U.S. GEOLOGICAL SURVEY
BIOLOGICAL RESOURCES DISCIPLINE

Draft
WETLANDS ECOLOGY

5-YEAR SCIENCE PLAN

TERRESTRIAL, FRESHWATER, AND MARINE ECOSYSTEMS PROGRAM

FY 2005-2010

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Executive Summary

Future Directions: The US Geological Survey (USGS) Terrestrial, Freshwater and Marine Ecosystems Program (TFME) – Wetlands Science supports investigations on scientific issues involving wetland restoration, coastal wetland subsidence and sea level rise, marsh habitat for migratory wildlife and stopover areas, carbon sequestration, and the interactions of wetlands within their landscapes among others. Wetlands science research supports development of tools and technologies for predictive management on federally managed lands such as National Wildlife Refuges, National Parks, and Bureau of Land Management areas.

Wetlands Science Vision: Providing a state-of-the-art, comprehensive, and fully-integrated foundation of wetlands science from which management decisions can be made.

Wetland Science Goals

This 5-year Science Plan was developed by scientists, managers, and policy-makers representing USGS, ……. . The science plan identifies 5 goals by which the vision statement will be accomplished over the next five years. These goals are:

Goal 1: Increase scientific understanding of wetlands structure, dynamics, and functions in the context of linkages with the surrounding landscapes. *The biotic and abiotic factors and processes that determine wetland development and function must be understood, along with their natural variability across different temporal and spatial scales, to provide background information that can be used in conducting research that addresses management needs with the greatest chances for success.*

Goal 2: Predict how wetland communities and processes respond to natural and anthropogenic stressors. *Determine predictive relationships for forecasting the effects of these threats on ecosystem and landscape structure and function and developing decision support systems and tools to better manage and protect wetland resources.*

Goal 3: Assess wetland functions from a socio-economic perspective and communicate this to others. *Develop wetland functional assessment tools and economic models for valuation of wetland functions to be applied by managers to evaluate the effects of management actions on wetland resources.*

Goal 4: Research support and technical assistance addressing management needs and applications. *Improve communications/interactions between land resource managers and scientists.*

Goal 5: Establish reference sites and maintain long-term studies and data sets for all major wetland types. *Establishing long-term reference sites for long-term data collection will provide better information for wetland management.*

Introduction

The Organizational Context and Role for this Plan

Department of the Interior

The DOI has responsibilities to manage and protect the Nation's living resources. Various legislative authorities, such as the Endangered Species Act, the Clean Water Act, and the Marine Mammal Protection Act, convey these responsibilities. The DOI revised its Strategic Plan in 2003 to emphasize the information base, resource management, and technical assistance for decision making. The DOI Strategic Plan aims to unify scientific knowledge with applications of that knowledge in resource management through collaboration among scientists and Federal, State, Tribal and non-governmental natural resource managers. The DOI mission promotes informed resource protection, resource use, and recreation, with the goal of serving communities by advancing knowledge and informing decisions through the application of science. The USGS TFME Program – Wetlands Science supports the DOI Resource Protection Strategic Goals by providing scientific information to sustain biological communities on DOI managed lands and waters.

U.S. Geological Survey

The U.S. Geological Survey (USGS), established in 1879, is the Nation's oldest principal natural science and information agency, conducting research, monitoring, and assessments to contribute to understanding the natural world. The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life. As the science agency for DOI, the USGS is entrusted to provide unbiased, independent data and information on biology, hydrology, geology, and geography to the DOI and the Nation. The USGS has a primary responsibility to provide high-quality scientific data to DOI and its bureaus that manage lands and biological resources. A major institutional strength of USGS is the opportunity to conduct truly interdisciplinary science. The USGS actively seeks to promote scientific undertakings that integrate its capabilities in biology, geology, geography, and hydrology on multiple spatial scales.

USGS Biological Resources Discipline and Mission

Part of the USGS mission is to ensure the continued availability of long-term environmental and natural resource information and to conduct systematic analyses and investigations for natural resource decision-making. The Biological Resources Discipline (BRD) serves this function through the activities of six science programs of Biological

Research and Monitoring:

- Contaminant Biology,
- Fisheries: Aquatic and Endangered Resources,
- Invasive Species,
- Status and Trends of Biological Resources,
- Terrestrial, Freshwater and Marine Ecosystems, and
- Wildlife: Terrestrial and Endangered Resources.

The Biological Informatics and Cooperative Research Unit Programs complement these programs.

The Biology Discipline Mission

. . . . to work with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our Nation's biological resources

Wetland Science Program History

Not until the last quarter of a century did society begin to understand the value of wetlands and the environmental functions they provide (e.g., wildlife habitat, flood attenuation, water quality improvements, sediment removal). Historically, in the U.S., wetlands were regarded as swampy lands that bred disease, impeded agriculture and development, and restricted overland travel. It has been estimated that greater than half of the naturally occurring wetlands in the U.S. have been lost since the 1700s.

The initial wetland policy of the U.S. government cast by the Swamp Land Act of 1849 (which granted control of all swamplands and overflow lands to the state of Louisiana for flood control purposes) set the direction for wetlands, that of elimination. In the 1940's to 1950's wetland classification attempts were made to group wetland ecosystems into similar categories that follow their structural and functional characteristics. These classifications (e.g., Cowardin et al), or definitions of different wetland types, are useful to resource managers in making decisions with respect to wetland regulation and protection in a consistent manner, for understanding restoration processes in wetland types, in identifying those wetlands types that are functionally more valuable to a given region or are receiving the most threats from impacts, and to provide uniformity in the use of inventories, mapping, concepts and terminology. As the DOI research and science bureau, the USGS is mandated to support Department of Interior bureaus in their missions, and as such has the responsibility to conduct research and collect scientific information in support of the conservation and management of DOI trust natural resources. USGS wetland science includes developing inventory and monitoring protocols, mapping of coastal and inland wetland areas, and developing restoration techniques for wetlands and coastal areas, models, and decision support tools for the NPS and FWS Refuge systems and the coastal States.

The Terrestrial, Freshwater, and Marine Ecosystem Program (TFME) investigates

interactions among abiotic and biotic ecosystem components, biogeochemical processes and biological interactions within and among ecosystems, and the development and dynamics of spatial heterogeneity across landscapes. The Wetlands Science research projects of the BRD form a research program of substantial significance to the Nation's wetlands resources and ecosystems. (Wetlands in this discussion include riparian ecosystems, especially the common streamside wetlands of the arid West). As indicated by a program review of the Global Change and Wetlands Science Programs in 1998, the set of wetlands projects identified as belonging to the Ecosystem Element of BRD, consisted of a diverse mix of projects derived from the several agencies that became part of the USGS in 1996. "No overall organizing questions, goals, or themes had been established. Nonetheless, we believe that these projects represent the substantial beginnings of what could become, and what should become, a comprehensive and integrated program at the front line of wetlands research nationwide".

The comments and recommendations of the 1998 review provide many reasons why BRD should develop and support a comprehensive Wetlands Ecosystem research program. First, the importance of wetlands as habitat for waterfowl, fur-bearing mammals, shorebirds, reptiles and amphibians, and more than half of all federally listed endangered plants and animals is well-established, as is their role in regulating water flows in landscapes and modifying the quality of water moving from uplands to rivers, lakes, and estuaries. These are all ecosystem and landscape functions for which the USGS now holds primary research responsibility. Second, wetlands constitute the largest fraction of Federal land holdings managed by the FWS, largely within the national refuge system, and a significant fraction of lands managed by other DOI agencies. Everglades National Park is almost entirely wetlands. The management of these lands requires knowledge that should derive from BRD research programs. Third, only a national research effort is likely to encompass the range of variability among the Nation's wetlands and the array of threats confronting them, or to possess the land resources needed to undertake the requisite long-term research. Fourth, the potential exists to develop a uniquely integrated understanding of wetlands by capitalizing on the biological and ecological strengths within BRD in combination with geological and hydrological strengths in other USGS disciplines. Fifth, wetlands, particularly coastal and arctic wetlands, are highly susceptible to climate change and sea-level rise because of their tight coupling with temperature and precipitation patterns.

Following the recommendations of the review panel that research provide the knowledge needed to manage the Nation's wetlands effectively, those wetlands ecology research projects the Panel reviewed must become part of an explicit Wetlands Ecosystem program within BRD. That program must operate within an organizing framework with explicit goals. The Wetlands Science Plan presented here has been developed with these comments in mind. Goals and objectives have been carefully thought out to address the gaps in wetlands science facing all agencies and the future needs of wetland managers and decision makers.

Wetlands Science Mission - Provide a strong scientific basis for wetlands and riparian management practices that are environmentally sound and that will maintain sustainable wetland ecosystems as part of sustainable benefits for humankind

Future Initiatives

To address gaps in wetlands science and the needs to better manage wetland resources and habitats USGS Wetlands Science will establish and maintain long-term reference sites and data sets for all major wetland types. Using inter-disciplinary teams, and data from the long-term study sites USGS will build, test, and validate assessment and ecosystem models to be implemented by wetland resource managers. In addition, online decision support tools on understanding the hydrologic setting of wetlands, the successional stage of wetlands in relation to management options, and the context in which wetlands are positioned within the landscape and the community structure will be developed based on information gained from long-term study sites.

Wetlands play an integral role in connecting groundwater and surface water. Strandplain wetlands of the Great Lakes will be evaluated in their role of surface water and ground water availability as part of the FY- 06 Water Availability Initiative. Wetlands also play an integral role in nutrient exchange with the surrounding landscape. This is of great importance in riverine wetlands along major waterways. Studies will be implemented to determine the effects of hydrologic changes on nutrient loading/exchange in these riverine wetlands in relation to the contribution of hypoxia in the Gulf.

Of national and international importance is the role and fate of wetlands in relation to sea level rise and climate change. Not only do we need to determine the rate of sea level rise but also the fate of wetland systems, both coastal and freshwater, in relation to sea level rise and increased temperatures. Studies addressing the physical and biological processes in wetlands in accretion/erosion with increasing sea level need to be identified in order to help mitigate negative effects in many of the nation's National Wildlife Refuges and National Parks.

Wetland Science Capabilities

USGS - BRD has a major opportunity and responsibility to provide leadership in understanding the consequences of multiple environmental and anthropogenic stressors and threats on wetland ecosystem integrity and developing sound science that will support assessments of ecosystem condition and performance. An integrated approach that focuses on ecosystem integrity and sustainability is necessary. New research approaches need to be initiated that examine how wetland ecosystems react to multiple stressors and threats. An understanding of ecosystem response to changes in the factors that drive ecosystem behavior in both natural and human dominated systems is important in order to prescribe ecosystem restoration and management strategies that would enhance the sustainability of ecological systems. New tools and methodologies must be developed to strengthen the capacity to assess the sustainability of wetland ecosystems to provide goods and services and the potential consequences of future changes to these systems. Predictive models including decision support systems and improved assessment methodologies of the likely outcomes of alternative management scenarios must be developed to help guide managers in their activities.

USGS scientists have embraced these needs and have initiated development of a diverse program with a central goal of providing decision support at levels ranging from federal and private land managers to policy makers. Specifically, the mission is not only to contribute knowledge to the field of wetland science, but also to build a strong scientific understanding of wetland processes that will improve the ability to (1) identify proper restoration and management activities relative to site conditions; (2) assess the impacts of specific habitat management practices on diversity and ecosystems; (3) effectively analyze potential impacts of secondary uses; (4) develop scientifically based plans; and (5) assess future land acquisition and conservation programs.

Wetlands are increasingly viewed as hydrologic units and parts of larger landscapes continuous with surface and groundwater systems. An emphasis on climate and hydrogeologic setting is increasingly viewed as the primary determinants of wetland characteristics. Increasingly, wetland science is moving toward a modern synthesis that incorporates physical and chemical factors within a landscape framework to determine wetland characteristics and their response to anthropogenic drivers. USGS scientists are studying the effects of these primary drivers and providing a foundation for predicting and forecasting the cumulative impacts of management actions on the maintenance and development of wetlands and the biological and functional diversity of wetland landscapes.

Wetland Science Accomplishments

USGS - Wetland Science scientists are recognized nationally and internationally in the areas of wetland restoration, carbon sequestration, sea level rise, water-level regulation, climate change, and landscape level analysis. USGS scientists are asked to participate in international forums and provide scientific expertise on various wetlands issues, from restoration to spatial analysis and monitoring of wetland loss. Wetland scientists have collaborated with hydrologists from USGS and major universities across the country to better understand water regimes, drought cycles, and community successional cycles. They have determined rates of biogeochemical transformation and removal of nitrogen on the flood plain ecosystem of the Upper Mississippi River showing the importance of river connectivity with riparian wetlands and backwaters in annual nitrogen removal. This is significant in helping to decrease hypoxia in the Gulf of Mexico.

USGS scientists have been major contributors to the published literature on wetlands, covering a wide variety of topics, from modeling to botany, from wetland birds to hydrology, from soils to invertebrates. In doing so, they have collaborated with a wide variety of other scientists from across the agency, academic, and private sectors. In addition, technical assistance has also been a high priority for USGS scientists. A wide variety of workshops and site visits have been held for land resource managers, regulators, and environmental consultants across the country to demonstrate how to apply basic wetland science to daily management questions.

Wetland Science 5-Year Goals

GOAL 1. Increase scientific understanding of wetlands structure, dynamics, and functions, in the context of linkages and interactions with the surrounding landscape.

Wetlands function at multiple spatial and temporal scales and cannot be divorced from their surrounding watersheds, landscapes, and developmental histories. The roles and functions of wetlands in the landscape are dependent on the underlying geologic, hydrologic, and biological development through time. The biotic and abiotic factors and processes that determine wetland development and function must be understood, along with their natural variability across different temporal and spatial scales, to provide background information that can be used in conducting research that addresses management needs with the greatest chances for success.

Objective 1.1 Increase understanding of the underlying biotic and abiotic factors and processes controlling natural, created, and managed wetland development.

Wetlands form at positions in the landscape where the underlying geology supports hydrologic conditions suitable for hydrophytic plant and animal communities to establish and survive. Those landscape settings and developmental processes must be understood before interpretations of natural wetland functions can be made. Wise management decisions regarding wetlands are dependent on a thorough knowledge of how a wetland works. Management actions that defy natural processes risk long-term, high maintenance costs or failure; thus, this initial objective is to gather the baseline information required for understanding natural wetland development and function.

Strategies

1.1A. Synthesize existing information of biotic/abiotic factors by wetland type to identify important information gaps.

1.1B. Conduct studies to characterize geologic settings and processes that formed the landscape settings of major wetland types.

1.1C. Conduct studies to characterize the hydrologic characteristics of major wetland types within their geologic settings.

1.1D. Conduct studies to characterize development of biological communities within major wetland types.

1.1E. Synthesize geologic, hydrologic, and biological information to develop an understanding of naturally sustainable functions within each major wetland type.1

Objective 1.2. Identify and quantify the linkages and interactions of wetlands to their surrounding landscapes at various spatial and temporal scales.

Considerable natural variability, both temporal and spatial, will likely be observed in wetland functions and developmental processes. The range of that variability must be understood to place bounds on conditions considered natural, such that variability is not mistaken for the effects of human alterations and management actions not be taken where unwarranted. Natural variability must be evaluated both temporally and spatially.

Strategies

1.2A. Develop landscape-scale data sets using GIS and remote sensing tools and technologies to identify the linkages between wetland functions and landscape-scale processes.

1.2B. Integrate landscape-scale data sets with applied research studies to reduce scientific uncertainties.

GOAL 2. Predict responses of natural wetland communities and processes to natural and anthropogenic stressors.

Anthropogenic and natural threats to wetland environments span multiple temporal and spatial scales. Consequent resource management problems involve complex interactions among hydrologic, geological, chemical, and biological processes, and their solutions demand interdisciplinary approaches. BRD Wetland Science seeks to understand the human activities and natural events that threaten wetland environments, the stresses to ecosystem integrity imposed by these threats, and their ecological consequences. The consequences to wetland systems are far reaching, ranging from changes in biogeochemical cycling and primary production to major shifts in the local and migratory biotic communities. BRD scientists should emphasize determining predictive relationships for forecasting the effects of these threats on ecosystem and landscape structure and function and developing decision support systems and other tools to better manage and protect wetland environments.

Objective 2.1. Identify and develop approaches to assess the dynamics of wetlands at multiple time scales.

BRD scientists should identify monitoring variables, define their natural temporal and spatial variability, design sampling programs, develop predictive relationships between monitoring variables and ecosystem response, and determine threshold values of monitoring variables that signal shifts from sustainable to degraded systems.

Strategies

2.1A. Develop conceptual models of predictive relationships between monitoring variables and ecosystem response.

2.1.B. Develop monitoring protocols for detecting long-term change in wetland communities and their watersheds.

2.1C. Develop modeling framework based on integrative science to predict ecosystem response to natural and anthropogenic changes in the landscape.

2.1D. Describe temporal dynamics of major wetland community types and the causal abiotic and biotic factors.

Objective 2.2. Develop tools for predicting the outcome of management practices.

Developments in GIS based decision support systems and predictive ecosystem modeling to link land use, stressors, and ecosystem responses within a landscape context should be used in modeling wetland landscape science. An emphasis on this type of modeling provides a powerful basis for integrative science and understanding of complex science issues. Such a modeling framework utilizes an empirical scientific and ecosystem based understanding of wetland systems in a way that can be used to improve management capabilities.

Strategies

2.2A. Develop necessary modeling programs to support prediction of ecosystem response to restoration and management actions/inactions.

Goal 3. Assess wetland functions from a socio-economic perspective and communicate this to others.

As the principal research entity of the DOI, the U.S. Geological Survey (USGS) has primary responsibility for developing an ecological understanding of processes that influence wetland functions and ecosystem services. New policies and directives mandate that many federal programs and land management agencies, and the private sector consider the necessity to maintain or restore the integrity of natural systems using sound science. Improving our scientific understanding of wetland processes is critical to accomplishing this goal because it will allow the development of ecologically based techniques to restore and manage wetlands to ensure sustainable productivity, environmental health, and biological diversity. This will increase the probability of successful management and reduce long-term maintenance management costs.

Objective 3.1. Conduct comparative assessment of ecosystem functions performed by wetlands.

Strategies

3.1A . Develop assessment tools to quantify wetland functions affected by DOI programs.

3.1B. Systematically quantify the factors controlling beneficial functions within wetlands that provide desired services on a regional and national scale.

3.1C. Assess wetland restoration and mitigation programs.

Objective 3.2. Determine socio-Economic valuation of wetland ecosystem functions.

Strategies

3.2A. Create/enhance existing economic models and techniques for accurate valuation of wetland functions (e.g., flood control, aquifer recharge, water quality improvement, Green House Gas removal, carbon sequestration, biodiversity support).

3.2B. Apply economic models to determine national and regional scale "value" of wetlands and their functions.

Objective 3.3. Communicate research findings to public and resource managers.

Strategies

3.3A. Develop a website to communicate USGS wetland research and its relevance to the public.

3.3B. Provide technical assistance on wetland functions and values to DOI agencies.

Goal 4. Research support and technical assistance addressing management needs and applications.

Short-term, rapid technical assistance provides results to meet the science needs of resource managers. Increased understanding of wetland processes and functions will allow research scientists to work with resource managers in assessing the scientific basis for management decisions. Examples include Brown Marsh restoration in the Gulf, evaluation of restoration activities in the Prairie Pothole region, evaluation of rate of marsh loss due to sea level rise and herbivory, and effects of water level changes on Great Lakes wetlands. Technical assistance may evolve into long-term research if scientific uncertainty prohibits sound decisions by natural resource mangers or decision makers. Short-term targeted research and studies complement long-term monitoring, research, and modeling activities to increase our understanding of complex issues such as carbon sequestration, sea level rise, and restoration trajectories.

Objective 4.1. Develop mechanisms to increase and improve interaction between land managers and USGS scientists.

Strategies

4.1A. Develop liaisons between USGS and other DOI/state/local agencies at appropriate levels (e.g., regional, science center).

4.1B. Sponsor regional workshops with USGS scientists and other

federal/state/local agencies.

4.1C Staff in Reston develops BRD wetlands science web page with scientist contacts at the science center level.

Objective 4.2. Develop system analysis and modeling methods for evaluation management and restoration actions at multiple scales (site specific, watershed, continental) that focus on interrelated biotic and abiotic processes.

Strategies

4.2A. Identify existing standardized methodologies (including monitoring of both biotic and abiotic parameters, etc) necessary to evaluate specific management actions.

4.2B. Synthesize biotic and abiotic responses to management actions across site-specific, watershed, and continental scales.

Objective 4.3. Develop decision support tools to help managers identify and achieve desired wetland conditions and functions across multiple temporal and spatial scales.

4.3A. Develop watershed model using GIS data sets to link wetland responses to change in land use and stressors (e.g., invasives, contaminants, hydrological changes) based on wetlands location in the landscape.

4.3B. Provide technical products and onsite technical assistance for resource managers.

4.3C. Provide follow-up assistance for plan development, implementation, and evaluation.

Goal 5. Establish reference sites and maintain long-term studies and data sets for all major wetland types.

BRD has a major opportunity and responsibility to provide leadership in understanding the consequences of multiple environmental and anthropogenic stressors and threats on wetland ecosystem integrity and developing sound science that will support assessments of ecosystem condition and performance. An integrated approach that focuses on ecosystem integrity and sustainability is necessary and will be achieved with long-term data obtained from established sites. An understanding of ecosystem response to changes in the factors that drive ecosystem behavior in both natural and anthropogenic influenced systems is important in order to prescribe ecosystem restoration and management strategies that would enhance the sustainability of ecological systems. New tools and methodologies based on long-term data sets must be developed to strengthen the capacity to assess the sustainability of wetland ecosystems to provide goods and services and the potential consequences of future changes to these systems.

Objective 5.1. Identify and catalogue potential reference sites and associated long-term data sets.

Strategy

5.1A. Survey DOI wetland managers and scientists to identify potential reference sites and long-term data sets.

Objective 5.2. Establish reference sites for long-term data collection.

Strategy

5.2A. Develop long-term monitoring program to detect changes in ecosystem integrity that might trigger management actions.

Objective 5.3. Establish support necessary to store and maintain long-term data sets.

Strategy

5.3A. Identify and procure resources needed to store and maintain existing (as identified in Obj 5.1) and future long-term data sets.

Partners and Customers

Wetlands Science of the Terrestrial, Freshwater, and Marine Ecosystems Program serves a large number of customers, both within and outside of DOI, and provides research support and technical assistance in areas of expertise. The BRD Wetlands Science Program forms partnerships internally with other USGS Programs to provide integrated science capabilities to Partners and Customers. The Program focus is on supporting DOI management of public lands and waters and DOI trust species and habitats.

Partners and customers include a variety of Federal and State agencies, non-governmental organizations, commercial entities and international governments that require information on wetland functions, restoration, and mitigation of impacts to wetlands. Established collaborative partnerships have been successful in addressing large and complex research initiatives with Wetland Science goals. Partners and customers rely on the continued involvement of USGS scientists in collaboratively addressing issues of regional and national significance identified in adaptive management plans. Such collaborative efforts focus USGS Wetlands Science expertise to solve natural resource management problems of regional and national scope and significance.

Appendix A

2005-2010 Wetland Science Plan: Goals, Objectives - Strategies, Outcomes, and Measures

Goal 1: Increase scientific understanding of wetlands structure, dynamics, and functions in the context of linkages and interactions with the surrounding landscape.

Objective 1.1. Increase understanding of the underlying biotic and abiotic factors and processes controlling natural, created, and managed wetland development and associated functions.

Strategy	Outcome	Measure
Synthesize existing information of biotic/abiotic factors by wetland type to identify important information gaps.	Technical advice to managers for project planning.	Data sets containing species lists for biota within each wetland type, measures of abundance, diversity, productivity, and community health, geology and hydrology. List of needed information.
Conduct studies to characterize geologic settings and processes that formed the landscape settings of major wetland types.	Technical advice to managers that facilitates decision-making.	Cross-sections, three-dimensional models illustrating abiotic wetland development of wetland types.
Conduct studies to characterize the hydrology of major wetland types within their geologic settings.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Models describing hydrologic development in each wetland type that are correlated to landscape changes.
Conduct studies to characterize development of biological communities within major wetland types.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Models describing biological development in each wetland type that are correlated to landscape changes.
Synthesize geologic, hydrologic, and biological information to develop an understanding of naturally sustainable functions within each major wetland type.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Conceptual models that demonstrate natural processes and functions of each wetland type for wetland resource managers.

Objective 1.2 Identify and quantify the linkages and interactions of wetlands to their surrounding landscapes at various spatial and temporal scales.

Strategy	Outcome	Measure
Develop landscape-scale data sets using GIS and remote sensing tools and technologies to identify the linkages between wetland functions and landscape-scale processes.	Technical advice to managers that facilitates decision-making.	GIS data layers of land use change, habitats, infrastructures, geology, soils, and ecological processes. Interpretative maps and reports.

Integrate landscape scale data sets with applied research studies to reduce scientific uncertainties.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Refined conceptual models of pattern and process at the landscape scale.

Goal 2: Predict responses of natural wetland communities and processes to natural and anthropogenic stressors.

Objective 2.1 Identify and develop approaches to assess the dynamics of wetlands at multiple time scales.

Strategy	Outcome	Measure
Develop conceptual models of predictive relationships between monitoring variables and ecosystem response.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Define relationships between natural, temporal, and spatial variability of monitoring variables and their threshold values signaling shifts from sustainable to degraded systems.
Develop monitoring protocols for detecting long-term change in wetland communities and their watersheds.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Protocol for managers to monitor wetlands.
Develop modeling framework based on integrative science to predict ecosystem response to natural and anthropogenic changes in the landscape.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Adaptive management tool to enable managers to make better decisions on wetland management in changing landscapes.
Describe temporal dynamics of major wetland community types and the causal abiotic and biotic factors.	Improved restoration, creation, and management of wetlands based on appropriate biotic and abiotic factors	Companion book to Cowardin et al.

Objective 2.2 Develop tools for predicting the outcomes of management practices.

Strategy	Outcome	Measure
Develop necessary modeling programs to support prediction of ecosystem response to restoration and management actions/inactions.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Modeling program that uses a progression of simple models and synthesis to more complex models providing a greater capacity to test complex issues in restoration and management.

Goal 3: Assess wetland functions from a socio-economic perspective and communicate this to others.

Objective 3.1 Conduct comparative assessments of ecosystem functions performed by wetlands.

Strategy	Outcome	Measure
Develop assessment tools to quantify wetland functions affected by DOI programs.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	New assessment techniques that can be applied by managers.

Systematically quantify the factors controlling beneficial functions within wetlands that provide desired services on a regional and national scale.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Guidance on the effects of management practices on wetland functions, productivity, and diversity.
Assess wetland restoration and mitigation programs.	Restored wetlands based on processes that provide the objective functions.	Guidance on assessing wetland functions.
Objective 3.2 Socio-Economic valuation of wetland ecosystem functions.		
Create/enhance existing economic models and techniques for accurate valuation of wetland functions (e.g., flood control, aquifer recharge, water quality improvement, Green House Gas removal, carbon sequestration, biodiversity support).	Decision support tool illustrating economic role of wetlands in providing various functions in different landscapes.	Guidance on assessment of wetland functions in an economic role.
Apply economic models to determine national and regional scale "value" of wetlands and their functions.	Decision support tool illustrating economic role of wetlands in providing various functions in different landscapes.	Guidance on wetland restoration and mitigation to be used by resource managers and policy makers.
Objective 3.3 Communicate research findings to public and resource managers		
Strategy	**Outcome**	**Measure**
Develop a website to communicate USGS wetland research and its relevance to the public.	Improved communication on USGS wetland science to the public, academia, and agencies.	Wetlands research and information website developed.
Provide technical assistance on wetland functions and values to DOI agencies.	Improved management of DOI wetland resources.	National and regional guidance documents developed. Effectiveness of technical assistance determined by customer survey.
Goal 4: Research support and technical assistance addressing management needs and applications.		
Objective 4.1. Develop mechanisms to increase and improve interaction between land managers and USGS scientists		
Strategy	**Outcome**	**Measure**
Develop liaisons between USGS and other DOI/state/local agencies at appropriate levels (e.g., regional, science center).	Increased interactions between USGS scientists and other DOI/state/local agencies.	Specific individuals are named as liaisons between USGS and other DOI/state/local agencies at appropriate levels (e.g., regional, science center).
Sponsor regional workshops with USGS scientists and other federal/state/local agencies.	Improved assessments of client needs and increased understanding of our expertise and capabilities by clients.	Three workshops per region held over the next five years with published summary listing of most prevalent/relevant management actions by region and/or wetland type.

Staff in Reston develops BRD wetlands science web page with scientist contacts at the science-center level.	Provide web-based information and technology transfer specific to wetland protection and management.	Use of web page by other agencies.

Objective 4.2. Develop system analysis and modeling methods for evaluating management and restoration actions at multiple spatial scales (site specific, watershed, continental) that focus on interrelated biotic and abiotic processes.

Strategy	Outcome	Measure
Identify existing standardized methodologies (including monitoring of both biotic and abiotic parameters, etc.) necessary to evaluate specific management actions.	Improved data quality and compatibility across regions, wetland types, etc.	Reports and accessible databases listing recommended standardized methodologies
Synthesize biotic and abiotic responses to management actions across site-specific, watershed, and continental scales	Better understanding of effects of management actions on wetland ecosystems at multiple spatial scales	Peer-reviewed publications and reports

Objective 4.3. Develop decision support tools to help managers identify and achieve desired wetland conditions and functions across multiple temporal and spatial scales.

Strategy	Outcome	Measure
Develop watershed model using GIS data sets to link wetland responses to change in land use and stressors (e.g., invasives, contaminants, hydrological changes) based on wetland location in the landscape.	Decision tool for resource managers that utilizes integrative science in an adaptive management framework.	Guidance for managers based on scientific and ecosystem understanding of wetland systems.
Provide technical products and on-site technical assistance for resource managers	Improved ability of resource managers to identify desired conditions based on an understanding of wetland-specific ecosystem processes.	Reports, peer-reviewed publications, models, software, technical assistance with CCP and biological reviews, and technology transfer (through Objectives 1 and 2) that identify priority wetland types, appropriate spatial scales, and desired conditions
Provide follow-up assistance for plan development, implementation, and evaluation	Strong scientific support for resource managers throughout the project (planning through evaluation)	Reports, models, peer-reviewed publications, software, technical assistance, and technology transfer (through Objectives 1 and 2) supporting plan development, implementation, and evaluation

Goal 5. Establish reference sites and maintain long-term studies and data sets for all major wetland types.

Objective 5.1. Identify and catalogue potential reference sites and associated long-term data sets.

Strategy	Outcome	Measure
Survey DOI wetland managers and scientists to identify potential reference sites and long-term data sets.	Potential reference sites and long-term data sets will be identified and located for all major wetland types.	Report and database with information identifying location of and point of contact for potential reference sites and long-term data sets.

Objective 5.2. Establish reference sites for long-term data collection.

Strategy	Outcome	Measure
Develop monitoring program to detect changes in ecosystem integrity for long-term reference sites that will provide information for management actions.	Improved restoration, creation, and management of wetlands in the appropriate landscape and watershed management context.	Status and trends to support assessment of ecosystem trajectories.

Objective 5.3. Establish support necessary to store and maintain long-term data sets

Strategy	Outcome	Measure
Identify and procure resources needed to store and maintain existing (as identified in Obj. 5.1) and future long-term data sets.	Long-term data sets for all major wetland types will be stored and maintained.	Report and database identifying location of and point of contact for long-term data sets for all major wetland types.