NESP ENV Report 6

UPPER MISSISSIPPI RIVER SYSTEM

NAVIGATION AND ECOSYSTEM SUSTAINABILITY PROGRAM

Environmental Science Panel Report: Establishing System-wide Goals and Objectives for the Upper Mississippi River System

US Army Corps of Engineers®
Rock Island District
St. Louis District
St. Paul District

November 2007

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Upper Midwest Environmental Sciences Center
2630 Fanta Reed Road
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1 November, 2007

Mr. Kenneth A. Barr
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Rock Island, IL 61204

Dear Mr. Barr,

Enclosed is the report of the NESP Science Panel Goals and Objectives work group. The Science Panel proposes to work with NESP stakeholders to further develop system-wide goals and objectives to implement UMRS adaptive management, but it is important to complete this first iteration of objective setting to gather and assess stakeholder input. Activities during 2005 and 2006 focused on developing a framework for Project Delivery Teams to establish and document site-scale objectives which we reported in the Science Panel's 2006 report. The work group collaborated during 2007 to help address NESP stakeholder requests for a "top-down" approach to establish system- and reach-scale environmental restoration objectives. Consideration of the top-down approach was requested because bottom-up objective setting exercises had already bounded the potential magnitude of restoration needs, and stakeholders hoped a top-down approach would help determine the proper sequence of project implementation for more than 1,000 projects in the NESP Recommended Plan. Stakeholders thought a larger scale perspective considering regional objectives would help them select and design projects at the site scale.

In this report, the members of the NESP Science Panel: (1) review the existing Vision Statement for the NESP and revise it for operational purposes; (2) propose and discuss goals for addressing the ecological component of the UMRS vision; (3) outline examples of potential UMR system- and reach-wide ecosystem objectives and performance criteria to stimulate discussion for further developing objectives through a collaborative process; (4) recommend initial guidelines for addressing system-wide ecosystem objectives, and; (5) identify steps to implement the process.

The Science Panel Team concluded that the NESP vision statement included three important system-level concepts: balance, sustainability, and ecological integrity. *Balance* implies an understanding of a co-dependency between economic and ecosystem conditions and that a successful NESP will result in a future balance between economic prosperity and ecosystem quality. A cornerstone of sustainability is *resilience*: the ability of the system to absorb disturbance and still retain its basic function, structure, and feedbacks. The UMRS has shifted to a new ecological regime wherein levels of underlying controlling variables and their feedbacks have changed. Sustaining the social-ecological integrity of the system encourages balancing its economy and ecology for all components of the System to be resilient to future threats.

A system-wide approach is process based, rather than site based. Restoring ecosystem structure and function will be more effective than restoring locations in order to achieve a sustainable UMRS because process-based restoration will be more resilient to human and natural disturbances. The success of restoration planning depends on identifying key ecological functions and processes within the UMRS and incorporating them into goals and objectives at all levels.

NESP stakeholders have made tremendous progress during the execution of the UMR-IWW System Navigation Feasibility Study and the Environmental Management Program. The task of refining these draft objectives and performance criteria at system and project levels depends on continued collaboration between river scientists, managers, and the entire NESP partnership. We are confident that past learning and planning will be built into the recommended NESP adaptive management plan to foster rapid restoration project implementation.

The Science Panel looks forward to future collaboration as the entire NESP partnership works toward refining environmental objectives for the system and individual sites.

Sincerely yours,

JOHN W. BARKO

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Science Panel Co-Chair

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Upper Mississippi River System
Navigation and Ecosystem Sustainability Program

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Preface

The Navigation and Ecosystem Sustainability Program (NESP) Science Panel was convened to provide scientific expertise for system-wide adaptive management of the Upper Mississippi River System (UMRS). A system-wide approach to UMRS restoration will help river managers determine enhancement outcomes that define performance for the NESP. Additionally, such an approach will aid identification of pool or project-specific activities to meet system-wide needs. Effective restoration planning begins with developing a vision statement; applying the vision statement to system- and reach-level goals; and assisting river managers in developing objectives and performance criteria to achieve these goals. Ever-evolving socio-economic values and incomplete scientific understanding contribute to the difficulty of specifying long-term, system-wide restoration goals for the UMRS. Thus, the restoration goals and objectives posed here should be viewed as approximations developed through careful analysis of existing data and anticipated stakeholder requirements. These goals and objectives will be periodically reevaluated in light of new information and responses from stakeholders. This document provides a foundation for developing and implementing a system-wide, adaptive approach to management and restoration of the UMRS.

Summary

In this report, the members of the NESP Science Panel: (1) review the existing Vision Statement for the NESP and revise it for operational purposes; (2) propose and discuss goals for addressing the ecological component of the UMRS vision; (3) outline examples of potential UMR system- and reach-wide ecosystem objectives and performance criteria to stimulate discussion for further developing objectives through a collaborative process; (4) recommend initial guidelines for addressing system-wide ecosystem objectives, and; (5) identify steps to implement the process.

The NESP vision statement provides the foundation for goals and objectives and sets the broad direction and sideboards for future ecosystem restoration work. The existing vision statement is:

> *"To seek long-term sustainability of the economic uses and ecological integrity of the Upper Mississippi River System"*.

Three concepts underpin this vision: balance, sustainability, and ecological integrity. *Balance* is emphasized by the word *and* linking economic uses *and* ecological integrity. It implies an understanding of a co-dependency between economic and ecosystem conditions and that a successful NESP will result in a future balance between economic prosperity and ecosystem quality. It acknowledges that NESP partners cannot "have it all" and that trade-offs will be necessary to realize the vision.

S*ustainability* is defined for NESP as, "*the balance of economic, environmental, and social conditions so as to meet the current and future needs of the UMRS without compromising the ability of future generations to meet their needs*" (Upper Mississippi River Summit 1996).

A cornerstone of UMRS sustainability is *resilience*: the ability of the system to absorb disturbance and still retain its basic function, structure, and feedbacks. Centuries of urbanization, poor land-use practices, stream channelization projects, and construction and operation of dams have changed the flow and stage relationships, sediment transport, and biotic patterns within the UMRS. The UMRS has shifted to a new ecological regime wherein levels of underlying controlling variables and their feedbacks have changed. Add to this the uncertainty associated with forecasted climate change effects, and it is challenging to predict when the UMRS might again become sustainable. The NESP partnership must determine the degree of sustainability desired and clearly reflect this desired sustainability in the implementation of economic and ecosystem restoration goals and objectives.

Adopting *ecological integrity* as a part of a NESP vision statement means targeting a system that resembles its natural state as much as possible with minimal influence from human actions. This is a goal that a program like NESP cannot realistically achieve. The NESP Science Panel proposes that the existing definition of UMRS sustainability be simplified for operational purposes: *to achieve sustainability of social-ecological systems within the Upper Mississippi River System*. The original statement implies that the vision will be achieved as long we can demonstrate that we are *seeking* sustainability, even if little progress towards *achieving* sustainability is made. Social-ecological systems are defined as linked systems of humans and nature and emphasize the dualism of social/economic prosperity and ecological quality. Sustaining the UMRS social-ecological system encourages balancing its economy and ecology for the System to be resilient to future threats.

A system-wide approach is process based, rather than site based. Restoring ecosystem structure and function will be more effective than restoring locations in order to achieve a sustainable UMRS because process-based restoration will be more resilient to human and natural disturbances. The success of restoration planning depends on identifying key ecological functions and processes within the UMRS and incorporating them into goals and objectives at all levels.

The ecosystem-wide goal proposed by the Science Panel to the NESP for consideration is:

> *…to conserve, restore, and maintain the ecological structure and function of the Upper Mississippi River System to achieve the vision of the Navigation and Ecosystem Sustainability Program.*

This goal implies conserving the UMRS's remaining structure and function while restoring the degraded components to realize a sustainable UMRS. Five system-wide objectives framed within essential ecosystem characteristics (EECs) are identified to manage for:

1. a more natural hydrologic regime (hydrology & hydraulics);
2. processes that shape a diverse and dynamic river channel (geomorphology);
3. processes that input, transport, assimilate, and output materials within UMR basin river-floodplains: water quality, sediments, and nutrients (biogeochemistry);
4. a diverse and dynamic pattern of habitats to support native biota (habitat), and;
5. viable populations of native species and diverse plant and animal communities (biota).

Examples of performance criteria (Section 5) are provided to promote thought and discussion among partners. Whatever performance criteria are ultimately adopted, they should be based on ecologically attainable future conditions defined by river managers and stakeholders aided by reference conditions. The task of refining these draft objectives and performance criteria at system and project levels depends on collaboration between river managers and the NESP partnership.

The NESP Panel recognizes that achieving system-wide objectives will remain largely project based and propose the following 10 guidelines to help facilitate linking project-scale activities and system-wide objectives:

1. describe and quantify ecosystem objectives (desired future conditions and outcomes) anticipated for the project;
2. identify system-wide goal(s) and objective(s) addressed by the project outcomes;
3. specify how the project will contribute to the desired future conditions;
4. evaluate the project in relation to other management and restoration actions;
5. identify and describe data to be collected and used to measure project performance;
6. implement the project (i.e., build, manage);
7. monitor project performance;
8. compare measured performance with anticipated outcomes/desired conditions;
9. if the project produces desired conditions, maintain project as necessary, and;
10. if the project has not produced the desired conditions, either revisit steps 3 through 9 or abandon the project.

The Science Panel proposes to further develop system-wide goals and objectives to implement UMRS adaptive management. It is anticipated these steps will include the following activities:

1. In collaboration with Project Delivery Teams (PDTs), Navigation Environmental Coordination Committee, and others, use this report and additional input to define an acceptable working approach for further developing reach- and system-wide objectives and performance criteria;

2. Integrate the 43 UMRS environmental objectives reported in Barko et al. (2006) into a system-wide perspective by clarifying the functions they address and the scales at which they apply;

3. With the aid of deliverables from activities 1 and 2 above, hold a series of workshops with the river management community to refine and quantify system-wide and reach- scale objectives and establish performance criteria;

4. Use the workshops to identify a target objective (e.g., restore in-channel sediment transport from the UMRS; re-establish migration pathways of native fishes) at each reach scale for testing and adapting goals, objectives, and performance criteria;

5. Translate these objectives into projects that collectively address reach- and system-level functions and processes;

6. Follow the guidelines to implement project(s), and;

7. Use lessons learned to revise ecosystem objective(s), performance criteria, and management actions.

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1 Introduction

Annually, over $1 billion are allocated to restoring rivers and streams in the United States (Bernhardt et al. 2005). Multi-million dollar, ecosystem-scale river restoration programs are underway for many of our nation's great rivers, including the Colorado, Columbia, Mississippi, Missouri, and Rio Grande, along with similar programs for river-associated wetlands in the California Bay-Delta, Chesapeake Bay, coastal Louisiana, and Florida Everglades. Specifically for navigated rivers within the Upper Mississippi River Basin (UMRB), about $152 million were expended on 175 restoration projects between 1972 and 2005 (O'Donnell and Galat 2007a).

All of these restoration programs involve a complexity of water resource issues and multiple, often competing, stakeholders interests (Hayes 2002). All reflect a contemporary perspective of *restoration* defined herein as *improving hydrologic, geomorphic and ecological processes to reestablish a river that is more self-regulating and integrated into its ecological, social, and economic landscapes*. (adapted from Middleton 1999, Society for Ecological Restoration 2004, Wohl et al. 2005; see Box 1 of Barko et al. 2006 for evolution of the term *restoration*). The diversity of conflicting issues, significant socio-economic consequences of management decisions, and degree of scientific knowledge required have resulted in numerous uncertainties regarding resource responses to past and current management actions.

The Navigation and Ecosystem Sustainability Program (NESP), when authorized, will direct $3.28 billion (2001 U. S. dollars) over the next 15 years for the dual proposes of improving navigation efficiency and environmental sustainability within the Upper Mississippi River System [(UMRS), U.S. Army Corps of Engineers (USACE) 2004]. Decisions within NESP to address and resolve the complex assortment of ecological needs and objectives within the UMRS will be conducted through a long-term commitment to a policy of adaptive management (USACE 2004). The NESP Science Panel was convened to provide the scientific expertise needed to guide system-wide adaptive management and restoration of the UMRS. The systemic perspective emphasized by the Science Panel derives from two sources. First, responsibilities of the Science Panel include, "develop(ing) a science-based process for sequencing *ecosystem* management and restoration work *system-wide*." [Pg 519, Section 14.3.7.2. Science Panel; italics added (USACE 2004)]. Secondly, the draft authorizing legislation for NESP directs it to, "establish *ecosystem* restoration goals and identify specific performance measures designed to demonstrate *ecosystem* restoration [S.728 WRDA 2006, Sect. 1002, (3), (i); italics added].

A reach- and system-wide approach will help river managers determine outcomes for individual projects that will contribute to NESP success at these larger spatial scales. The process will capture large-scale objectives such as animal migrations and sediment dynamics that may not appear in project or site plans.

The first steps in system-wide adaptive management are to develop a "top-down" process that starts with a vision statement, then steps down to system and reach level goals, and assists project teams in developing objectives to achieve these goals. *Adaptive management* is *a process that promotes flexible decision making that can be adjusted as outcomes from management actions and other event s become better understood* (Williams et al. 2007). A system-based approach for UMRS restoration encompasses project-based planning and management and effective science within an adaptive management conceptual framework (Figure 1).

Figure 1. A conceptual framework of adaptive ecosystem management (AEM) for large floodplain river restoration. The three loops of the figure represent: scientific research (inner loop); bottom-up, project-based adaptive management (middle loop); and a top-down, system-wide perspective (outer loop). Also represented in the figure is the interaction among the three loops (vertical white arrows) necessary for successful AEM. Loop interaction and communication may be accomplished by use of numerical models that allow scientific hypotheses developed and tested in the inner loop to be transformed to knowledge for better project development in the middle loop and potential systemic forecasting on the outer loop. Alternatively, system-wide goals and objectives proposed in the outer loop can be translated into draft design criteria in the middle loop and tested using the scientific approach outlined within the inner loop. (L. Weber, IIHR, University of Iowa, Iowa City, Iowa)

Evolving political and scientific issues contribute to the difficulty of specifying long-term restoration goals for the UMRS. The goals, therefore, cannot be viewed as fixed endpoints, but are instead approximations developed by careful analysis of existing data and anticipated stakeholder requirements, reevaluated as new knowledge becomes available, and updated in response to changing social perspectives. The Science Panel believes that a final set of system-wide goals and objectives for the NESP will result from integration of system-reach and pool-project approaches within a single framework as illustrated in Figure 1.

This document is intended as a foundation for developing and implementing a system-wide, adaptive approach to management and restoration of the UMRS (Lubinski and Barko, 2003, Barko et al. 2006). In this report the Science Panel will: (1) review the existing Vision Statement for the NESP and revise it for operational purposes; (2) propose and discuss goals for addressing the ecological component of the UMRS vision; (3) outline examples of potential UMR system- and reach-wide ecosystem objectives and performance criteria to stimulate discussion for further developing objectives through a collaborative process; (4) recommend initial guidelines for addressing system-wide ecosystem objectives; and (5) identify next steps to implement the process.

The intent is to provide river managers, decision makers, and stakeholders a living document that can be updated as knowledge about the river's response to management and restoration actions become available.

2. Navigation and Ecosystem Sustainability Program Geographical Jurisdiction and Authority

The spatial hierarchy for the Upper Mississippi River (UMR) includes the UMRB, the UMRS, river-floodplain reaches, navigation pools, and project areas (Barko et al. 2006). The UMRB is approximately 189,000 mi^2 and includes the entire watershed of the Upper Mississippi River above the confluence of the Ohio River, excluding the Missouri River Basin (UMRB, Figure 2). The UMRS was defined by Congress in the Water Resources Development Act (WRDA) of 1986 (33 U.S.C. §§ 2211) as the commercially navigable reaches of the Upper Mississippi River from Minneapolis, Minnesota, to Cairo, Illinois (854 river miles); the Illinois Waterway from Chicago to Grafton Illinois (327 river miles); and navigable portions of the Minnesota (15 river miles), St. Croix (24 river miles), Black (1 river mile) and Kaskaskia Rivers (36 river miles) (Figure 3). Within these floodplain river reaches, the UMRS encompasses aquatic, terrestrial, and transitional habitats and their biota. A river *reach* is a continuous segment of river and its associated floodplain. Four commonly referenced UMRS reaches are defined largely by land use and navigation system development (Box 1).

The geographic jurisdiction for the NESP, as defined in the 1986 WRDA, is limited to the main channel and floodplain of the UMRS. However, many of the ecological challenges experienced by the UMRS derive from activities at the watershed or UMRB scale, well outside the river channel and immediate floodplain. Additionally, about 95 percent of the UMRB is in private ownership (O'Donnell and Galat 2007); therefore private-land stewardship programs are an essential component of a system-wide approach to restoring the UMR within a social-ecological context. To resolve restoration challenges deriving from watershed activities (e.g., excessive sedimentation and nutrient loading due to changes in land use), NESP managers must collaborate with other agencies and landowner groups having authorities and interests in the watershed.

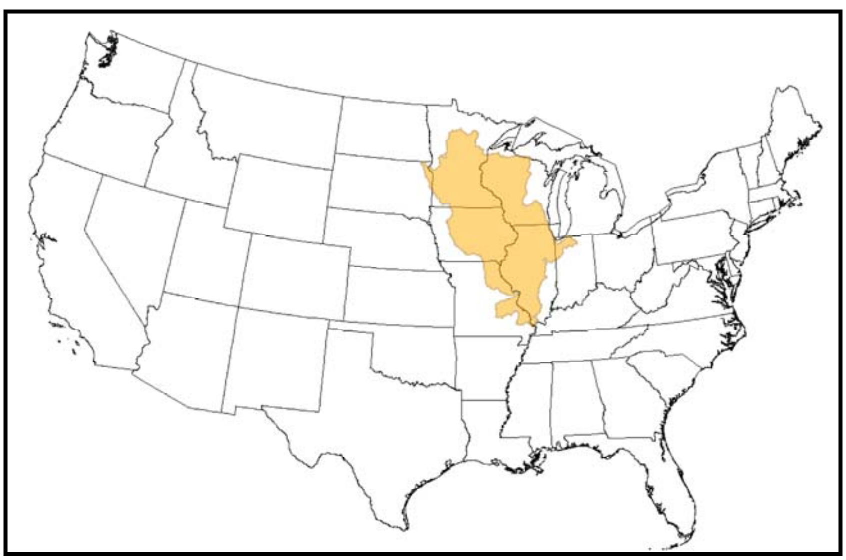

Figure 2. Upper Mississippi River Basin (Barko et al. 2006)

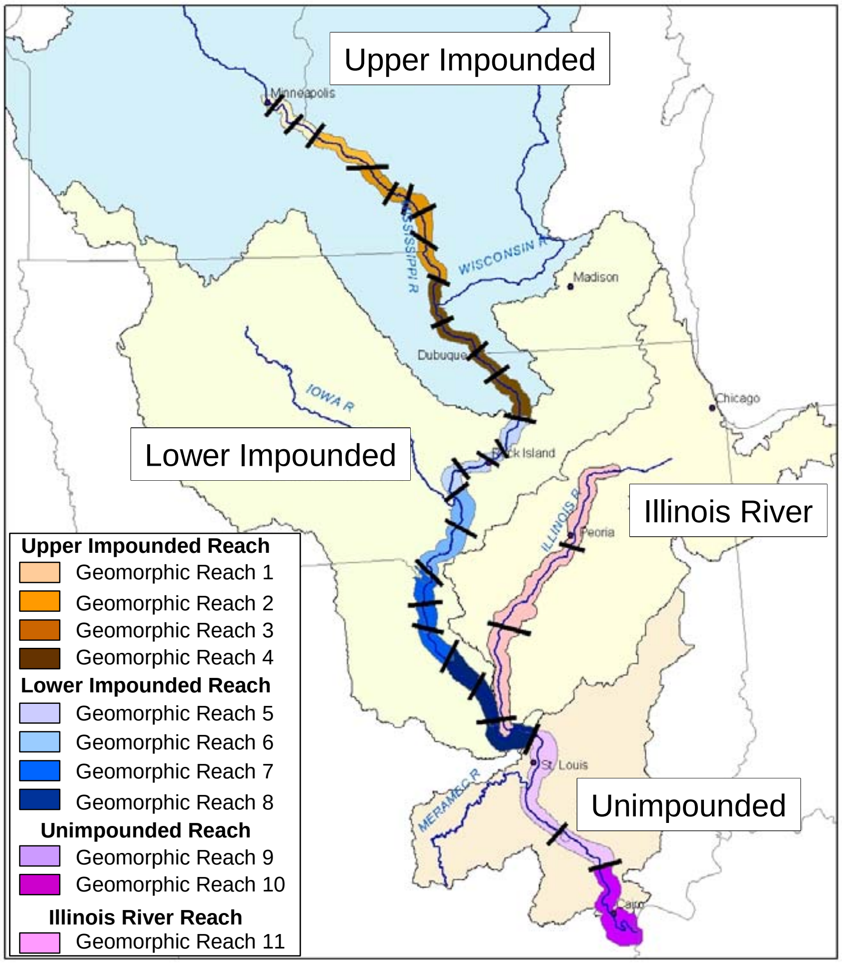

Figure 3. The UMRS is frequently classified into 4 major floodplain reaches and 11 geomorphic reaches (adapted from The Nature Conservancy, Madison, Wisconsin).

BOX 1: Commonly-Referenced Upper Mississippi River System Floodplain Reaches (USGS 1999)

- **Upper Impounded Reach** includes UMR Upper St. Anthony Falls Pool in Minneapolis downstream to Lock and Dam 13 near Clinton, Iowa.
- **Lower Impounded Reach** includes UMR Pools 14 through 27 near St. Louis Missouri.
- **Unimpounded Reach** or **Open-river** is the unimpounded part of the UMR beginning just south of the Missouri River (below Lock 27 near St. Louis) and extending to the mouth of the Ohio River at Cairo Illinois.
- **Illinois Waterway** extends from Chicago Illinois to the confluence with the Mississippi River at Alton, Illinois.

3. A Science Perspective of the NESP Vision Statement

The NESP vision statement provides the foundation for and justifies the program's goals and objectives. It also sets the broad direction for future ecosystem restoration work. The NESP vision statement originates from events referred to collectively as the River Summit (Upper Mississippi River Summit 1996). The Summit was a series of meetings that brought together people from many different river interest groups, including agriculture, navigation, and conservation non-governmental organizations as well as state (e.g., Departments of Natural Resources, Departments of Transportation) and federal (U. S. Fish & Wildlife Service, U. S. Coast Guard, Natural Resources Conservation Service, U. S. Environmental Protection Agency, National Park Service) agencies. The vision statement drafted by River Summit participants and subsequently recommended as the NESP vision (Barko et al. 2006) is: *to seek long-term sustainability of the economic uses and ecological integrity of the Upper Mississippi River System.*

Three concepts underpin the vision statement: balance, sustainability, and ecological integrity. These concepts and their definitions need to be fully understood, revised if need be, and endorsed by NESP partners. Without a consensus understanding of these terms and their potential consequences for future program development, the vision statement is merely a platitude instead of being a viable, long-term foundation of the NESP goals and objectives hierarchy.

Balance. The word "*and*" in the vision statement linking economic uses *and* ecological integrity implies a mutual agreement or belief among the program partners, and society as a whole, that total UMRS well-being requires a balance between economic prosperity and ecosystem quality. This emphasizes that achieving only one set of values, economic or ecosystem, will not equate to NESP program success. It also points to the need to develop methods for measuring ecosystem quality and socio-economic prosperity so that *balance* can be defined and evaluated operationally (Figure 4).

Less obvious perhaps, is that by recognizing the co-dependencies that exist between socio-economic prosperity and ecosystem quality, NESP partners also accept that they cannot "have it all." At certain times and locations, socio-economic and ecosystem goals of the UMRS conflict with each other. Achieving maximum economic values and un-compromised ecosystem quality across all projects planned for the UMRS is not feasible. By embracing the vision statement, program partners have committed to finding a mixture of human uses and ecosystem condition in which each is at an acceptable, but not maximum, level. To achieve certain ecosystem restoration goals, some management changes by navigation or development interests will likely be necessary. Clearly increased costs incurred by any such changes will have to be strongly justified and valued, because the river's economic interests and needs are well established. The NESP cannot succeed if such economic and ecological trade-offs are not recognized and incorporated into the management and restoration process. The inclusion in NESP of measures of UMRS ecosystem goods and services will contribute to future quantitative trade-off analyses.

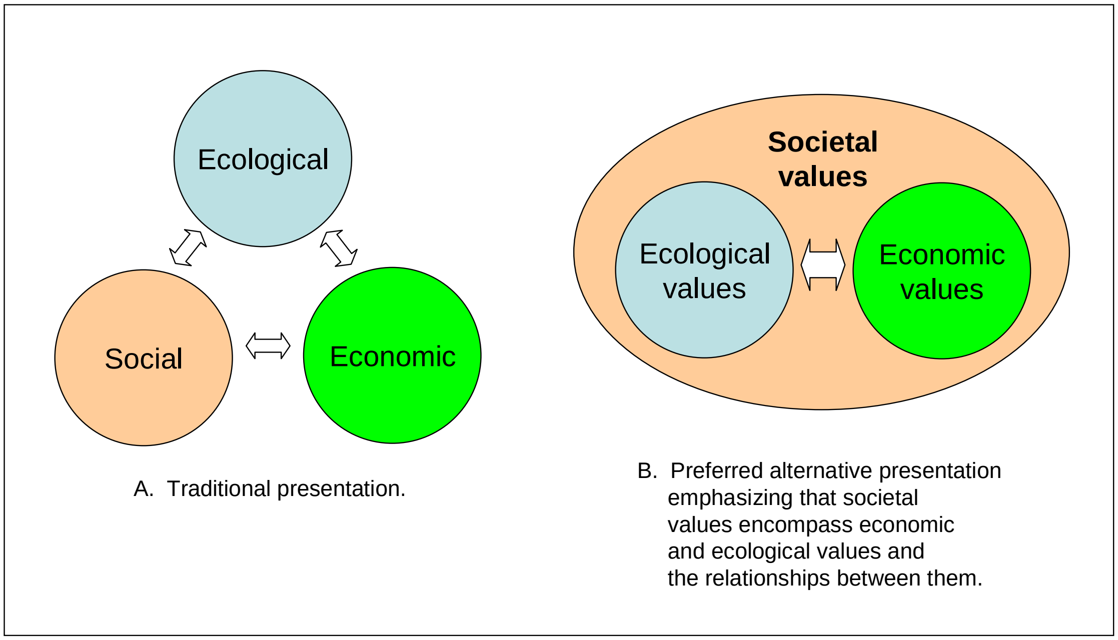

Figure 4. Two Perspectives of the Capacity of Ecosystem Management To Embrace Ecological, Economic, and Social Conditions and Values. A. The traditional view illustrating the relationships among social, economical, and ecological components of ecosystem management (adapted from Harris and van Diggelen 2006). B. A more adaptive perspective of ecosystem management. (Lubinski et al. 2007)

Sustainability as defined for NESP is, *"the balance of economic, environmental, and social conditions so as to meet the current and future needs of the Upper Mississippi River System without compromising the ability of future generations to meet their needs"* (Upper Mississippi River Summit 1996). This goal for sustainability of social-ecological systems was adapted from the Bruntland Commission (World Commission on Environment and Development 1987) and endorsed by the Upper Mississippi River Basin Association and the 1997 Joint Governors' Proclamation (Upper Mississippi River Basin Association 1997).

Understanding the term *sustainability* as it has been applied to ecosystems is critical to successful restoration planning (Box 2). Since the last glacial episode ended about 18,000 years ago, ecological conditions of the UMRS have varied in space and time, controlled largely by global and regional climate patterns and hydrologic regimes. These driving forces define a historical range of variation and many of the animals and plants of the river have adapted to this variability. The temporal and spatial variability of conditions over time contributed to the river's physical and biological diversity. The sustainable river ecosystem was *resilient* (Box 2) to natural disturbances (channel-forming floods, droughts, ice dams and scour, cold or warm decades, etc.) and thus retained its structural and functional attributes.

BOX 2: Definitions Helpful to Understanding the NESP Vision Statement
(Walker and Salt 2006 unless otherwise indicated)

Sustainability (general) – "The likelihood an existing system of resource use will persist indefinitely without a decline in the resource base or in the social welfare it delivers". The cornerstone of sustainability is **resilience**.

Resilience (ecological) - The ability of a system to absorb disturbance and still retain its basic function, structure, and feedbacks.

Sustainability (UMRS specific) - "The balance of economic, environmental, and social conditions so as to meet the current and future needs of the Upper Mississippi River System without compromising the ability of future generations to meet their needs" (Upper Mississippi River Summit 1996; Upper Mississippi River Basin Association 1997).

Social-ecological systems – Interacting systems of humans and nature.

The flow and stage relationships of the UMRS reaches have been substantially changed by two centuries of increased urbanization, agricultural land-use practices in the basin, stream channelization projects, and construction and operation of dams on the tributaries and the main channel. The most visible outcomes of these changes in the impounded reaches of the UMRS have been, first, the expansion of the water surface, and second sedimentation and ecological "aging" of the navigation pools. In the open river, the main channel has deepened as a result of erosion.

The NESP Science Panel contends that these collective disturbances have changed controlling variables and feedbacks that drive the UMRS's ecological dynamics sufficiently to have forced the UMRS over a threshold and into a new ecological regime wherein the patterns and magnitudes of the underlying controlling variables and their feedbacks to the rest of the system have changed. Changes in the physical template of the river, its flow regime, biota, and socio-economic activities within the basin will continue for decades as the river approaches a new dynamic equilibrium. The long-term degradation, and especially homogenization, of many river habitats is the underlying justification for the environmental component of the NESP.

Climate change is an additional source of uncertainty that may affect the river's resilience (i.e., stage, flow, sediment transport, and biotic relationships) in the future. Many reliable reports point to increasing extreme events (Milly et al. 2005; Falloon and Betts 2006; Jha et al. 2006) with rivers likely experiencing new flow and sediment regimes (Poff et al. 2002). It is no longer clear that rivers will retain the ability to adjust to these changes in ways that minimize threats to social-ecological systems (Palmer et al. in press). Flood effects will be intensified by agricultural levees in the floodplain that force the river's flows through a narrow channel (Pinter 2005), while droughts will compound the negative effects of impoundment. Forecasting future conditions for the UMRS will need to embrace increased uncertainty under a changing climate.

These situations make it difficult to predict when the river ecosystem might again become sustainable. That is, when it might be resilient enough to establish a new, long-term "range of variation" to which its plants and animals will adapt and thereby have the capacity to avoid unwelcome surprises in the face of external disturbances.

A sustainable river has obvious benefits to humans, mainly that a sustainable UMRS will maintain its capacity to provide the nation with the goods and services that support our expected quality of life. It would require less effort and funding for management, and be better able to withstand future threats. However, we know that the navigation system is not self-sustaining, and early NESP planning efforts have not made it clear if sustainability is in fact an important ecological criterion (Figure 5). The NESP partnership must determine the degree of sustainability desired and make that clear in their economic and ecosystem restoration goals and objectives. In addition, special features of the NESP modeling and monitoring strategies will have to be designed to forecast the degree to which the system is expected to be sustainable and to evaluate that prediction.

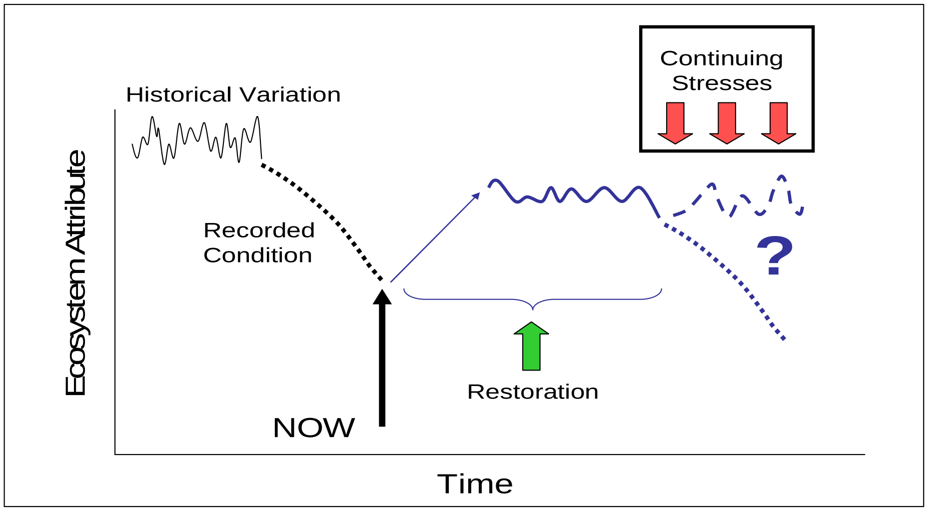

Figure 5. Many of the stresses, such as altered land use, urbanization, commercial navigation, and floodplain isolation that have degraded the quality of the UMRS in the past are expected to continue. Restoration is intended to bring the level of the river's quality up to some desired state, but if that state is not self-sustaining, restoration efforts will have to continue indefinitely. (K. Lubinski, UMESC, U. S. Geological Survey)

Ecological integrity is defined as "*the capacity of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region.*" (Karr and Dudley 1981, Karr and Chu 1999). Ecological integrity refers to a system's wholeness, including the presence of all appropriate elements and the occurrence of all processes at appropriate rates (Angermeier and Karr 1994). As defined here, it refers to conditions under little or no influence from human actions; a biota with high integrity reflects natural evolutionary and biogeographic processes (Angermeier and Karr 1994).

Adopting *integrity* as a part of a vision statement means aiming for a system that resembles this naturally evolved state as much as possible (Angermeier 1997). It seems unrealistic, and perhaps irresponsible, to state that the vision of NESP is to return the UMRS to this level of ecological integrity (i.e., exhibiting undisturbed conditions). This would require elimination of dams, levees, and the basin agricultural practices that humans now depend on. This is a practical limitation that is fundamental to understanding what a program like NESP can and cannot achieve. At this point, the overall vision of NESP should be thought of as a choice that will be influenced by scientific forecasts as well as economic and social values (Figure 6).

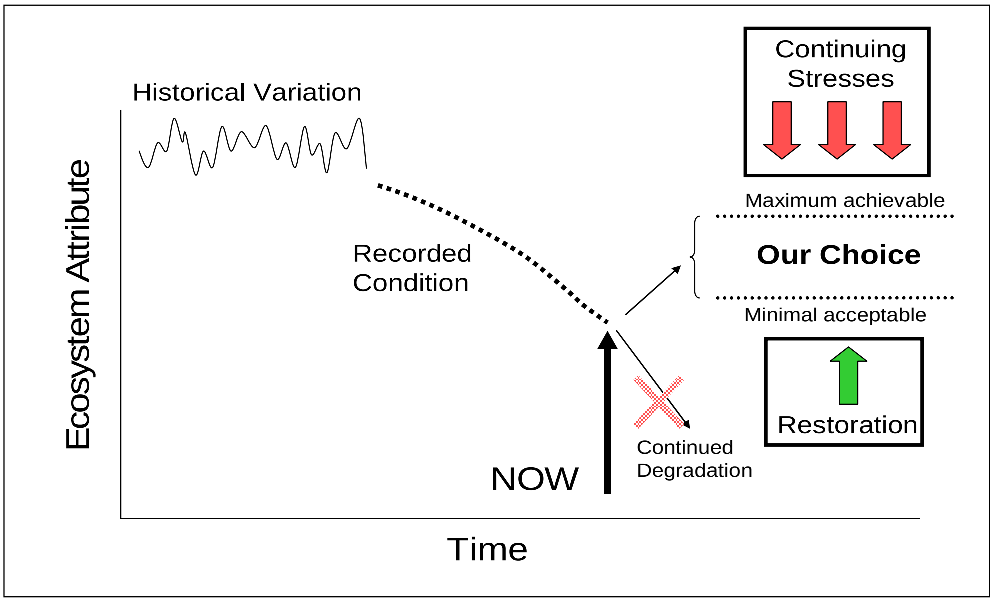

Figure 6. Society has decided that is unacceptable to let the quality of the UMR continue to degrade. The ultimate restoration state will be greater than what is minimally acceptable, but less than the historical quality of the river. The maximum achievable level will be constrained by continuing stresses and restoration resources. (K. Lubinski, UMESC, U. S. Geological Survey)

Because ecosystem management is a relatively new approach to natural resource management, the terminology associated with it is still in development. Partners need to understand what the vision term "ecological integrity" implies based on the above definitions and consider revising the vision statement accordingly.

The NESP Science Panel proposes that the existing definition of UMRS sustainability can be simplified for operational purposes as: *to achieve sustainability of social-ecological systems within the Upper Mississippi River System*. The intent of the original statement implies that the vision will be achieved as long we can demonstrate that we are *seeking* sustainability, even if little progress towards *achieving* sustainability is made. The term sustainability as defined herein (Box 2) "…*will persist indefinitely…*" making inclusion of *long-term* in the vision statement redundant.We all live and operate in socio-economic systems that interact with the ecological system of the UMRS; we exist in what is referred to as a *social-ecological system* (Walker and Salt 2006; Box 2). This term encompasses the dualism of economic uses and ecological quality in the original vision statement, retains the concept of balance, but eliminates the 'return to the past' issues associated with *ecological integrity*.

Sustaining the UMRS social-ecological system necessitates balancing its economy and ecology for it to be resilient to future threats (Figure 4). The attributes of a sustainable UMRS will be defined by the goals and objectives that the partners adopt. It is the position of the NESP Science Panel that for the UMRS to be sustainable, sustainability of the entire UMRB must be sought. The UMRS does not operate independently of watersheds in the UMRB; its economy and ecology extend beyond Corps authorities and so must a system-wide approach to restoration.

4. Rationale for a System-Wide Approach to UMR Restoration

A system-wide approach is *process based*, rather than *site based.* Restoring ecosystem processes and function will be more effective at achieving a sustainable UMRS than restoring sites because a functionally intact UMRS will be more resilient to human and natural disturbances. Successful river restoration planning begins with the recognition that ecosystem processes operate at multiple spatial and temporal scales (Bohn and Kershner 2002). Addressing restoration from a process and function perspective at ecologically relevant spatial scales (e.g., pool, reach, UMRS) in addition to the more traditional local project-based approach of directing efforts to restoring compositional and structural elements at individual sites is required for success at achieving social-ecological sustainability (Box 3).

BOX 3: Elements of Ecosystems
(adapted from Society for Ecological Restoration 2004)

Process refers to rates of essential ecosystem functions, such as population growth, photosynthetic rate, decomposition rate, dispersal rate. (e.g., effects of a 2-foot early-summer drawdown on production of annual moist-soil plants)

Function defines the dynamic attributes of ecosystems, including density of organisms, interactions among organisms, and interactions between organisms and their environment. (e.g., effects of changes in winter dissolved oxygen levels on density of overwintering white crappie)

Structure refers to the parts of the whole or the architecture of a community. It includes the pattern of habitats, the frequency distribution of species-populations, and the sizes and life forms of the organisms that compose communities. (e.g., size-frequency distribution of largemouth bass in Pool 11)

Composition refers to the taxonomic array of species present, and species richness, (e.g., number of different floodplain forest tree species present at Pool 5)

The success of restoration planning depends on identifying key ecological functions and processes within the ecosystem of concern and understanding these in relation to the project vision, goals, and objectives (Pastorok et al. 1997). For example, a system-level objective from a functional perspective might direct planning efforts towards restoring recruitment of native migratory fishes. Constructing fishways at locks and dams is a necessary activity contributing to this objective. However, reconnecting longitudinal migratory pathways is likely insufficient by itself to achieve the system objective as other stressors such as loss of spawning habitat or poor water quality may also be contributing to declines in recruitment of native migratory fishes.

While this difference may seem to be one of semantics, it has powerful implications for evaluating restoration success. A performance criterion for building a fishway is, *do X number of fishes pass through the dam?* Performance criteria for a local project are often limited to implementation effectiveness (Did the fishway work as designed?), whereas performance criteria for restoring migratory fish recruitment might include, *do a sufficient number of fish reach their ancestral spawning areas and reproduce, or is there a detectable population-level response within a river reach?* In our example, a system-level approach encompasses the project objective (Figure 1); additionally, it addresses the fundamental restoration goal of ecological effectiveness.

Ecosystem objectives at the project-area scale can be more than simply ways to test implementation performance. At this resolution ecosystem objectives can address ecological effectiveness by setting Specific, Measurable, Achievable, Relevant, and Time bound criteria for structure, function, or process. An important point is that project-scale objectives do not necessarily accumulate to achieve system-scale objectives. Project scale management actions that increase structure (e.g., habitat) may add up, but others for function or process generally do not. For example, a system-level objective of reducing export of nitrogen could be attained by many projects that reduce nitrogen loading in the UMRB and other projects that remove nitrogen (N) in shallow-aquatic mainstem and floodplain habitats. The nitrogen cycle processes are complex and the simple sum of loading reductions and floodplain N-removal efforts may not add up to the objective for N export (as nitrate—not Total N) at Cairo, Illinois.

How one looks at the challenge of restoration planning, from the top-down (restore recruitment of migratory fishes) or the bottom–up (construct fishways), will influence ecological effectiveness of restoration practices. There is strong ecological evidence supporting the NESP Science Panel's view that a system-wide perspective is a holistic, cost-effective, and ecologically sound planning approach to maintaining social-ecological sustainability of the UMRS (National Research Council 1992, Angermeier and Karr, 1994, Meffe and Carroll 1994, Harwell et al. 1999, Ehrenfeld 2000, Ryder and Miller 2005, Jentsch 2007).

Nevertheless, system-wide restoration is less often implemented than site-based solutions. Reasons for this include: ecosystem based solutions are more abstract, typically more difficult to measure and judge if successful, and slower to show a response (Ruiz-Jaen and Aide 2005). Much has been written on what constitutes indicators of ecological processes and functions in ecology, and Table 1 summarizes many of these. A major challenge within the NESP will be to develop realistic system-wide performance criteria, related endpoints, and monitoring programs to track restoration success.

Table 1. Processes affecting river restoration included under "ecosystem function". Variables included are expanded from National Research Council (1992), Angermeier and Karr (1994), Meffe and Carroll (1994), Harwell et al. (1999), Ehrenfeld (2000) and others. See Box 3 for distinctions among functions and processes.

Category	**Function/Process**
Material Flow	Nutrient cycling (N, P, Si, C)
	Nutrient retention/loss (processing/fluxes)
	Energy flow
	Primary and secondary productivity
	Organic matter size fractioning and processing
	Carbon storage
	Water flow
	Transfers to/from other ecosystems
	Decomposition rate
	Contaminant dispersal, transformations
Physical Elements	Intra-and inter-annual hydroperiods
	Flooding and drying cycles (including stage changes)
	Channel cut & fill alluviation (channel mosaic)
	Island/bar deposition and erosion (channel mosaic)
	Delta formation/erosion (channel mosaic)
	Sediment supply/loss/transport
	Retention dynamics (see biological)
	Light/heat input
	Longitudinal, lateral, and vertical (groundwater) hydrologic connectivity
	Water quality changes
	Soil formation rates
	Climate change
Biological Elements	
Genetic	Inbreeding/outbreeding rate
	Rate of genetic interchange between populations
	Genetic drift
Population/species	Population growth, colonization, range expansion or contraction, fluctuation trends of species of interest
	Fertility, fecundity, recruitment, survivorship, mortality, turnover and other individual and population health parameters
	Dispersal/migration rates
Community/ecosystem	Frequency, intensity, periodicity, predictability, or rotation period of natural (e.g., fires, floods, storms, disease) and anthropogenic (e.g., flow alterations, disking, logging, shoreline development) disturbances
	Resilience (ecological) to disturbances
	Rebounding from disturbances (engineering resilience)
	Herbivory rates
	Predation rates
	Rates of competitive displacement
	Rate of parasitism
	Rate of patch fragmentation
	Rate of plant succession
	Large woody debris retention

5. System-Wide Goals and Objectives and Examples of Performance Criteria for the UMRS

Once an agreed-upon vision for the restored UMRS is reached, goals and objectives to realize the vision must be articulated (Reckhow 1994; Pastorok et al. 1997; Ehrenfeld 2000; Williams et al. 2007). The ecosystem-wide goal proposed by the Science Panel to the NESP for their consideration is: *to conserve, restore, and maintain the ecological structure and function of the Upper Mississippi River System to achieve the vision of the Navigation and Ecosystem Sustainability Program*. This goal implies conserving the best available examples of the UMRS's existing structure and function and enhancing the degraded components to realize a sustainable UMRS. The NESP Science Panel (Lubinski and Barko 2003) identified five essential ecosystem characteristics [(EECs) Harwell et al. 1999] that compose the ecological structure and function of the UMRS and are necessary to achieve this goal. These EECs were incorporated into a general conceptual model of the UMR (Lubinski and Barko 2003) that illustrates how hydrology/hydraulics, geomorphology, and biogeochemistry (tier 1) provide a physical template for habitat and biota (tier 2) and the strong interdependencies among all EECs (Figure 7). Following is a brief review of the rationale for UMRS EECs as each provides the foundation for system-wide objectives.

Hydrology and Hydraulics. River hydrology and incipient hydraulic conditions provide the environment within which native river species flourish (Poff et al. 1997, Bunn and Arthington 2002). Regulation of the river system by construction and operation of locks and dams, construction of channel "training" structures, and development of massive levee systems have significantly altered hydraulic conditions throughout the entire UMRS. In general, the diversity of hydraulic conditions in the UMRS has been simplified both spatially and temporally by river regulation. Moreover, variability in the hydraulic regime has been altered throughout the entire system. Associated changes in river geomorphology and habitat conditions have been extensive, thus affecting the integrity of river biological assemblages.

To the extent possible under current conditions of river regulation, restoration and maintenance of native river biota will require reestablishing a more natural hydrograph with attention to the magnitude, frequency, seasonal timing, duration, rate of change, and spatial extent of both low-water and high-water periods. Hydrodynamic conditions and hydraulic residence times in channels, backwater areas, and in floodplains will have to be restored to the extent possible to meet requirements of native species (as opposed to invasive, non-native species (Figure 8), recognizing that many of these requirements are essentially unknown at present, but likely lie within the range of historical variation that existed prior to regulation.

In conjunction with the implementation of flow and water-level projects to restore hydrologic and hydraulic regimes, it will be necessary to evaluate a variety of biotic response variables (unknown at present) in addition to traditional physical indicators (e.g. flow velocities, water levels, discharge, hydraulic residence time, etc.). These projects with full attention to their biological effects need to be undertaken under the auspices of the NESP.

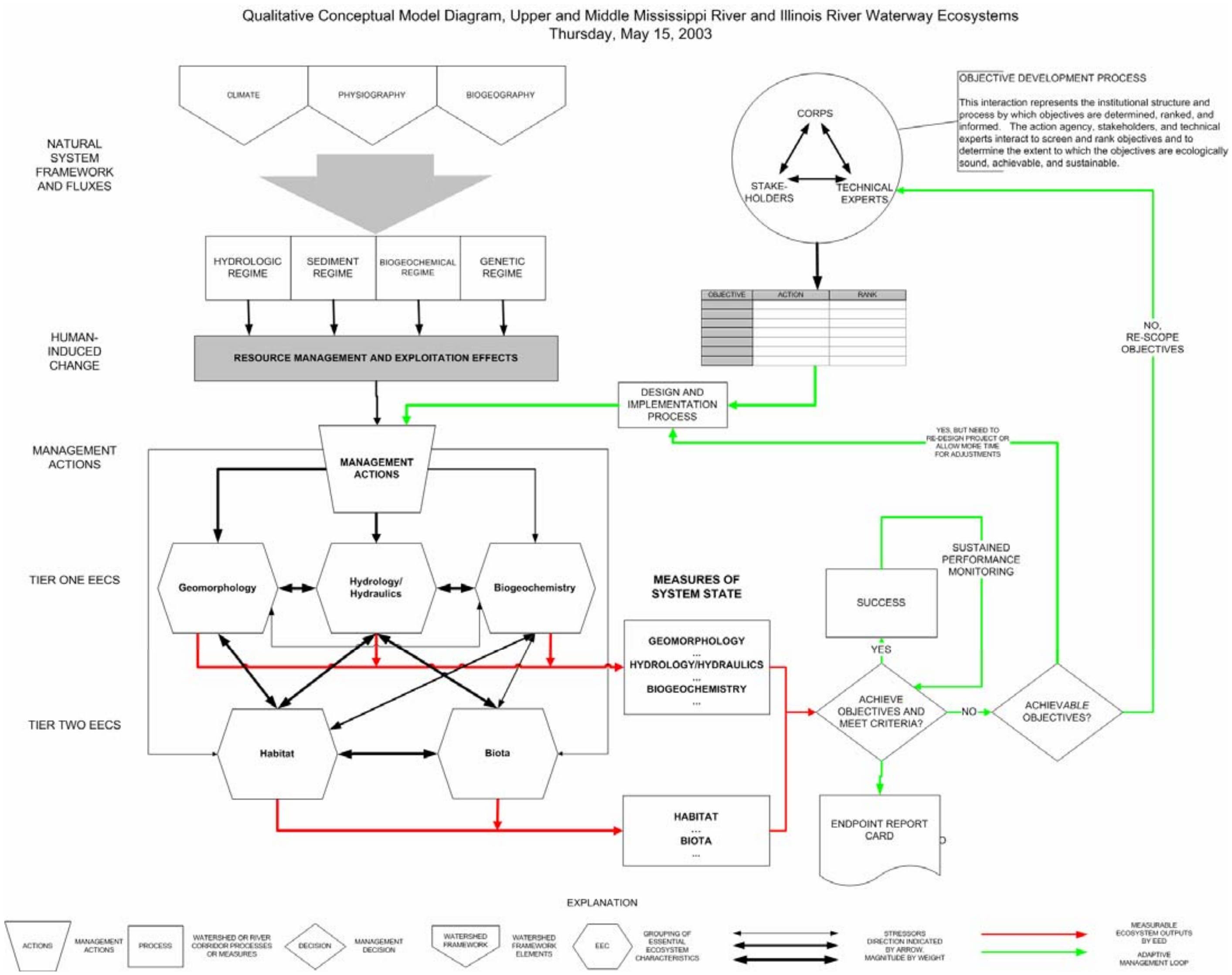

Figure 7. General conceptual model for the Upper Mississippi River. The model identifies important drivers, stressors, and endpoints relevant to risk assessment and adaptive management in the large-scale and complex UMR ecosystem. The conceptual model identifies the natural framework as including climatic, physiographic, and biogeographic drivers that influence the nature and dynamics of water, sediments, chemicals, and biota. (See Lubinski and Barko 2003 for additional explanation)

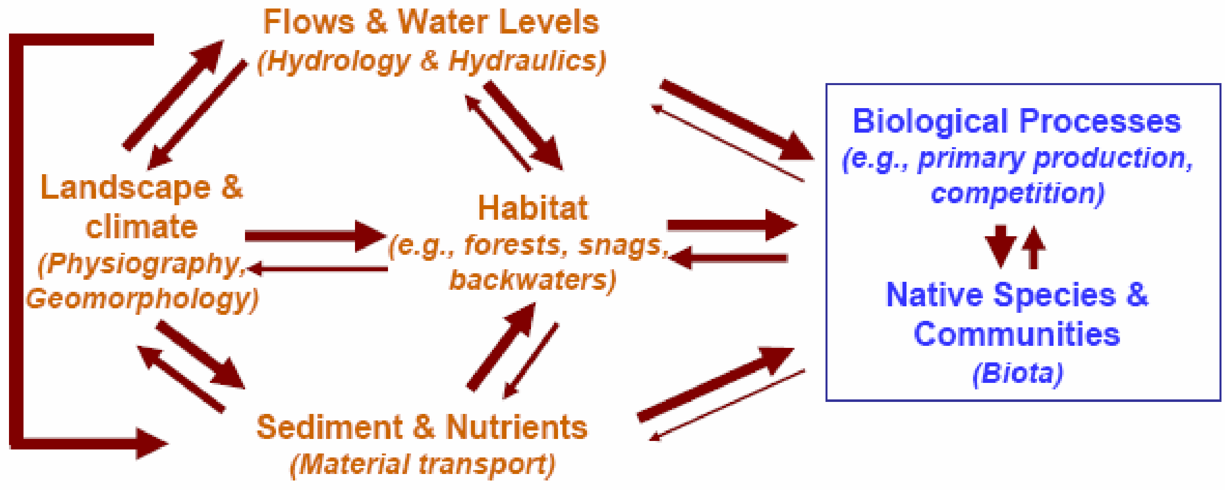

Figure 8. Essential Ecosystem Characteristics (EECs) and their interactions within the Upper Mississippi River System. Biological processes and species/communities (in blue) are "bottom line" restoration targets within the Navigation and Ecosystem Sustainability Program. Arrows indicate interactions among most elements are bi-directional, but relative strengths vary as shown by width. Biological processes and biota are primary end-points for evaluating success through enhancement of physical processes and habitat. Commonly used terms are in bold, along with some of their technical analogs.

Geomorphology. Movements of water and sediments to deposit, maintain, and erode topographic features of UMR channels and floodplain surfaces constitute geomorphic processes. Sources of water movement include river and tributary flows, surface runoff, and direct precipitation. Geomorphic processes operate at all spatial and temporal scales within the UMR basin (Figure 8). Physiography and climate, including glaciations, have interacted over millennia at the landscape scale to create the tributary network, river bluffs, floodplain terraces, meander belts, and complex channel gradients and configurations that collectively define the UMRS. Erosion, transportation, and deposition of sediments from the UMRB to its tributaries, river channels and their floodplains, and ultimately to the Gulf of Mexico are primary geomorphic processes. Water movement shapes UMRS channels and controls connectivity between the channel and its floodplain. Water movement and sediment transport interact to produce the topographic diversity, elevation variability, and substrate or soil composition of channel and floodplain landscapes. Dominant channel and floodplain habitats sculpted by these geomorphic processes that differ among reaches include main-channel borders, secondary and tertiary channels, tributary deltas, distributary channels, islands and sandbars, mudflats, backwaters, floodplain lakes and wetlands.

It is this ever-changing pattern of channel and floodplain surface features that constitutes the habitat template which supports a diverse and healthy native biota and the goods and services they provide the UMRS. For example, geomorphic processes build sandbars and maintain them free of perennial vegetation. These sandbars provide nesting habitat for softshell turtles and federally endangered least terns. Many riverine fishes require shallow, slow-velocity shoals adjacent to these sandbars as nurseries, and submersed aquatic plants flourish in their down stream, wind-protected zones. The diverse mosaic of vegetation communities ranging from wet meadows, deep marshes, early successional cottonwood-willow forests, and mature silver maple-ash floodplain forests that characterize a cross-section of the UMR floodplain largely result from geomorphic processes that create a variable topography, a diversity of soil types, and dynamic transitions among plant communities.

Primary challenges to restoring dynamic geomorphic processes within the UMRS are the apparent desires of society and the economic benefits afforded by fixed channel configurations, a stable navigation-channel depth, and persistent floodplain landforms. Opportunities for learning center on our ability to substitute mechanical activities such as island building, main-channel dredging, and excavating connections between the main channel and backwaters for the natural hydro-geomorphic processes of cut-and-fill alluviation.

Biogeochemistry (transport and cycling of sediments and nutrients; water quality). Sediments are eroded and transported, often as fine particulate matter that greatly influences water transparency and nutrients. Nutrients (mainly nitrogen, phosphorous, and carbon) fuel the primary production that supports populations of invertebrates, fishes, herpetofauna, and birds. But, excess nutrients can produce noxious algae blooms that inhibit the growth of submersed aquatic plants and contribute to hypoxia in the Gulf of Mexico. Sediments (particularly fine-grained materials) and nutrients are a system-wide concern because the inputs are derived throughout the UMRS and the effects of nutrients accumulate downstream.

The dynamics of sediments and nutrients are defined by their inputs, transportation (including erosion, deposition, and export), and storage. Carbon and nutrients are stored as plant and animal biomass. Nitrogen can be released to the atmosphere through denitrification. Phosphorous is generally bound to sediments; thus, efforts to control phosphorous and sediments are intertwined.

Large inputs to rivers of sediments and nutrients typically occur during extreme flow events, and are therefore linked to the hydrologic and geomorphic processes just outlined (Figure 8). Flood flows bring in new material, redistribute material within the channels and floodplain, and flush accumulated sediments downstream. Droughts and low water levels allow sediments to dry and organic matter to decompose and stimulate plant growth that sequesters nutrients.

Within the UMRS, many of these processes have been affected by human modifications to the river and its floodplain. Inputs of sediments and nutrients from tributaries depend largely on management of the watershed and dams on tributaries, which are beyond the control of NESP. However, management actions within the river channel and floodplain can have substantial effects on the distribution and dynamics of these materials. These actions and processes include dechannelizing tributary deltas to increase sedimentation on the floodplain; increasing floodplain connectivity (levee modifications) to transport materials to and from the floodplain; modifying hydraulic conditions within channels; managing water levels to flood areas or expose sediments; modifying flow patterns that provide water to off-channel areas; and rebuilding eroded terrestrial features such as natural channel levee networks, and channel islands to create wind and flow refuges. Because many natural processes of sediment flushing have been compromised under the current multi-use management strategy, dredging and sediment removal may be necessary as a replacement for natural erosive processes.

Water quality is included under this category because it is greatly influenced by sediments and nutrients. The Science Panel considers water quality to be a critical element in UMRS restoration; however it is one that is likely to be more effectively addressed at site scales (e.g., winter dissolved oxygen concentration in backwaters, water transparency in open-water areas of individual pools). Restoring processes that input, transport, assimilate, and output materials within the UMRB will undoubtedly result in measurable improvements in site-specific water quality.

Habitat. The diverse and dynamic hydraulic and geomorphic features of river systems provide habitat, the physical basis for biological productivity and diversity (Figure 8). Through altered hydraulic conditions and altered geomorphology, the physical habitats of the UMRS have been significantly changed in response to river regulation. The pre-impoundment distribution, abundance, configuration, and diversity of habitat types (e.g., main channel border areas, secondary channels, mudflats, sandbars and islands) have changed.

Habitat requirements of most native species resident to the UMRS are not well known, and a multitude of assumptions typically underlie the restoration—mainly through dredging or construction—of habitat types. One critical, but untested, assumption in habitat restoration is that the provision of "limiting" structure (e.g., islands or sandbars) will result in the reintroduction of processes, both physical and biological, resulting in improved viability of native species. It is important to learn how and to what extent the restoration of processes (i.e., reduction in wind fetch owing to island building) and the distribution of such processes will result in biological improvements. In other words, will island building result in increased biological production and/or increased spatial extent of submersed aquatic biomass?

Habitat restoration is extremely important to the broad goal of improving the biological integrity of the UMRS. However, it needs to be viewed in the context of our ability to restore the hydrologic and geomorphic processes outlined above, upon which biological responses and their maintenance rely. Habitat restoration projects are likely to be most successful, and the results more sustainable, as resource managers orient their actions toward improvements in process (function) as well as structure (places).

Biota. Among the many kinds of ecosystems, floodplain rivers rank near the top in terms of biological abundance and diversity (Welcomme 1985). This is one reason rivers have been so important to the development of civilizations. Rivers of the UMRS now run through a region dominated by agriculture, greatly increasing its value as a biological refuge. The UMRS supports 326 bird species, 260 fish species, 37 mussel species, and 45 amphibian and reptile species (Upper Mississippi River Conservation Committee 2000). The local, regional, and national value of the river's biological abundance and diversity is reflected in the fact that the Upper Mississippi National Fish and Wildlife Refuge, one of several on the river, is the most visited of all of the U. S. refuges, supporting over 12 million visitor days annually (Upper Mississippi River Conservation Committee 2000).

The central position of the UMRS river corridors on the North American continent, and their north-south orientation allowed them to function as refuge corridors during glacial periods (Hocutt and Wiley 1986). But this role also promoted genetic mixing, and kept the number of endemic species in the system relatively low. The annual flood pulse and summer low-flow features of the rivers are key factors that control annual abundance and long-term biodiversity of the system's communities, which include aquatic, terrestrial and transitional types. The migratory corridor functions of the UMRS rivers are of national importance. The UMR functions as the upper end of a migratory corridor that supports 40% of all North American waterfowl (Upper Mississippi River Conservation Committee 2000). It is also serves as a migratory route for at least 34 species of large river fishes (Upper Mississippi River Conservation Committee 2000). The migratory functions of the UMRS are systemic features that cannot be managed solely by efforts within a navigation pool or reach.

Managers will likely ask, "Which species should be considered most important within NESP?" The management approach being proposed for NESP is an adaptive and ecosystem approach that expands upon existing programs focused on individual species. Performance should also be evaluated by assemblage and community responses to restoration efforts in addition to valuable commercial and recreational species or recovery of threatened and endangered species.

Native species and communities, when evaluated over time and across an area as large as the UMRS, go through peaks and valleys of abundance. These cycles define a population's or a community's historical range of variability, an important yardstick against which to measure current status. However, the upper and lower limits of a historical range of variability are often difficult to quantify, and NESP numeric population objectives will need to be regularly re-evaluated in light of new monitoring information and response thresholds of important causal factors.

The five system-wide objectives proposed below follow from the UMRS system-wide goal provided above, and incorporate essential ecosystem characteristics that define UMRS structure and function. These system-wide objectives are suggested by the Science Panel and, along with the performance criteria listed, are examples intended to promote thought and discussion. Performance criteria should be based on desired future trends defined by river managers and stakeholders aided by reference conditions. The utility of reference conditions to help define performance criteria for UMRS sustainability is well established in general (Hughes 1995; Stoddard et al. 2006) and for the UMRS specifically (Lubinski and Barko 2003; Nestler et al. 2007; O'Donnell and Galat 2007b).

The listed performance criteria following objectives are not intended as comprehensive, and each presents just one approach of many potential ways to measure sustainability. We have intentionally left specific values and years blank or inserted *X* so as not to be overly prescriptive. Many system-wide objectives and performance criteria still need to be quantified. Some of the performance criteria suggest using a relatively simple indicator to represent a much more complex response (e.g., using skipjack herring as a single species indicator of increased fish passage for a variety of species). Performance criteria listed in *italics* will probably be outside the authority of the NESP. They are included because of their perceived importance for fully attaining higher level objectives (i.e. UMRB), but they need to be addressed by other programs. Ultimately, the job of establishing objectives and targets at all levels falls to river managers collaborating within the NESP partnership.

1. Manage for a more natural hydrologic regime (Hydrology and Hydraulics)

Examples of Performance Criteria

1.1. Modify river regulation in navigation pools to create a more natural discharge and stage hydrograph including frequencies of magnitude, timing, duration, and rates of change.

- 1.1.1. Modify dam operations in a coordinated fashion systemically to emulate seasonal low-flow water elevations in navigation pools to support ecosystem functions.
- 1.1.2. Decrease water elevations during summer low flows in navigation pools where possible at a frequency, magnitude, and duration necessary to establish and maintain aquatic plants, floodplain forest species richness, and aquatic soil cohesiveness by year *X*.
- 1.1.3. Develop winter pool operating strategies that balance the need for fish overwintering habitat with mammal overwintering habitat and floodplain forestry requirements by year *X*.
- 1.1.4. Develop the capability for dam-point stage control during critical fish spawning periods at navigation pools where possible by year *X*.
  - Acquire sufficient real estate interests by year *X* to allow for dam point control in navigation pools where substantial ecological benefits could be obtained.

1.2. Reduce short term fluctuations (hourly to daily) in water levels to [measure?] by year *X*.

1.2.1. Develop and implement management strategies to dampen short term variations from operations of dams, wicket gates, and hydropower facilities by year *X*.

1.2.2. *Develop strategies that will dampen variation in tributary flows (especially high flows) into the UMRS. (To be implemented by other programs.)*

2. Manage for processes that shape a diverse and dynamic river channel (Geomorphology)

Examples of Performance Criteria

2.1. Modify the distribution of flow among habitat types (main channel, side channels, backwaters) in ways that will maintain hydraulic conditions needed for navigation in the main channel, but increase flows to secondary channels and backwaters to help maintain diversity of the pattern of aquatic and floodplain habitats.

2.2. Develop hydraulic conditions within channels that create and maintain habitat features (e.g., dunes, scour holes, depositional areas, and retention zones) critical to channel-dwelling fishes.

2.3. Rebuild the structure and function of eroded or filled channels and natural channel-levee networks to an extent that they will be self sustaining.

2.4. Remove or setback constructed levees to expand seasonally flooded landscape area.

2.5. Modify channel training structures that unnecessarily prevent the formation of natural channel features (channel migration oxbows, point bars, side channel formation/abandonment, and island erosion/creation)

3. Manage for processes that input, transport, assimilate, and output materials within UMR Basin river-floodplains: sediments and nutrients, water quality (Biogeochemistry)

Examples of Performance Criteria:

3.1. Reduce mean annual export of nitrogen at Cairo, Illinois, by __% by year *X*.

3.1.1. Expand the amount of river water flowing into floodplains to increase denitrification rates within the river corridor to __% of the estimated maximum potential by year *X*.

3.1.2. Increase storage of nutrients in plant and animal biomass on the floodplain by __% by year *X*.

3.1.3. Reduce loading of nitrogen from major tributaries to an annual total of less than ____tons by year *X*. (to be implemented by other programs)

3.2. Reduce inputs of sediment to impounded reaches by __% by year *X*.

3.2.1. Increase connection of critical tributary streams with their floodplains to allow sediment and nutrients to be deposited on the floodplain and reduce cumulative direct input to the UMR by __% by year *X*.

- Restore the Zumbro River channel by year *X*
- Restore the Root River channel by year *X*

3.2.2. Reduce inputs from the uplands into tributary streams. [To be implemented by other programs.]

3.3. Increase export of sediments past Chain-of Rocks by __% by year *X*. [To be implemented by programs on the Missouri River (e.g., sediment flushing or bypass].

4. Manage for a diverse and dynamic pattern of habitats to support native biota (Habitat)

Examples of Performance Criteria

4.1. Develop a floodplain habitat matrix that achieves target values for diversity, patch size, connectivity, [other measures?] of major habitat types at the river reach and system-wide scales by year X.

4.2. Achieve and maintain target values for diversity of depths and current velocities in aquatic areas by year X based on the needs of local populations and long distance migrants.

4.3. Modify channel and floodplain morphometry to achieve target values for restoring flows to, and increasing access by aquatic organisms to, areas off the main channel (side channels, backwaters, floodplains, etc.) by year *X*.

- Acquire sufficient real estate interests by year *X* to allow rehabilitation of critical habitats and to connect at least __% of the floodplain to the river channel in each major river reach during a 10 year flood.

5. Manage for viable populations of native species and diverse plant and animal communities (Biota)

Examples of Performance Criteria

5.1. Restore longitudinal and lateral migration and dispersal pathways to give native fishes access to critical habitats.

5.1.1. Restore migratory capability that allows skipjack herring and other migratory species past to reach Minneapolis, Minnesota, and Joliet, Illinois, at least __ years out of __ , on average, by year *X*.

- Design and install a fishway capable of passing skipjack herring and other migratory species past on Dam 19 by year *X*.
- Insure that all other dams can pass of skipjack herring and other migratory species past for a minimum of __ days during appropriate times of year at least once every __ years by year *X*2.
    - Increase opportunities for upstream passage of migratory fishes by extending the period of open-river conditions at all dams where possible, consistent with maintenance of the navigation channel, by year *X*.
- Provide for fish access to upper reaches of tributaries. [To be implemented by other programs]

5.2. Restore habitat conditions systemically to support viable populations of ebony shell mussel in at least 3 locations in the UMRS by year *X*.

- By year *X*, re-introduce ebony shell mussels in at least __ locations with suitable habitat and where association with skipjack herring is likely to occur.

5.3. Restore or maintain communities of aquatic vegetation at abundances and spatial extent consistent with reach and system-wide capabilities by year *X*.

5.4. Ensure that migrating waterfowl and Neotropical birds have appropriate feeding and resting areas within the UMRS corridor by year *X* to allow them to reach breeding and wintering areas with adequate energy reserves.

5.5. Increase diversity of the floodplain forest tree community at reach and system-wide scales by [measure?] by year *X*.

5.6. Reduce the rate at which exotic species become established within the system by __% by year *X*.

Whereas ecological planning is most effective at the system and reach spatial scales, the tangible activities of restoration implementation will remain largely project-based. Reconciling this reality and dealing with it during the planning process can be aided by following an adaptive decision framework that couples system-wide planning with project-scale planning. Here a 10-step ecological planning framework for the UMRS NESP is proposed, somewhat similar to that presented in the Corps Evaluation of Environmental Investments Research Program (EEIRP, Pastorok et al. 1997). This process proposes to integrate a fundamental understanding of ecological principles into the existing project planning framework used by the USACE for aquatic and floodplain ecosystem restoration projects (USACE 1999, 2000). The challenge here is to integrate the project-oriented approach expressed in the Corps planning guidance into a system- and river reach-wide functional perspective (e.g., sediment/nutrient fluxes, migration pathways, channel-floodplain exchange).

For a proposed management/restoration action (i.e., project) the PDTs, with input from the Science Panel if requested, will consider the following guidelines:

1. Describe and quantify ecosystem objectives (desired future ecosystem conditions and outcomes) anticipated for the project.
    - 1.1. develop (or use existing) conceptual model
    - 1.2. identify scales
    - 1.3. define/use reference conditions

2. Identify system-wide goal (s) and objective(s) addressed by the project outcomes.
    - 2.1. specify associated reach and system-level indicators
    - 2.2. identify scales

3. Specify how the project will contribute to the desired future conditions
    - 3.1. develop hypotheses, describe ideas
    - 3.2. identify uncertainties
    - 3.3. modify conceptual model
    - 3.4. build/implement operational models
    - 3.5. identify learning opportunities
    - 3.6. identify potential ecosystem services provided or enhanced and trade-offs

4. Evaluate the project in relation to other management and restoration actions.
    - 4.1. consider existing and planned actions
    - 4.2. explore opportunities for synergy
    - 4.3. identify potential conflicting actions
    - 4.4. use this evaluation determine if the project is feasible, and if so, to help design proposed project

5. Identify and describe data to be collected and used to measure project performance.
    5.1. determine appropriate scales (space, time)
    5.2. construct appropriate sampling design
    5.3. conduct pre-project monitoring as needed

6. Implement the project (i.e., build, manage).

7. Monitor project performance.
    7.1. collect and analyze data for implementation and effectiveness monitoring
    7.2. report (e.g., Report Card, see Barko et al. 2006)
    7.3. communicate

8. Compare measured performance with anticipated outcomes/desired conditions.
    8.1. evaluate/test hypotheses
    8.2. solicit review and comment
    8.3. report on lessons learned

9. If the project produces desired conditions, maintain project as necessary, or;

10. If the project has not produced desired conditions, either revisit steps 3 through 9 or abandon the project.

6. Next Steps to Implement System-wide Goals and Objectives

The NESP Science Panel proposes to lead activities to:

1. Use this report and additional input in collaboration with PDTs, Navigation Environmental Coordination Committee, and others, to define an acceptable working approach for further developing reach and system-wide objectives and performance criteria.
2. Integrate the 43 existing UMRS environmental objectives into a system-wide perspective by clarifying the functions they address and the scales at which they apply.
3. With the aid of deliverables from activities 1 and 2, hold a series of workshops with the river management community to refine and quantify system-wide and reach-scale objectives and establish ecological performance criteria.
4. Use the workshops to identify a target objective (e.g., restore in-channel sediment transport from the UMRS; re-establish migration pathways of native fishes) at each reach scale for testing and adapting goals, objectives, and performance criteria.
5. Translate these objectives into projects that collectively address reach and system-level functions and processes.
6. Follow the guidelines to implement project(s).
7. Use lessons learned to revise ecosystem objective(s), performance criteria and management actions.

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