans and decisions. DOI would benefit from a central capacity that provides decision makers across the Nation with the following:

- ***Data and data products.*** Access to inventories of existing data, models, and other data products that explain how the information can be used in terms relevant to managers; and easy access and documentation of new data and products.
- ***Analysis and synthesis.*** Access to impact and vulnerability assessments of DOI lands and resources that serve as a precursor for the decision-making process; summaries and other products (e.g., technical and briefing materials) on key resource issues that come with quality assurance and consistent messages. Information that is be spatially explicit and systematically organized so that it is relevant both biologically and geographically.
- ***A process for using information.*** A process to bring data and scientific information together with field-level needs to develop management solutions, including options and support for adaptation and mitigation efforts (e.g., efforts to reduce DOI’s carbon footprint, use green facilities, establish climate-friendly operational guidelines, plan for climate change scenarios, and establish best management practices).
- ***A mechanism for disseminating information.*** Reliable access to interdisciplinary teams and ongoing participation in knowledge/action partnerships; interagency training for applying knowledge to specific on-the-ground situations, delivered remotely (e.g., web, telecommunications), in-house (e.g., classrooms) and/or on-site (e.g., place-based mobile modules).

DOI will need to work together across bureaus to successfully respond to the challenge of climate change in the context of other stressors affecting natural resources. Without a mechanism for coordination and integration, we lose the opportunity to collectively identify knowledge gaps, share information, and develop consistent policy and adaptation responses.

The potential scope of this capacity will be affected by the implementation options chosen for Components 1–3. With limited data collection and limited applicability of models and decision-support tools, the information available for integration, interpretation, and dissemination will also be limited. However, the scope of implementation of this component could serve to bring in additional data from outside of DOI, expanding and enhancing the amount and applicability of information available to DOI decision makers.

Options for Implementation

Option 1: Establish a National Interagency Climate Change Science and Learning Center. Create a national center of excellence for integrating science data collection, data interpretation, and applications development. Provide decision-support tools across DOI bureaus by disseminating through regional support staff.

Option 2: Establish a Central Office for Integrating and Disseminating Information. Create a central office for integrating and disseminating climate change information relying on science and applications capabilities across the bureaus.

Option 3: Develop a Central Capability for Integrating and Disseminating Information. Develop capability for integrating and disseminating climate change information that enhances interaction and response among and disseminates information beyond the investigators.

Analysis of the Options

Option 1: Establish a National Interagency Climate Change Science and Learning Center. An Interagency Climate Change Science and Learning Center would allow DOI to build and maintain a core capacity for responding to climate change across the bureaus, as well as with other climate change science agencies, partners, and stakeholders. A national center could provide a venue for sharing and integrating data and information and applying that information to on-the-ground problems. By engaging resource managers directly in the development of adaptive management strategies, a national center could also provide a venue for capturing local manager knowledge.

DOI has tools and programs in place that are helping DOI agencies work together to find solutions to complex issues and make DOI land management more efficient. For example, DOI currently manages fire through a coordinated interagency response center, the National Interagency Fire Center, which provides a useful model for managing landscape-scale resource issues. The fire center is staffed by national fire management staff of four DOI agencies, the U.S. Forest Service, the National Weather Service, and other Federal cooperators. It was established as the coordination center for resource distribution to address wildland fire and other fire-related issues throughout the United States. While it still serves this function, fire center agencies also develop agency and Departmental fire management strategies and related policy. Bureaus are responsible for interagency procedures, qualifications, and training for fire suppression, incident business management, aviation operations, fuels management, fire reporting, and fire planning. The fire center maintains national resources such as the Remote Automated Weather Station network; hosts the Joint Fire Science Program; and maintains a national Web site for current fire information, statistics, and public education about living in a fire environment. Through the fire center, the Federal government has saved taxpayer money, increased efficiency for fire management and incident response, and engaged in mutual learning among bureaus, the public, and specialists.

DOI has the opportunity to emulate the success of the fire center model by implementing an Interagency Climate Change Science and Learning Center that would enhance the knowledge and response capability of resource managers for coping with climate change. Such a center could have the following features and capabilities:

- ***A central location*** for accessing information, exchanging knowledge, and building effective response strategies. The center could serve as a central conduit and interface for decision-support tools, training opportunities, data management, science applications development, and science coordination. The center could be the “go to” place where managers and staff find the information and expertise they need.

- ***Staffing by each bureau*** according to their needs with new, permanent, full-time employees. For most bureaus (USGS, NPS, FWS, BOR, BLM, MMS, and BIA) this would entail 5 to 15 personnel. Staff would also include other climate science agencies and partners (i.e., the USDA Forest Service, NASA, EPA, NOAA, DOE, and others).
- ***Knowledge “center of excellence”*** hosted at a university or institution that conducts climate change research. This center of excellence could leverage the host institution’s intellectual capacity (e.g., graduate students, post-docs, and professors) and support services (e.g., administration, libraries, and archives) as well as the resources of the participating agencies. A combined staff of multidisciplinary experts could engage science partners, provide inventories of existing and needed science data and information, and respond to field-level needs. The center could have the following components of key functionality and staff knowledge, skills, and abilities:
  - *Climate change science capability*. The center could serve to identify and coordinate Departmental science needs and priorities and provide a link to the broader scientific community. Science staff expertise would represent key ecoregions and include landscape and wildlife ecology, hydrology, geomorphology, oceanography, fire ecology, soils/watersheds, plant ecology, modeling, monitoring, natural resource management programs and techniques, economics, and social science. It would link and provide continued feedback between field users and science developers.
  - *Information integration and technology capacity.* The center could use technology to bring climate change science data and information together to support the needs of DOI land managers and decision makers. Center staff would synthesize climate change science and application results in a form that field managers—who are addressing the effects of climate change on natural resources at the landscape and site-specific level—could readily use. Staff (which would include technical specialists in GIS and remote-sensing applications and geo-database development and management) would provide field assistance with GIS data and related applications, identify information and techniques that are appropriate for on-the-ground situations, and link monitoring and modeling efforts to field-level needs.
  - *Communication and visualization capacity*. The center could develop products that communicate and show the impacts of climate change impacts on DOI lands. Staff could develop communication packages that carry consistent messages and are delivered through a range of technologies and media (e.g., briefing and technical papers, interactive Web sites, and visual presentations). Center staff would possess experience and skill in technical writing, desktop and online publishing, and oral communication.
  - *Decision-support capability*. The center could provide managers with practical tools for developing, evaluating, and implementing mitigation and adaptation strategies. Center staff would develop applications, provide support and guidance for planning and implementation, and provide training for managers and staff using

remote, in-house, and on-site methods and technologies (with responses tailored to the needs of the field). To support this function, staff could have expertise in GIS; skills for interpreting and integrating science; knowledge of adaptive resource management, risk management, and decision analysis and support; and experience in application of science to field-based management decisions.

- *Learning community approach.* The center could take a learning community approach that emphasizes team knowledge sharing and “many-to-many” communication that assumes all participants are teachers as well as learners. The center would fundamentally be a service center that listens and learns. This approach would make a significant effort to address landscape-scale issues (e.g., species migration and range shifts, potential loss of biodiversity and other services provided by an ecosystem, and hydrological changes) that affect multiple jurisdictions and require collaboration across the bureaus.

Options for building the Interagency Climate Change Science and Learning Center vary in the level of staffing, depth and breadth of capacity, and the timeframe for implementation. The Interagency Climate Change Science and Learning Center would be a proactive approach that could build on our collective strengths, lessen our vulnerabilities, and increase our efficiency and effectiveness.

Option 2: Establish a Central Office for Integrating and Disseminating Information. DOI could create a central office for integrating and disseminating climate change information, relying on science and applications capabilities across the bureaus. This reduced central capability would enhance regional interaction and response and provide a common vision for data and information integration and dissemination across DOI. The primary tradeoff in not establishing a physical center would be reduced opportunity for ongoing and collective interaction and integration across the bureaus. Bureaus would either develop their own approach, in piecemeal fashion, or not develop a capacity for effectively managing resources in the face of climate change. This could result in an inconsistent and fragmented response within DOI and could lead to more costly adaptation and mitigation.

Option 3: Develop a Central Capability for Integrating and Disseminating Information. DOI could establish a central capability to integrate and disseminate information on climate change that enhances interaction and response among and disseminates information beyond the investigators. The primary tradeoff is lack of interaction and integration across the bureaus. Bureaus may develop their own approach, in piecemeal fashion, or not develop a capacity for effectively managing resources in the face of climate change. This could result in an inconsistent and fragmented response within DOI and could lead to more costly adaptation and mitigation.

An overview of the options for all four components is presented in Table 1 on page 22.

Options Summary

A DOI science strategy for dealing with the impacts of climate change could include four major components: an evaluation of capabilities; research and monitoring; applied science for making decisions; and a system to manage, analyze, and disseminate information. This table shows the associated benefits and drawbacks for three levels of options for implementing such a strategy.

Table 1. Summary of benefits and drawbacks for component options.

<table>
<tr><th>Component</th><th colspan="2">Implementation Options</th><th>Benefits</th><th>Drawbacks</th></tr>
<tr><td rowspan="3">Component 1: Evaluate Climate-Related Issues and Existing Capacity</td><td>Option 1</td><td>Conduct a national inventory of climate change research sites and monitoring stations and associated data and data products. Analyze data gaps for addressing significant climate effects questions.</td><td>A national assessment of infrastructure and ecosystem vulnerabilities, existing data archives, collection capabilities, and dissemination services. Allows a complete analysis of gaps in DOI's national capabilities.</td><td>Higher initial funding investment.</td></tr>
<tr><td>Option 2</td><td>Conduct multiple regional inventories of climate change research sites and monitoring stations and associated data and data products. Analyze data gaps for addressing significant climate effects questions.</td><td>Assessment of vulnerabilities, capabilities, and services of specific regions of known climate sensitivity.</td><td>Cannot cost-effectively implement Option 1 of Components 2–4. DOI capabilities outside of the chosen regions remain undocumented. May result in more costly adaptation or mitigation of climate effects.</td></tr>
<tr><td>Option 3</td><td>Focus on ecosystems of immediate concern to conduct a local inventory. Analyze data gaps for addressing significant climate effects questions.</td><td>Assessment of vulnerabilities, capabilities, and services in specific study areas of known climate sensitivity.</td><td>Cannot cost-effectively implement Option 1 or 2 of Components 2–4.Does not support decision making outside of the study areas.</td></tr>
<tr><td rowspan="2">Component 2: Researching and Monitoring Climate Change Effects</td><td>Option 1</td><td>Create a multi-scale, multi-disciplinary monitoring and research network including 6–10 CORE watersheds, multiple surveys, and remote-sensing tools that provide a national synthesis of climate impact information needed for effective adaptation and mitigation actions.</td><td>Rapid development of a national Climate Effects Network (CEN) with extensive capabilities.</td><td>Substantial initial and ongoing investment of funds and personnel.</td></tr>
<tr><td>Option 2</td><td>Create a monitoring and research network including 3–6 CORE watersheds, multiple surveys, and remote-sensing tools that provide regional synthesis of climate impact information needed for effective adaptation and mitigation actions.</td><td>Rapid development of capability within specific regions of known climate sensitivity.</td><td>Data will be limited to ecoregions studied. Limited data available for Components 3–4.</td></tr>
</table>

Component		Implementation Options	Benefits	Drawbacks
Researching and Monitoring Climate Change Effects	Option 3	Create a monitoring and research network including 2 CORE watersheds, multiple surveys, and remote-sensing tools that provide sub-regional climate impacts information needed for effective adaptation and mitigation actions in ecosystems of immediate concern.	Testing of national network concept in ecosystems of immediate concern	Data will be limited to ecoregions studied. Limited data available for Components 3–4.
Component 3: Developing Science Applications and Decision-Support Tools	Option 1	Create a Science Applications and Decision-Support team with modeling experts and social and economic scientists that would be on-call for managers. Create a decision-support toolkit with customized strategies, tactics, and methods for mitigation and adaptation. Include in-house and on-site delivery mechanisms.	A national suite of decision-support tools and systems to address DOI land and water resource management issues due to climate change impacts	Would require building and/or partnering to build social and economic science capabilities at a comprehensive scale. Capabilities affected by options chosen for Components 1 and 2.
	Option 2	Create and implement a decision-support team that relies heavily on partnerships to develop social and economic science capabilities. Provide a toolkit tailored to meet managers' needs and provide decision-support tools.	A multi-regional suite of decision-support tools and systems	Limited applicability. Would require building and/or partnering to build social and economic science capabilities. Capabilities affected by options chosen for Components 1 and 2.
	Option 3	Provide decision-support tools for ecosystems of immediate concern on an ad-hoc basis.	Decision-support tools and systems for ecosystems of immediate concern	Limited applicability. Capabilities affected by options chosen for Components 1 and 2.
Component 4: Integrating, Interpreting, and Disseminating Information	Option 1	Create a national center of excellence for integrating science data collection, data interpretation, and applications development. Provide decision-support tools across DOI bureaus by disseminating through regional support staff.	Nationwide interaction among scientists and resource managers, maximizing DOI's response to climate effects issues. A national clearinghouse for data and information	Higher initial investment. Requires relocating existing and hiring new staff. Capabilities affected by options chosen for Components 1–3
	Option 2	Create a central office for integrating and disseminating information relying on existing science and applications capabilities across bureaus.	Enhanced interaction and response. A common vision across DOI	Reduced capacity to address national issues. Capabilities affected by options chosen for Components 1–3
	Option 3	Develop a central capability for integrating and disseminating information that enhances interaction among and disseminates information beyond the investigators.	Enhanced interaction and response among investigators. Dissemination of information to others	Reduced capacity to address national issues and establish a common vision. Capabilities affected by options chosen for Components 1–3

Appendices

Appendix 1: The CORE Framework

The Collaborative Observation and REsearch (CORE) strategy, a conceptual model that brings data from disparate programs together to address common questions, could serve as a framework for the design and implementation of a national network for researching and monitoring the effects of climate change.

Logistical limitations impose inherent tradeoffs among the number of variables that can be measured, the frequency at which they can be measured, and the number of sites that can be involved. Different methods, at different scales, are required to understand the myriad interactive processes and their consequences for specific ecosystems. No single method can provide the complete suite of information that resource managers need. These constraints lead to a hierarchical structure for data collection, which can be represented by a pyramid with the measurements that can be made at the greatest number of sites as the base of the pyramid and the measurements that, because of their complexity and frequency, can only be made at a limited number of sites at the apex (Figure 4). The types of monitoring within the framework can be divided into four general classes:

- **Tier 1**: **Intensive Monitoring and Research Sites.** At this tier, researchers would typically measure a greater number of properties at a higher frequency than at the other tiers, but at a much smaller number of locations. The critical feature of this level is that all of the major potential causes of environmental change are measured at the same locations where environmental responses of concern to society are also measured. This level is essential for understanding processes that occur at local scales, for understanding the integrated effects of multiple processes, for understanding the causes of changes at other tiers of the framework, and for developing and testing predictive models of environmental response. Measurements at this level also provide information for determining the level of uncertainty associated with inventory, remote sensing, and survey results, as well as of model predictions.

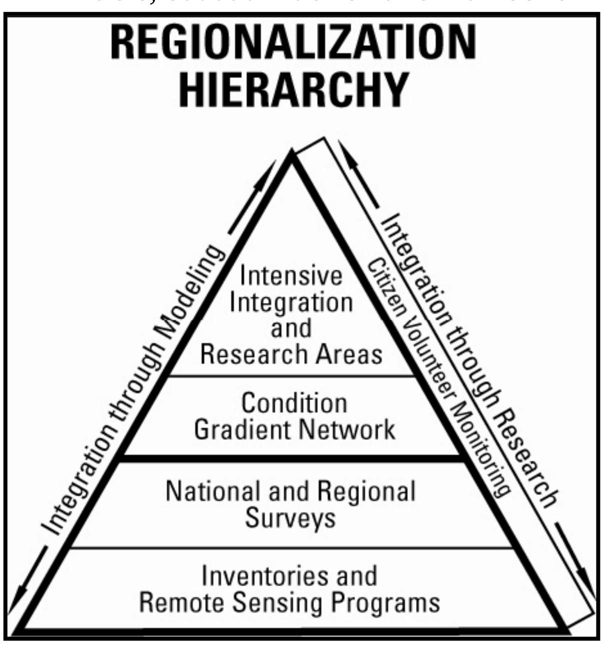

Figure 4. Hierarchy of monitoring pyramid shows measurements that can only be made at a limited number of sites at the apex and monitoring measurements that can be made at the greatest number of sites at the base.

- **Tier 2: Gradient studies.** At this tier, either several locations would represent the condition range that is relative to a specific environmental issue or the ecosystem states and processes would be monitored for common parameters in order to determine the range and variability of possible responses to a given environmental condition or stressor. Regression relationships that relate stress with response variables are typically used to estimate how the location range or passing of time effect the environmental condition. The results from gradient studies would also be used to evaluate the application of models that incorporate information from Tier 1 studies. Such evaluation is important for reconciling scaling issues when applying models developed from fine-scale knowledge to different locations.
- **Tier 3: National and Regional Resource Surveys.** These surveys would be designed to characterize specific properties of a region by sampling a subset of the total area, rather than the entire area. Such programs are typically designed to address specific resources or environmental issues and may cover the entire country or only the region where a specific issue is important. Integration between Tiers 1, 2 and 3 can help "ground truth," or identify differences between on-the-ground observation and environmental change detected by remote sensing, but generally cannot indicate why a specific change has occurred. Tiers 2 and 3 are essential for quantifying the extent, distribution, condition, and rate of change of specific environmental properties and for understanding processes that occur over large areas.
- **Tier 4: Inventories and Remote-Sensing Programs.** Basin-scale wall-to-wall monitoring, such as satellite remote sensing and aerial photography, could be used with the primary objective of developing continuous time and geographic information, such as land-use and land-cover change, forest species distributions, forest fragmentation, fire occurrence and history, ecosystem performance (e.g., production), snow cover, lake area, and stream flow.

With the tier design as a template, DOI would be able to categorize existing capabilities and determine what additional data would need to be collected in order to meet DOI objectives. Application of enhanced ecosystem models using the data collected provide an understanding of the system's most important environmental indicators; these indicators could then be used to develop regional monitoring capabilities to measure changes to the key indicators.

Each tier of this framework would provide unique observations that would contribute to a comprehensive, multi-component, multi-scale information system. For example, intensive monitoring and research sites are necessary for developing the process-level, cause-and-effect understanding necessary for building predictive models. These models are critical for forecasting changes in temperature, precipitation, fire risk, water supplies, and other features that are central to management decisions. Observations made at different locations are then needed to calibrate the models to new areas and to scale results up to a regional or national scale. New remote-sensing tools developed through calibration with this ground-based network would eventually lead to earlier detection and more cost-effective tracking than has been possible so far. Managers have long recognized the inadequacy of the existing data for solving complex ecosystem problems and the need for an understanding that brings all the pieces of the ecosystem puzzle together to address key management issues. The purpose of the framework is, therefore, to create a structure within which the complex effects of climate change can be addressed in a systematic and long-term manner.

Selection of Key Variables

The four-tiered CORE Framework provides an overarching design for implementing a comprehensive science program. Similarly, the Ecological Indicator selection framework developed by the National Park Service provides a decision-support system for organizing and selecting indicators from both proposed research and lists already identified in workshops involving more than one thousand managers and scientists. Combining the CORE and Ecological Indicator frameworks would provide a structure for expediting the selection of specific variables. Examples of potential variables to be measured are shown in Table 2.

Table 2. Ecological Indicator Framework

Level 1 Category	Level 2 Category	Examples of attributes or measurements
Air and Climate	Air Quality	Ozone, wet and dry deposition, visibility, air contaminants
	Weather and Climate	Weather and climate
Geology and Soils	Geomorphology	Glaciers, shoreline change, channel morphology, physical habitat index
	Subsurface Geologic Processes	Cave air quality and humidity, seismic activity
	Soil Quality	Biological soil crusts, soil structure and stability, soil cover, permafrost
Water	Hydrology	Groundwater dynamics, surface water dynamics, stream flow, lake and pond elevation, saltwater marsh water table
	Water Quality	Water chemistry, chloride flux, kettle pond acidification, nutrient loading and eutrophication, aquatic macroinvertebrates
Biological Integrity	Invasive Species	Invasive/Exotic plants early detection, areal extent of established populations, exotic aquatic assemblages
	Infestations and Disease	Whitebark pine disease, forest insect/disease outbreaks
	Focal Species or Communities	Landbirds, forest vegetation structure & composition, fish communities, intertidal communities, salt marsh vegetation, seagrass communities,
	At-risk Biota	T&E plants, western prairie fringed orchid,, Topeka shiner
Human use	Point-Source Human Effects	Contaminants, illegal roads and trails
	Non-point Source Human Effects	Estuarine nutrient inputs
	Consumptive Use	Fisheries harvest, poaching of native plants and animals
	Visitor and Recreation Use	Timing and magnitude of visitor usage
Landscapes (Ecosystem Pattern and Processes)	Fire and fuel dynamics	Fire occurrence and extent, fuel loading
	Landscape Dynamics	Land cover and use
	Nutrient Dynamics	Nutrient cycling
	Productivity	Productivity, plant phenology

Appendix 2: Members of the Science Subcommittee

NAME	BUREAU
Thomas Armstrong (Chair)	USGS
Leigh Welling	NPS
Melanie Miller	BLM
Peter Murdoch	USGS
Indur Goklany	OS
Dan Ashe	FWS
Roman Gould	FWS
DeWayne Cecil	USGS
Earl Greene	USGS
John Payne	BLM
John Gross	NPS
Eric Sundquist	USGS
Robert Thompson	USGS
Ralph Morgenweck	FWS
Fred A Johnson	FWS
Tim Mayer	FWS
Mike Soukup	NPS
Shawn Carter	NPS
Jim Renfro	NPS
Carrie Phillips	NPS
Nancy Finley	NPS
George Oviatt	BLM
Ron Huntsinger	BLM
Scott Archer	BLM
James Cimato	MMS
Jayne Belnap	USGS
Thomas Loveland	USGS
Richard L Bernknopf	USGS
Gary Clow	USGS
Ned Euliss	USGS
James Nichols	USGS
Bruce Muller	BOR
Chris Paolino	OS
Curtis Brown	BOR
Dirk Herkhof	MMS