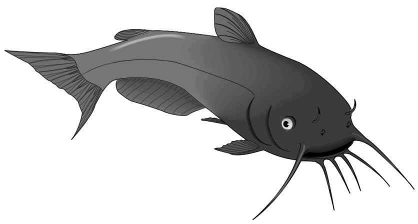
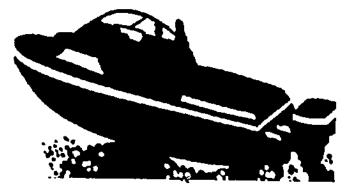
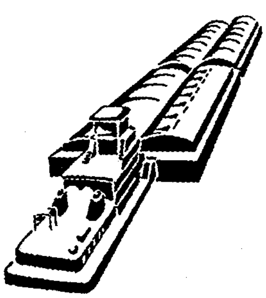
ENV Report 52

Interim Report For The Upper Mississippi River – Illinois Waterway System Navigation Study





Upper Mississippi River – Illinois Waterway System Navigation Feasibility Study: Environmental Science Panel Report



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Rock Island District
St. Louis District
St. Paul District

US Army Corps
of Engineers

Upper Mississippi River - Illinois Waterway System Navigation Study

ENV Report 52
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Upper Mississippi River – Illinois Waterway System Navigation Feasibility Study: Environmental Science Panel Report

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Interim report

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ABSTRACT: This report summarizes the considerations and recommendations of an Environmental Science Panel that was convened in early 2003 to provide guidance to the U.S. Army Corps of Engineers and Upper Mississippi River (UMR) – Illinois Waterway (IWW) stakeholders regarding the restructured UMR – IWW System Navigation Feasibility Study. Between January and April of 2003, the Corps organized four Panel workshops to review and contribute to Navigation Study progress and to begin work on several specific tasks. Those tasks required considerations of not only procedural steps anticipated during the remainder of the Navigation Study, but also issues related to the future establishment of an adaptive management process on the UMR – IWW. At the conclusion of the workshops, the Panel made the following recommendations:

- Planning for a formal Adaptive Management approach on the UMR – IWW should be accelerated and expanded to include multiple organizations and programs.
- Ecosystem goals and objectives developed so far through stakeholder input should be clarified and integrated. A structured process for evaluation of the unavoidable trade-offs between the ecological and economic values of the system should be established.
- Conceptual and simulation modeling should be established as vital steps in the adaptive management process in order to:
    1) Record the current state of the system.
    2) Create a holistic “virtual” reference system.
    3) Predict system-level outcomes of alternative actions and policies.
- Management actions available for implementation on the UMR – IWW should focus on attaining goals and objectives at the system level—with appropriate attention to risk and uncertainty.
- A UMR – IWW report card system and appropriate monitoring system should be developed to evaluate system condition and attainment of objectives.
- Selected future management actions should be considered as experimental manipulations, which will achieve stated objectives, enhance ecosystem health, and provide knowledge in a predictable and structured way.

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Preface

The work reported herein was conducted as part of the Upper Mississippi River – Illinois Waterway (UMR – IWW) System Navigation Study. The information generated for this interim report will be considered as part of the plan formulation process for the System Navigation Study.

The UMR – IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts, Rock Island, St. Louis, and St. Paul, under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing and, in consideration of existing system lock constraints, will result in traffic delays that will continue to grow in the future. The system navigation study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic and to consider ecosystem restoration needs related to the Navigation System. The study will determine the location and appropriate sequencing of potential navigation and improvements and ecosystem restoration measures in the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report, which is the decision document for processing to Congress.

Charles H. Theiling, U.S. Army Engineer District, Rock Island, compiled this report. Amy A. Lee, U.S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory (EL), Vicksburg, MS, recorded and compiled Science Panel Workshop notes. Nicole M. McVay, Rock Island District, helped record notes and prepare for the Science Panel Workshops. Angela G. Poovey, ERDC, EL, helped record notes and prepare for the Science Panel Workshops.

This report was edited by Drs. Kenneth S. Lubinski, U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, WI, and John W. Barko, ERDC, EL. Each member of the Panel listed on page 5 contributed to sections of the report.

COL James R. Rowan, EN, was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

Purpose and Structure of the Report

The purpose of this report is to summarize and present the considerations and recommendations of an Environmental Science Panel (Panel) that was convened in early 2003 to provide guidance to the U.S. Army Corps of Engineers (USACE or Corps) and Upper Mississippi River System-Illinois Waterway (UMR – IWW) stakeholders regarding the restructured Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study (Navigation Study). Between January and April of 2003, the Corps organized four Panel workshops to review and contribute to navigation study progress and to begin work on several specific tasks. Those tasks (see “Background and Panel Responsibilities” section below) required considerations of not only procedural steps anticipated during the remainder of the navigation study, but issues related to the future establishment of an adaptive management process on the UMR – IWW.

The development of an adaptive management process to guide the coordinated work of pertinent agencies and programs is the overarching theme of future integrated efforts for the management of the UMR – IWW. This report is structured to present thoughts and recommendations in an order that reflects the parts of the needed adaptive management process. First, background information clarifies the role of the Panel and how they conducted business. A general discussion of adaptive management and the broad issues that need to be addressed on the UMR – IWW follow. Details of the major elements of adaptive management are discussed: Goals and Objectives; Modeling; Management Actions; Monitoring and Evaluation; and Adaptation and Learning. The report ends with specific recommendations. To assure a common understanding of terminology among the broad audience of this report, the Panel’s accepted definitions of key terms are provided in Appendix A: Glossary.

We feel that the Panel has made significant progress in undertaking the various tasks assigned by both the Corps and the Navigation Environmental Coordinating Committee (NECC). Input from stakeholders and the NECC contributed greatly to that progress. The role of science in adaptive management is, by definition, iterative. For that reason, one of our recommendations is to continue, in some form, the Panel’s role and responsibilities to objectively evaluate progress and to regularly provide new scientific information to the UMR – IWW management process.

Background and Panel Responsibilities

In 1993, the U.S. Army Corps of Engineers began a study of the Upper Mississippi River – Illinois Waterway navigation infrastructure to evaluate the need to reduce navigation congestion at the system's locks. The navigation study focused on the economic costs and benefits of upgrading and expanding the original 9-ft-channel project to include, among other potential measures, 1,200-ft-long locks at some of the dams. Along with the economic analysis, a traditional environmental assessment of the expanded project was conducted between 1993 and 1999. Studies were made to understand both the physical and environmental effects of an expanded navigational system with different levels of improvement. Features and processes considered in these environmental studies included: sediment resuspension, sediment deposition, turbidity effects on submerged aquatic vegetation, fish and native mussels, and effects on shoreline erosion. In addition, a cumulative effects analysis was conducted by a team of nationally recognized environmental specialists matched with local experts (West Consultants, Inc. 2000). In February 2001 the National Research Council (NRC 2001b) suggested that the original environmental assessment was too narrowly focused. The Council observed that the evaluation of environmental impacts was limited to increased traffic effects alone and recommended the Corps expand the environmental impact analysis of the navigation project to the entire river ecosystem. The Corps of Engineers Headquarters (USACE-HQ) adopted this stance in August 2001 and restructured the navigation study to look at navigation and environmental sustainability over a 50-year planning horizon with a new focus on sustainability.

To execute this new mandate, the Corps first requested the help of stakeholders in preparing a common vision for the future of the UMR – IWW. In November 2001, the Economic Coordinating Committee (ECC) and the NECC drafted the following vision statement:

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

The following definition of sustainability was collaboratively developed and agreed to by the group as well:

> "The balance of economic, ecological, and social conditions so as to meet the current, projected, and future needs of the Upper Mississippi River System without compromising the ability of future generations to meet their needs."

The Corps next prepared a Project Management Plan to outline and schedule the specific steps for the remainder of the restructured navigation study. The navigation study and its objectives were described as follows:

> The restructured Feasibility Study will focus on the authorized Federal navigation projects on the Upper Mississippi River System (including the Illinois Waterway) and the ecological and floodplain resources that are affected by these navigation

projects. The objectives of this restructured Feasibility Study are to relieve lock congestion, achieve environmental sustainability in conjunction with ongoing navigation, and address ecosystem and floodplain management needs related to navigation in a holistic manner.

The Project Management Plan organized the proposed work of the Corps during the navigation study into five tasks:

Task 1 – Establish Goals and Objectives for the Condition of the River Ecosystem
Task 2 – Determine Management Actions
Task 3 – Establish Costs and Expected Outcomes
Task 4 – Perform Incremental Analysis (Analysis of Environmental Alternatives)
Task 5 – Perform Integrated Alternatives and Tradeoff Analysis

The Corps convened the Science Panel to obtain scientific expertise for these tasks. Specific guidance from the Corps to the Panel was contained in a Scope of Work, which is summarized below.

Work Required from the Panel Members:

- Further develop and refine UMR – IWW conceptual models.
- Identify appropriate evaluation tools and data (e.g., GIS, numerical, and empirical) that address ecosystem needs at multiple scales.
- Provide guidance in developing a process (that incorporates linkages and sustainability) to establish environmental goals and objectives in a standardized format throughout the entire UMR – IWW.
- Assist in identifying and evaluating management actions that focus on the established environmental goals and objectives.
- Assist with developing and participating in an adaptive process of establishing environmental alternative plans that seek to address balanced local, river reach, and systemic ecosystem restoration needs.

The NECC clarified stakeholder expectation of the Panel in a letter that expanded on the tasks presented in the Project Management Plan (listed above). The following are excerpts from that letter grouped by subject:

<u>Goals and objectives (identified at Corps-sponsored 2002 Stakeholder Workshops)</u>

" … your broader perspective should help confirm or counter that all the essential goals and/or objectives are included."

" … from a scientific perspective, are the goals and objectives measurable, are they time-dependent, what metrics should be used, and/or suggestions for performance evaluation."

Management actions

"… your broader perspective may provide additional innovative restoration techniques that would benefit the adaptive management restoration plan."

Costs and outcomes

"NECC expects the Science Panel to concentrate their expertise on Expected Outcomes more than Expected Costs. The most important component of restoration outcomes that river managers and scientists agree on is that each restoration project or series of restoration projects will have an impact on river dynamics and therefore adaptive management will be the cornerstone of any future restoration of the Upper Mississippi River."

Incremental analysis

"While no economic analysis experts have been identified to assist in the valuation of non-traditional benefits, such as natural resource services, you may help guide natural resource modeling efforts in conjunction with the economic models."

For consideration in the Science Panel's deliberations, guidance was provided in the following documents:

- Status and Trends Report (USGS 1999).
- UMR – IWW Cumulative Effects Report (West Consultants, Inc. 2000).
- Habitat Needs Assessment (Theiling et al 2000).
- Fish and Wildlife Interagency Committee (FWIC) Pool Plans (FWIC 2003).
- A River that Works and a Working River (Upper Mississippi River Conservation Committee (UMRCC) 2001).
- Fish and Wildlife Work Group (FWWG) Pool Plans (FWWG 2003).
- Preliminary Description of Habitat Objectives and Estimated Costs Report (UMRCC 2002).
- Stakeholder Goals and Objectives (DeHaan et al. 2003).

Panel Assumptions

As the Panel began synthesizing material for this report, it was recognized that many of their recommendations were based on assumptions about future adaptive management on the UMR – IWW. These are listed below to help readers understand the context of the recommendations.

a. The Corps and other river stakeholders, because of their common interest in seeking both economic and ecological sustainability on the

UMR – IWW, will work toward the establishment of an adaptive management process.

b. All stakeholders understand the need to work toward commonly accepted goals that will improve the whole system, encompassing both economic and ecological values.

c. The adaptive management process will include active stakeholder participation in defining "balance" between economic and ecological conditions and values.

d. The adaptive management process will include regularly scheduled objective assessments of UMR – IWW economic and ecological conditions and use those assessments to take appropriate action to achieve a long-term sustainable economy and a sustainable ecosystem.

Participants

Members of the Science Panel:

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2 Adaptive Management for the UMR – IWW

Definition

As implied in its name, adaptive management prescribes a management process wherein management activities can be changed in relation to their efficacy in restoring and/or maintaining an ecological system in a specified desired state or ecological potential (Gunderson and Holling 2002). The desired state may specify some precisely defined structural condition, or more realistically, a range of structural conditions; desired state can also specify rates of ecological processes or some description of biotic potential (e.g., energy capture and processing or production). A key component in adaptive management is the establishment of a feedback mechanism wherein characterization of current conditions (monitoring) can be used in conjunction with an understanding (model) of the system to alter management actions, if necessary, to produce future system conditions compatible with the desired state. Successful adaptive management requires the support of stakeholders and collaborative institutional arrangements to plan and implement a river management program that is based on the best available knowledge. These institutions must also have the capability to evaluate management activities, to learn from experience, and to alter management accordingly. Adaptive Management is prescribed for the UMR – IWW because it provides a structure for action while addressing and resolving the uncertainties facing UMR – IWW agencies and stakeholders.

Walters (1986) offers three ways to structure environmental management as an adaptive process: (1) evolutionary (trial and error), (2) passive adaptive, and (3) active adaptive. Evolutionary adaptive management defines a management approach that attempts to achieve desired conditions through educated guesses and accumulated knowledge of system response to previous management activities. The benefits of this largely trial-and-error approach include comparatively low costs in implementation. The main drawback is the potentially low effectiveness in achieving management goals and objectives. Another negative aspect of this approach is the informal and minimal investment in gaining an understanding of system dynamics as the result of management.

Passive adaptive management describes a management approach that uses current understanding of the system to change management actions in response to monitoring conditions that change as a result of the "natural" range of perturbations to the system. An advantage of passive adaptive management is learning to manage effectively by monitoring system conditions, undertaking management actions in light of current understanding, and determining the utility of the management actions toward obtaining conditions consistent with management goals and objectives. One limitation of this approach lies in developing management capabilities that are effective only within the range of conditions experienced during management. Passive adaptive management may provide sufficient management capability for a reasonable range of system conditions, yet preclude the development of management skills necessary to correctly respond to highly episodic circumstances (e.g., 1993 flood).

Active adaptive management views management actions as purposeful and uses scientific experimental manipulations of the system (e.g., Walters and Holling 1990) to increase understanding of system behavior in the short term and as a result, achieve management goals and objectives in the long term. A substantial advantage of active adaptive management over passive adaptive management is the ability to structure management actions in order to achieve the greatest scientific information content, and thereby assure the greatest relevance of science to management decision-making. Active adaptive management encounters a "dual control" problem, where trade-offs between short-term gains in understanding through system manipulation must be weighed against the probability that such manipulations might produce substantial and irreversible changes that reduce the likelihood of achieving the long-term desired conditions.

Uses and Benefits of Adaptive Management

One of the main benefits of adaptive management is the development of an approach to management and decision-making that is iterative and flexible. This iterative approach, in contrast to more centralized "command and control" management, emphasizes that management actions can be viewed as experimental manipulations of the system. The results of the manipulations can be monitored, and future management decisions can then be informed based on the outcomes of previous decisions. A second important benefit of adaptive management lies in the opportunity for scientists and managers to collaborate in the design of novel and imaginative solutions to the challenges of managing complex and incompletely understood ecological systems (Walters and Holling 1990). Alternative management actions can be stated as hypotheses and addressed from the perspectives of experimental design and decision analysis. The probable outcomes of management alternatives and the values of such outcomes can be estimated in relation to management goals and objectives. The adaptive approach recognizes that uncertainty is unavoidable in managing large-scale ecological systems. The third benefit is that uncertainty can be formally analyzed and exploited to identify key gaps in information and understanding. The results of uncertainty analyses can be used to efficiently allocate limited management resources to research and monitoring. The large variation in river conditions from north to south in the UMR – IWW contributes to uncertainty and points as well to the need for an adaptive management approach. Adaptive management is considered key to attaining desired future conditions on the UMR – IWW, considering the dynamic nature of river features spatially as well as through time.

Adaptive Management Concepts

Sustainability

Sustainability is generally defined as maintaining the quality of human life while living within the carrying capacity of supporting ecosystems (International Union for Conservation of Nature and Natural Resources (IUCN) 1980). Richter et al. (2003) introduce the concept of ecological integrity in their definition of ecologically sustainable water management which: "...protects the ecological integrity of affected ecosystems while meeting intergenerational human needs for water and sustaining the full array of other products and services provided by natural freshwater ecosystems." The Corps planning process defines sustainability in the more practical terms expected of a water resources development agency tasked with balancing development and environmental as "A synergistic process whereby environmental, economic, and societal considerations are effectively balanced in Project Planning, Design, Construction, Operation and Maintenance in meeting the needs of the present without compromising the quality of life for future generations." This report attempts to develop an approach to management of the UMR – IWW in a sustainable fashion, both in terms of the general definition of sustainability (IUCN 1980) as well as the more facile Corps of Engineers definition (EC-1105-2-404).

Ecological integrity

The concept of ecological integrity is often used as a descriptor of quality or health of the ecosystem, and a goal of sustainable ecosystem management. Karr and Dudley (1981) defined ecological integrity as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region." Richter et al. (2003) state that ecological integrity is protected when "the compositional and structural diversity and natural functioning of affected ecosystems is [sic] maintained." For highly altered ecosystems like the UMR – IWW, the question arises whether the magnitude of alteration precludes restoration of ecological integrity under these definitions. The Panel believes that ecological integrity should benefit from improvements and maintenance of biological diversity and ecosystem structure/function, even if the system cannot be returned to pre-disturbance physical conditions, natural species composition, or structure and function.

Baseline conditions

Baseline conditions are often used to describe systems, referring to the condition of the system at some selected point, period in time, or both. For ecosystems, a baseline can be a pre-project or pre-disturbance historic condition, or the present condition. For the UMR – IWW, baseline conditions have been variously identified as pre-European settlement (year 1800), pre-navigation project (year 1850), pre-dam construction (year 1900), early post-dam construction (year 1940), or present conditions (year 2000). Older data to quantify ecosystem characteristics are sparse, but are instructive as to changes brought about by human activity in the last 150 years.

The Cumulative Effects Report prepared for the navigation study (West Consultants, Inc. 2000) documented physical and ecological changes on the UMR – IWW from the 1930's to year 2000, and forecasted future changes to year 2050. For purposes of planning for a sustainable river ecosystem, the authors acknowledge the historic changes to the UMR – IWW, and most often refer to recent existing conditions (year 2000) as the baseline.

Reference conditions

Reference conditions are system conditions used to gauge progress of management from baseline toward some target system state. A "physical" reference system can be a similar existing and relatively undisturbed ecosystem or area. Given the scale and diversity of the UMR – IWW, no similarly sized and relatively undisturbed river system exists in this region for use as a physical reference. Smaller scale internal physical reference systems can be of use in planning for river management and restoration projects (e.g., the unregulated Lower Chippewa River in Wisconsin), where the area to be managed or restored can be designed to have geometry, substrate, and hydraulic conditions similar to the reference.

A "virtual" reference can also be constructed using a defined set of ecosystem attributes that, in combination, would define a sustaining, entire, and socially desired ecosystem. For the UMR – IWW, we are in the process of defining a "virtual" reference system by setting goals and objectives for the system. This target set of future conditions will continue to be refined in the future and will serve as the reference for purposes of the navigation study and future UMR – IWW management and restoration.

Defining and applying the "reference conditions"

An important element of ecosystem restoration is a reference condition that can serve as a template for restoration and the application of management actions. Over a long time period, an ecosystem can be restored to be closer to a reference condition through the combined effect of many smaller actions even in the absence of a large-scale management and restoration program. A fairly complete understanding of critical mechanisms regulating natural river ecosystems is critical to holistic environmental restoration, since the restoration of ecological processes and functionality is key to achieving environmental sustainability.

A natural condition is the most defensible selection for a reference because often a pre-impact, historical reference condition can be assumed to be sustainable. Snapshot comparisons made at time intervals between the reference and impacted system can be used to determine the status (trajectory and momentum) of the impacted system. Ecosystem integrity should increase as differences between reference conditions and status of the impacted system decrease.

Table 1
Strategies for UMR – IWW Restoration and Management

A dynamic blend of processes in natural rivers establishes and maintains their persistence, supports populations of desirable fish and wildlife, and defines river ecosystem integrity. Restoring a perturbed large river ecosystem to a state of integrity can be approached in several ways (reviewed in Cairns (1990)). Two of these approaches were evaluated for applicability to the UMRS in order to propose a river restoration strategy that embodies aspects of both approaches.

Self-Recovery to a Natural State
Conceptually, transforming a system to a pre-disturbance condition is the simplest form of restoration and, where feasible, is the preferred foundation of ecosystem restoration. Self-recovery to a natural state implies that the system will revert to a pre-disturbance state on its own with no requirement for human intervention. A significant portion of the UMRS is regulated by a series of locks and dams and other structures that are used primarily to increase low discharge water depths and concentrate flows in the main channel for the purpose of maintaining navigation. The UMRS has been continuously modified from its natural state over many decades by changes in land use in the basin, navigation traffic, dredging and material placement, channel structures, tributary impoundments, alteration of the floodplain through levees and development, and climate change. Limited information is available to provide a detailed description of the historical condition of this river for use in defining the natural state. Therefore, the desired future condition of the UMRS ecosystem cannot be based on pre-navigation project natural conditions. Restoration of the UMRS cannot practically include a return to a natural state, because such a state would not support commercial navigation and many other economic goods and services that society has come to expect from the river. In any case, the river will not self-restore to a pre-disturbance condition in the foreseeable future, because of the fundamental barriers presented by the engineering structures.

Rehabilitation of Select Ecosystem Processes and Characteristics
Recently, before the management of ecosystems was embraced, it was common practice (and still is today, owing to legal and economic pressures) to manage land and water resources in support of a limited number of characteristics (e.g., selected habitats) or charismatic species (e.g., selected sport fish, waterfowl, or endangered species). With neither an ecosystem perspective nor an understanding of natural river function, there is a danger that such management actions will become a disjointed series of expensive engineering fixes in discrete managed areas. Inattention to how the original ecosystem functioned as a whole makes selective rehabilitation speculative, unlikely to achieve widespread success, and unlikely to be sustainable. It is therefore critical that restoration actions be planned and implemented with a fairly complete knowledge of key riverine and ecological processes, so that restoration and management actions can be selected to capitalize on that knowledge. Here, it is assumed that the restoration of key processes (rather than selected habitats) will result in a return to more natural and sustainable conditions. With this approach, improved process understanding may need to derive from studies of similar, but unregulated rivers or from portions of the UMRS that remain relatively unaffected by river regulation.

Establish an Alternative Ecosystem
Establishing an alternative river ecosystem for which no natural analog is available is the most challenging of the restoration alternatives listed by Cairns (1990). This challenge is particularly severe if the objectives for establishing an alternative river ecosystem include sustainability and self-maintenance because lack of a natural analogue, by itself, implies that the alternative river ecosystem may not be persistent over long time periods. The authors suggest that, although most difficult, this option is the best choice for restoration of the UMRS (see Section titled "Establishing Goals and Objectives.").

Improvements in ecosystem health and integrity can be assumed when important processes in the impacted system appear to be generally consistent with reference conditions. Therefore, the best strategy to ensure successful restoration is to either use a natural reference river as a template or to develop a sufficient understanding of the ecosystem so that sustainable reference conditions can be devised through adaptive management.

The importance of natural reference conditions and knowledge about natural rivers cannot be overemphasized. Bayley (1995), Poff et al. (1997), and Richter et al. (2003) (among others) document that river-floodplain ecosystems are sustained through complex interactions among physical, chemical, and biological processes. Sparks et al. (1990) argue that disturbance and recovery of large rivers cannot be understood without a detailed understanding of the complex, "normal behavior" of the river-floodplain system.

Adaptive Management Elements

Establishing goals and objectives

Planning for restoration of the UMR – IWW, without a natural analog, will face two major challenges (posed as critical questions below) that must be addressed to ensure continuance of a sustainable and self-maintaining ecosystem, exhibiting measurable features of ecological integrity comparable to a natural system.

- How can priorities for resource features (e.g., habitat and associated biota) in time and/or space be assigned in attempting to achieve a desired future condition?
- What dynamic blend of processes will be required to reduce ecological maintenance costs, support desirable populations of fish and wildlife, and provide ecosystem goods and services in a sustainable manner?

The answer to the first question was actively pursued by the Corps in a series of workshops held in the basin in which "stakeholders" (primarily resource managers and the public) were requested to identify specific goals and objectives for those parts of the UMR – IWW in which they had responsibilities and interest. These goals and objectives were further consolidated and analyzed by the Panel. They collectively represent approximate attributes of a desired future condition for the UMR – IWW, as perceived by participants in the stakeholder workshops. For purposes of restoring and managing the river to attain these attributes, a relatively complete understanding of the underlying ecological processes will be required. Through adaptive management, river managers will be able to learn which processes are key, and among them, which processes are most sustainable over the long term in support of desired future conditions.

This set of goals and objectives should be considered a first approximation. Some of the objectives are mutually exclusive, and some are unattainable. The spatial and temporal specificity of many of the objectives needs to be refined. Inevitably, this set of goals and objectives will be refined and revised as river management and restoration proceeds. This can be done systematically through an adaptive management process.

The second question is also difficult. No natural examples exist for large, regulated rivers like the UMR – IWW. Hence there are no existing models to indicate precisely how the UMR – IWW should function. Large river analogues are relatively few in number, widely dispersed across continents, and have been generally subjected to anthropogenic impacts for hundreds of years. Reconstructing historical ecological conditions as a means of developing a reference river condition is difficult, because most large rivers were impacted many years ago. Further exacerbating this problem is the reality that data pertinent to the restoration of large rivers are limited.

The concept of a "virtual" reference is proposed as a solution to the problem of "no suitable reference." The virtual reference approach establishes reference conditions by integrating information from multiple sources. For the UMR – IWW, reference information is available from at least three different sources. First, some historical information is available for parts of the Mississippi River, and many map products are being adapted to modern GIS tools. While incomplete, the historical information can provide valuable insights into processes that existed before and during alteration. For example, water quality conditions in different parts of the historical channels and floodplain can be inferred from early elevation surveys of the system coupled with hydraulic modeling because water quality patterns are heavily influenced by hydraulic residence times. By comparing residence time of water in different parts of the historical and present system, insight can be gained into the restoration of biogeochemical processes in the present system. Second, the UMR – IWW should be inventoried to identify specific areas that can be classified as "internal references," because these areas support valuable living resources and appear sustainable within the existing system. These areas should be studied and assessed to determine blends of processes that are sustainable within the present ecosystem. Criteria used in the establishment of these internal reference areas should be based on knowledge, albeit limited, of historical physical and biological conditions.

An independent source of information to determine target ecosystem conditions can perhaps be obtained from rivers outside the UMR – IWW. Information from medium to higher-order streams and rivers nearby and/or interconnected to the UMR – IWW (e.g., the Lower Chippewa River in west central Wisconsin) can perhaps be extrapolated to large rivers. A principle components analysis of the world's large rivers demonstrates that the Mississippi River is somewhat similar to the Parana River of South America.[1] The Parana River, unlike the southern reaches of the UMR – IWW, remains substantially connected to its floodplain. Thus, appropriate studies on the Parana River may provide useful insight into pre-existing conditions on the UMR – IWW for purposes of ecosystem restoration. Without recovery of both temporal and spatial patterns of floodplain connectivity in the UMR – IWW, it may be impossible to restore biodiversity, the general baseline of natural processes, and habitat complexity—all critical end points in the restoration of large river systems. Alternatively, it may be possible to create spatial and temporal conditions of slack water and high flow that are functionally analogous to backwater and main channel areas of unregulated rivers.

[1] Personal Communication. N. Oldani and C. Baingun, University of Iowa, Iowa City.

Increasing understanding through models

Predicting outcomes of management decisions requires projections of ecosystem responses before restoration and management measures are implemented. These projections must be made with full realization of the vagaries of nature in a dynamic context. The time frame over which restoration and management measures are implemented could be indefinite – as suggested by the many definitions of sustainability. Adaptive management decision-making will unavoidably and extensively rely on the use of ecological and environmental models for such projections.

The kinds of models supporting the decision process will likely range from simple empirical rules, to more rigorous statistical tools, to complex ecological models of populations, communities, ecosystems, and landscapes. Regardless of the nature of the models, each must to be able to translate effects of manipulations of environmental conditions to associated responses of resources of concern. Furthermore, these models must be inherently straightforward, and their outcomes readily understood by stakeholders. Existing models that are capable of translating management actions into estimated outcomes for resources of concern in the UMR – IWW System will need to be identified. The ecological modeling literature is extensive and diffuse, and the identification and evaluation of models for application can prove challenging (Pastorok et al. 2002).

Based on existing information and conceptual modeling, a first-generation virtual reference template could be valuable in evaluating goals and objectives in view of site-specific and regional differences in hydrologic, water quality, and physical features. This reference could also be valuable in identifying potential inconsistencies between goals and objectives, particularly on a local scale. The present UMR – IWW (based on Long Term Resource Monitoring Program (LTRMP) monitoring and other sources of information) could be compared to the virtual reference template to develop prioritized actions comprising an integrated restoration plan. A first generation virtual reference template (perhaps in map form) for the UMR – IWW could be created from the outputs of relatively simple engineering models that simulate the hydrology, transport, and physico-chemical conditions in the rivers.

Many excellent hydraulic models for the system are presently available, and routinely used to develop stage-discharge relationships. Information on water stages associated with a particular operation can be used to generate maps of inundation depth contours using GIS. Depth and duration of inundation are good predictors of the potential coverage of submerged and riparian vegetation. Higher trophic levels can be added later to this foundation using accepted methods, many of which are described in this report. This first-generation model would be valuable in evaluating goals and objectives on the basis of site-specific and regional hydrologic, water quality, and physical structures. By incorporating goals and objectives into the structure of the model, the model could be used as a reference for desired future conditions. The present UMR – IWW can be compared to the desired future condition to prioritize management actions in an integrated restoration plan. Quantitative numerical modeling can later be used to create much more sophisticated virtual reference systems, based on fundamental principles of river ecology, as a guide to river management.

Implementing management actions

The scales of potential management actions vary considerably in time and space. They range from widely and frequently applied routine management actions to large habitat restoration projects that might be constructed only once. Some management actions such as navigation dam gate operation are routine, conducted daily at all the dams in the river system. Other management actions such as channel maintenance dredging are also routine, but are conducted at specific locations (dredge cuts) at varying frequencies ranging from twice a year to once in decades. Some management actions such as removal of invasive plants or timber harvesting are only implemented in selected areas as needed. Many management actions involve major construction that would be implemented infrequently and in selected areas as part of a habitat restoration project.

Planning and applying these actions in the context of adaptive management entails the selection and use of specific management actions with the intention of restoring or maintaining the current system to those conditions defined by the goals and objectives. Where alternative management actions can produce the same desired conditions, the decision will involve selection of the "best" combination of alternatives – consistent with Corps planning and guidance procedures.

The traditional Corps planning process is an iterative one that generally follows this sequence: 1) evaluate problems and opportunities, 2) inventory existing and forecast future conditions, 3) formulate alternative plans, 4) evaluate alternative plans using models, 5) compare alternative plans, and 6) select and implement a plan. The process notably lacks post-implementation evaluation and learning steps.

UMR – IWW stakeholders have significant experience implementing restoration measures on the UMR – IWW through the Environmental Management Program Habitat Rehabilitation and Enhancement Projects (HREP) and other Corps, Federal, and state authorities. Since 1986, 64 HREPs affecting almost 140,000 acres have been planned, designed, or constructed. Various Federal and state agencies manage timberlands, wetlands, and grasslands on a routine basis. States have varied specific responsibilities for managing fisheries and wildlife. All of these activities benefit from interagency coordinating committees and project teams, but there are clear inconsistencies and deficiencies in current institutional arrangements and management schema.

Monitoring and evaluation

Economically feasible, logistically practical, and scientifically defensible monitoring programs are critical to using the adaptive management framework. Monitoring is the tool for establishing feedback between decision-making and the effectiveness of decisions in achieving management goals and objectives. While the models forecast probable future system states in relation to decision-making, monitoring characterizes actual system states subsequent to management actions. Of central importance, the feedback from monitoring to the decision-makers provides the 'adaptive' feature that is the basis of adaptive management.

Informative monitoring programs must specify what is to be monitored (assessment endpoints in the language of risk assessment) to usefully describe the system state in relation to management goals and objectives. Appropriate scales must be addressed as well (e.g., Gardner et al. (2001)). These spatial and temporal scales include:

- The environmental/ecological scales that provide for the most accurate and precise measures of the endpoint, i.e., the characteristic scale of the monitored entity or process.
- The scales of monitoring, i.e., the extent, locations, and frequency of sampling and analysis permitted by available resources and technical monitoring capabilities.
- The scales of management, i.e., the scales in space and time determined by management actions, e.g., locations, frequency, and amount of dredging.

The results of monitoring also provide information that leads to understanding from which effective models derive. Monitoring further provides data for estimating initial conditions and parameter values of models used in support of Adaptive Management. Monitoring results can also be used to describe and decipher differences between forecast and measured system response to management actions. Models can be revised and improved through model-data comparisons afforded by monitoring. An effective monitoring plan can facilitate enhanced learning from management actions to improve future applications.

Challenges to Implementing an Adaptive Management Process

The goals and objectives of the Revised Navigation Study have been formulated in the context of economic and environmental sustainability. These goals and objectives will be translated into management actions applied to a large and complex environmental system – the UMR – IWW. The combination of desired sustainability, large-scale environmental improvements, and system complexity justifies the use of an adaptive management approach to management and decision-making. In fact, it is difficult to think of an alternative management approach for this large-scale river and floodplain ecosystem. Notably, however, there are some significant challenges to putting an effective adaptive management program into practice. Walters (1997) identifies the following four challenges:

- Modeling in support of adaptive management is often replaced by never-ending model development and modeling exercises with the presumption that detailed modeling can replace field experimentation in defining best management practices. There are also technical issues (e.g., accuracy, reliability, uncertainty, etc.) associated with the development and use of models in adaptive management. The most difficult technical issue may be the cross-scale linkages among physical (hydrodynamic), chemical (water quality), and ecological models that are necessary in using the models to design and evaluate management alternatives.

- Using active adaptive management in the context of system manipulations as large-scale experiments often is viewed as excessively expensive or ecologically risky, compared to traditional management approaches. Indeed costly modeling studies may be needed to select effective management alternatives/manipulations. Follow-on monitoring programs certainly add to the costs of adaptive management, and the manipulations themselves may result in economic losses (lost revenues from reduced navigation in the case of a pool level drawdown, as an example). Additionally management manipulations might result in unanticipated effects on non-target populations or resources with unacceptable consequences.
- People in management bureaucracies often oppose experimental management policies (i.e., adaptive management) in order to protect self-interests and retain the status quo. Complex institutional settings involving multiple agencies with overlapping responsibilities and legal mandates can lead to interference in operations and resistance to proposed changes in management policy.
- Value conflicts often occur within the community of ecological (e.g., preservation) and environmental (e.g., conservation) management interests. In some cases, these conflicts can run deeper than more traditional conflicts between ecological and industrial (e.g., power production, navigation) values.

In addition to the challenges identified by Walters (1997), the current planning and guidance procedures (USACE 1990) that have directed Corps activities in the past may require modifications that facilitate the practice of adaptive management. For example, identification of a ‘best’ management plan (i.e., National Economic Development plan) seems to run counter to the basic philosophy of adaptive management, wherein the best current plan might well change in the future. Identifying a best plan might have to be replaced by identifying or describing the most effective process for performing adaptive management. Yet in the context of adaptive management, even ‘the best adaptive management process’ defined *a priori* as the result of a feasibility study might change during the course of management. So, the potential incompatibility of current planning and guidance with directives to embrace sustainability and practice adaptive management might require modifications to such guidance (Martin and Stakhiv 1999). In addition, it is not clear how efficiently adaptive management can be practiced within the framework of the NEPA, which typically requires selection of a well-defined alternative.

Designing and Maintaining Institutional Arrangements

The Panel was not asked to review current institutional arrangements on the UMR – IWW or to recommend changes, but we are aware that institutional alternatives have been evaluated in the past (UMRBC 1982) and that the Corps will be including a discussion of potential institutional arrangements in the feasibility report. The Panel does recognize, however, the importance of the positive or negative effects that an institutional arrangement can have on building and maintaining an adaptive management approach. The following questions and discussion are offered to encourage constructive future comparisons of existing and proposed institutional arrangements from the perspective of their value in facilitating adaptive management.

1. Does the institutional arrangement provide a formal, clear, and effective process for using available, accurate scientific knowledge to plan corrective action?

- Institutional arrangements must promote a consensus-based, collective understanding of current UMR – IWW ecosystem conditions, and use that understanding as the primary basis for action.
- Institutional arrangements must provide for regular review and updating of the collective understanding.
- Institutional arrangements must facilitate effective dialog about system conditions and stressors among technical, management, and stakeholder groups.
- Institutional arrangements must encourage rigorous scientific verification of "conventional wisdom."

2. Does the current system provide for objective learning and inference based on the results of actions?

- Institutional arrangements must support actions that are designed to improve the information base while achieving specific ecological objectives.
- Institutional arrangements must facilitate shared learning from actions taken outside the system.

3. Does the institutional arrangement include mechanisms to assure that management actions are accountable to the adaptive management process?

- Institutional arrangements must assure stakeholder groups that their goals and objectives are sufficiently considered within the management process.
- Institutional arrangement must assure technical and scientific groups that their understanding is sufficiently considered within the management process.

Surmounting Barriers to Adaptive Management

It is not easy to anticipate the extent to which the previously described barriers will influence the implementation of adaptive management in the context of the Revised Navigational Feasibility Study. Several important steps highlighted below have been undertaken that might be of value in surmounting these barriers and facilitate the effective use of adaptive management in managing the UMR – IWW System:

- A comprehensive conceptual environmental model (Lubinski 1993, see “Conceptual Models” in Chapter 4) relevant to managing the UMR – IWW has been developed. The model was used to help guide the identification, organization, and selection of management goals and objectives consistent with the sustainability directives that have reshaped the navigation study.
- The long-standing and continuing relationship between the Corps and key stakeholders (i.e., NECC, ECC) provides a mechanism for sharing information, exchanging ideas, identifying concerns, and creating solutions in the context of adaptive management and sustainability in the revised study. Whether that mechanism is effective enough to support a more extensive adaptive management approach is something that only the community of stakeholders can judge.
- Peer review has been established, in part through the assembly of this Panel, to evaluate the technical aspects of environmental sustainability in the context of the evaluation of goals and objectives, as well as models, data, and other tools needed to practice adaptive management. The continued involvement of this or a reconstituted Panel, as a permanent feature of a future adaptive management process/practice, needs to be assured.
- The Corps has accumulated experience in the use of complex hydro-dynamic and ecological models in assessing ecological risks posed by commercial navigation. The important cross-linkages among these models have been worked through and the models appear amenable for applications in adaptive management, as well as for continued evaluation of risks posed by commercial (and recreational) navigation.

3 Environmental Goals and Objectives

The Panel devoted a large fraction of its time structuring a set of environmental goals and objectives that were inclusive of stakeholder inputs and consistent with a sustainable river ecosystem. Goals in the context of river ecosystem management and restoration are an articulation of societal values and desired future conditions and are generally broad in nature (Harwell et al.1999). Goals are further defined by objectives and endpoints. Objectives are specific targets (measurable, time-bound) for ranges of ecosystem conditions that define the desired ecosystem state. Endpoints are the selected conditions used to measure attainment of objectives. Endpoints have metrics (units of measurement, resolution, certainty, target dates) that enable quantitative assessment of progress toward the objectives and goals.

Clearly defined goals, objectives, and endpoints for river system management and restoration are essential. Rogers (1998) suggests:

> ...too few ecologists and managers spend enough time in collaborative efforts to unambiguously define the end points (Costanza 1992) or desired conditions (Christensen 1997, Rogers 1997) of the system being managed; in other words, coming to consensus on the job to be done and goals to be achieved.

Goals for sustainability (refer to definition in previous chapter) of the river ecosystem and quantitative objectives for its condition provide a framework for restoration and management. Planning for integrated river management, including navigation system infrastructure expansion; navigation system operation and maintenance; habitat protection, enhancement, and restoration; fish and wildlife management; management of river recreation; floodplain management; and water quality management should be conducted in the context of a set of clear goals and objectives for condition of the UMR – IWW ecosystem. These goals and objectives are being set collaboratively, with participation of the community of river stakeholders.

Goals from Previous UMR – IWW Plans and Reports

Many goals for the condition of the UMR – IWW ecosystem have been proposed in various management proposals and plans. Most previous efforts to plan for river management focused on either management actions or institutional arrangements for river management, rather than the condition of the river ecosystem. Recent efforts that have recommended goals and objectives for the UMR – IWW or Illinois River have been sanctioned by interagency and non-governmental organizations (Upper Mississippi River Conservation Committee 2001, The Nature Conservancy 1998). Notably lacking in most of the historic and existing management plans and proposals are quantitative objectives for the desired ecosystem condition. The recently conducted EMP Habitat Needs Assessment (Theiling et al. 2000) was the first multi-agency-sanctioned and supported effort to set objectives for the condition of the UMR – IWW ecosystem.

The Panel summarized purpose statements and goals from existing Upper Mississippi River System planning documents prepared between 1980 and 2001. Purpose statements from the reports are listed in Table 2. Goals from each document were listed by topic and the topics addressed in the goal statements are summarized in Figure 1. Many of the "goals" were more accurately described as recommendations about institutional arrangements, "how-to" strategies, calls for studies, and other planning activities, but few plans actually presented goals and quantifiable objectives for the condition of the ecosystem or defined a future condition. This review focused on environmental goals for UMR – IWW ecosystem management, but many of the reports that were reviewed also included economic, institutional, recreation, and other goals.

There has been an evolution over time in the types of goals for UMR – IWW river management and their level of specificity (Figure 1). The Upper Mississippi River Conservation Committee (UMRCC) was one of the first inter-agency groups to address UMR – IWW environmental issues. It was formed by fisheries managers in 1943 with the purpose to "Promote the preservation and wise utilization of the natural and recreational resources of the Upper Mississippi River (UMR) and to formulate policies, plans and programs for conducting cooperative studies."

The first comprehensive plans for UMR – IWW management, initiated in the 1960's with the Upper Mississippi River Basin Commission's Level B reconnaissance, were directed toward dredging, sedimentation, and point-source water pollution. Goals were generally specific enough to be acted on without further efforts to define objectives within goals.

As planning efforts matured through time, more information was obtained, and some of the obvious big problems, such as point source pollution and dredged material placement, were resolved or coordinated. Planners then identified needs for specific studies and monitoring. Habitat restoration also became an important goal. Institutional arrangements for river management were refined as

Table 2
Purpose Statements from Upper Mississippi River System Planning Documents

Upper Mississippi River Main Stem Level B Study (Upper Mississippi River Basin Commission 1980)**:** "The study thus is intended to provide a basis for future management and related resource programs for the Upper Mississippi River Main Stem through a comprehensive resource management approach."

UMR – **IWW Master Plan** (Upper Mississippi River Basin Commission 1982): "The purpose of the Master Plan study was to develop a "comprehensive master plan for the management of the Upper Mississippi River System." "This series of recommendations provides a balanced comprehensive plan for the management of the System which recognizes its importance as an economic, environmental, and recreational resource."

Facing the Threat (Upper Mississippi River Conservation Committee 1993): "A resource as complex and important as the Mississippi River cannot be successfully managed in bits and pieces. A comprehensive ecosystem management strategy needs to be developed and implemented for the Upper Mississippi River."

Restoring the Big River (Robinson and Marks 1994): "This report proposes a Clean Water Act framework for action to stop the Mississippi River's further decline and to begin its restoration."

Galloway Report (Interagency Floodplain Management Review Committee 1994): "To coordinate and sustain water resource development consistent with national floodplain management goals, [a complex of independently managed federal programs for navigation, flood damage reduction, water quality improvement, natural resources protection and enhancement, and agricultural production] need to be integrated using existing or modified institutional arrangements among federal, state, tribal, and local agencies." The committee went on to note that "Currently, no single agency has federal or federal-state oversight responsibility for the range of activities within the upper Mississippi River basin, or for ensuring that funding and performance among programs are commensurate with national goals."

McKnight Report (The McKnight Foundation 1996): "This report explores how the river and its watershed comprise a dynamic, expansive, and highly complex system of natural and human forces that influence each other as they continually evolve. This information is intended to provide a more concrete framework for efforts to sustain and enhance the environment and economy of the Upper Mississippi."

Fish and Wildlife Interagency Committee (FWIC; USFWS 1995): "The FWIC will strive to preserve the Upper Mississippi River floodplain for the enjoyment and use of this and future generations.
Goal I – Environmental quality – To preserve and enhance the environmental quality, wild character, and natural beauty of the River's floodplain ecosystem.
Goal II – Migratory Birds – To provide the life requisites of waterfowl and other migratory birds.
Goal III – Fisheries and Aquatic Resources – To provide the life requirements of fish and other aquatic plant and animal life occurring naturally along or in the Upper Mississippi River.
Goal IV – Other wildlife – To provide the life requirements of resident wildlife species."

Upper Mississippi River Summit (Upper Mississippi River Summit 1996): "To seek long term compatibility of the economic use and ecological integrity of the Upper Mississippi River."

Upper Mississippi River System Status and Trends (U.S. Geological Survey 1999): "The purpose of this report is to present, analyze, and discuss information about the ecological condition of the UMR – IWW."

Habitat Needs Assessment (Theiling et al. 2000): "The purpose of this Habitat Needs Assessment is to help guide future habitat projects on the UMR – IWW."

A River That Works and a Working River (Upper Mississippi River Conservation Committee 2001): "This report describes the critical elements of a strategy for operation and maintenance of the Upper Mississippi River and its navigable tributaries."

Study/Report	Basin Commission Level B Study 1977	GREAT I	GREAT II 1980	Basin Commission Master Plan 1982	UMRCC Facing the Threat 1993	Restoring the Big River 1994	Galloway Report 1994	McKnight Report 1996	FWIC 1996	UMR Summit 1997-99	UMRS Status and Trends Report 1998	Habitat Needs Assessment 2000	Working River 2000	Conservation Biology
Recreaction	X	X	X	X				X						
Dredging Issues	X			X						X			X	
Bank Stabilization (veg., rip-rap, channelization)	X	X	X										X	
Sedimentation	X	X	X									X	X	
Water Quality	X	X	X			X				X			X	
Monitoring & Study		X	X	X		X		X						
Institutional Coordination		X	X		X			X						
Habitat Restoration		X	X			X						X	X	
Acquire Floodplain Lands							X			X				
Environmental Integrity (EI)									X					
Provide Life Requisites for Waterfowl and Mig. Birds									X					
Provide Life Requisite for Fish, Aquatic Plants, and other Aq. Resources									X					
Provide Life Requisites for Wildlife									X					
Conserve, Restore, and Enhance T&E Species									X					
Water Level Management										X		X	X	
Environmentally Sympathetic Training Structures										X				
Maintain or enhance viable native populations and habitats											X			
Maintain or enhance ability to recover from disturbances											X			
Maintain or enhance ecosystem sustainability											X			
Maintain or enhance capacity to function as part of a healthy basin											X			
Maintain or enhance annual floodplain connectivity											X		X	
Maintain or enhance ecological value of natural disturbances											X			
Improve Habitat Quality												X		
Improve Habitat Diversity												X		
Sever Pathways for Exotic Species													X	
Provide Fish Passage at Dams													X	
Represent native ecosystem types														X
Maintain viable populations of native species														X
Maintain ecological and evolutionary processes														X
Maintain evolutionary potential of biota														X

Figure 1. Summary of goal topics from previous UMR – IWW plans and reports

collaboration required increased communication and shared responsibilities among agencies in the late 1970's and 1980s. Ecosystem management became important in the 1990s and the goals for UMR – IWW natural resource management were revised with the new emphasis on ecosystem management. Goals were set for target species, species guilds, and habitat types, but they were broad enough that measurable objectives and endpoints were also needed.

Increased scientific understanding of the UMR – IWW ecosystem resulted in further refinement of natural resource management goals for the UMR – IWW, emphasizing ecological integrity. Naturalization of the hydrologic regime and connectivity of habitats along the river and floodplain became stated objectives in several planning efforts. Invasions of economically and environmentally damaging exotic species (e.g., zebra mussels and Asian carp) meant that objectives for the exclusion and management of exotic species were also needed in UMR – IWW management.

Work groups in the three UMR – IWW Corps of Engineer Districts developed ecosystem management strategies for navigation pools and implemented some changes in river system management (notably Pool Planning and Water Level Management in St. Paul District, Pool Planning and Water Level Management in Rock Island District, and Environmental Pool Management in St. Louis District), but these strategies have not yet been combined into an integrated approach to river management or formally adopted by management agencies. Additionally, other river groups such as the UMRCC Fish, Wildlife, Water Quality, and Vegetation Technical Sections or state conservation agencies have prepared planning documents but similarly, these documents have not been synthesized to represent an integrated approach.

Tiered Goals and Objectives for the UMR – IWW

In November 2001, the Navigation Study Environmental and Economic Coordination Committees adopted the UMR – IWW Summit vision statement to "Seek long term compatibility of the economic uses and ecological integrity of the Upper Mississippi River" (Upper Mississippi River Summit 1996) as a first tier goal. The UMR – IWW Summit participants also agreed to a definition of sustainability, "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." This latter goal for sustainability of human society and ecosystems is adopted from the Bruntland Commission (World Commission on Environment and Development 1987) and has been endorsed by the five UMR – IWW states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin) through the Upper Mississippi River Basin Association and a 1997 Joint Governors' Proclamation.

A tiered set of goals and objectives for the future condition of the UMR - IWW is being developed as part of the Upper Mississippi – Illinois Waterway Navigation Study (Table 3). In the first level, the broad goal of sustainability is a directive from U.S. Army Corps of Engineers Headquarters, based on national and international policies, which is similar to the vision statement of the NECC/ECC.

In 1994, the Upper Mississippi River System Environmental Management Program (UMR – IWW-EMP) and the Upper Mississippi River Basin Association sponsored a conference on institutional arrangements for river management. Presenters related many examples of large ecosystem management efforts from around the world. Several presenters offered goals for ecosystem management based on principles from restoration and conservation ecology. Partly in response to this conference, the Upper Mississippi River Conservation Committee (UMRCC 1995) endorsed a set of goals for condition of the river ecosystem from Grumbine (1994), which were adapted as second-tier goals.

Table 3
UMR – IWW Higher Order Goals

First Tier Goal:

- 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.

Second Tier Goals:

- Maintain viable populations of native species in situ.
- Represent all native ecosystem types across their natural range of variation.
- Restore and maintain evolutionary and ecological processes (e.g., disturbance regimes, hydrologic regime, nutrient cycles, etc.).
- Integrate human uses and occupancy within these constraints.

Objectives for Condition of the River Ecosystem

Objectives for condition of the river ecosystem have been reviewed and synthesized by the Science Panel (Table 4). The objectives were compiled from a number of sources, including “Working River and a River That Works” (UMRCC 2001), from the Habitat Needs Assessment (Theiling et al. 2000), from interagency efforts in two UMR – IWW Corps Districts to develop navigation pool-scale plans (Fish and Wildlife Work Group 2003, Fish and Wildlife Interagency Committee 2003), and from four navigation study-sponsored stakeholder workshops held in November 2002 (DeHaan et al. 2003). At the stakeholder workshops, over 2,500 spatially explicit objectives or management needs were identified, entered into a computer geographic information system (GIS), and a set of more general or “pool-wide” objectives were identified for each navigation pool and river reach. A distinction was made between objectives for condition of the river ecosystem and management actions.

The objectives identified collaboratively for the UMR – IWW are grouped by essential ecosystem characteristics, or ecosystem features: biogeochemistry, hydrology and river hydraulics, geomorphology, habitat, and biota (EECs, see definition in Chapter 4 and Appendices B and C adopted for this study. The objectives cover a wide range of ecological conditions both within the mainstem river corridors and throughout the river basin, and there are a multitude of management actions available to affect them (Appendix D). The list of objectives is long, befitting the scale and complexity of the UMR – IWW; many of the objectives require further refinement to make them practical and quantitative. The objectives were entered into a relational database (Appendix E), linking them to the higher-level goals and management actions (see below).

Table 4 Ecological Objectives and Need Statements (81 total)
Biogeochemistry
• Achieve state water quality standards for all uses • Reduce contaminant loadings to the river • Reduce mobilization of sediment contaminants • Achieve state total maximum daily load (TMDL) standards • Reduce fine sediment loadings to the river • Reduce coarse sediment loadings to the river • Reduce nutrient (N and P) loading from tributaries to river • Reduce nutrient (N and P) export from UMR – IWW to Gulf of Mexico • Maintain adequate DO concentrations during ice-free periods for fish • Maintain adequate DO concentrations during winter for fish • Create thermal and velocity refugia (e.g. holes >3 m) in backwaters and channels • Maintain water clarity sufficient to support submersed aquatic vegetation, aquatic invertebrates, and sight feeding fishes
Geomorphology
• Increase the number and area of secondary channels • Increase depth diversity in secondary channels • Restore the channel geometry and floodplains of tributary rivers • Restore the channel geometry of tertiary channels • Increase the depth diversity in main channel border areas • Increase the extent and number of sandbars • Increase the extent and number of mud flats • Increase the extent and number of gravel bars • Increase the area and number of islands • Increase the area and number of rock and gravel riffles • Increase the extent and number of rock and gravel substrate areas • Increase the area and relief of ridge and swale topography in the floodplain • Increase topographic diversity and elevation of floodplain areas • Restore channelized tributaries in the mainstem river floodplains • Restore fluvial dynamics (e.g. channel avulsion - secondary channel - distributary channels – etc.) • Reduce rate of delta formation • Increase the rate of delta formation • Increase connectivity between channels and contiguous backwater areas • Reduce connectivity between channels and contiguous backwater areas • Increase connectivity of floodplain areas • Reduce connectivity of floodplain areas • Increase extent of contiguous backwater areas • Increase the number and extent of isolated floodplain lakes • Increase the extent of unleveed floodplain at tributary confluences • Increase the extent of unleveed floodplain
(Sheet 1 of 3)

Table 4 (Continued)

Hydrology/River Hydraulics

- Naturalize hydrologic regime
- Reduce stage and discharge fluctuations caused by dam operation
- Restore desirable stage: discharge relationship
- Restore or naturalize hydraulic interactions between the river and tributaries
- Naturalize tributary discharge hydrographs - reduce effects of hydropower
- Increase storage and conveyance of flood water on the floodplain
- Provide desirable pattern of hydraulic conditions in tailwaters (e.g. increase area of <0.3 m/sec current velocity - attract fish to fishways)
- Provide pathways for animal movements through and across dams
- Reduce wind fetch in open-water areas (e.g. backwaters and impounded areas)
- Provide desirable current velocity and residence time in aquatic areas

Habitat

- Restore and maintain a diverse mosaic of plant communities
- Increase extent, abundance, and diversity of submersed aquatic plants
- Increase extent, abundance, and diversity of emergent aquatic plants
- Increase extent, abundance, and diversity of floodplain grassland
- Increase extent, abundance, and diversity of floodplain shrub cover
- Restore and maintain large contiguous grassland patches (>1000 acres)
- Restore and maintain large contiguous forest patches (>1000 acres) with connected corridors
- Restore and maintain large contiguous wetland patches (>1000 acres) every 30-40 miles
- Increase the extent, diversity, and successional variety of the floodplain forest
- Increase the number and area of backwaters with suitable habitat for fish
- Increase the number and extent of managed marsh areas in leveed floodplain
- Maintain the existing extent of floodplain agricultural areas
- Increase the number and extent of continuous habitat corridors (floodplain forest - prairie - marsh)
- Increase the number, width, and length of vegetated riparian buffer strips along tributaries and ditches
- Increase woody debris in secondary channels
- Increase the area of suitable winter habitat for lentic fishes
- Increase the area of suitable winter habitat for lotic fishes

Biota

- Maintain viable populations of native plant species throughout their range in the UMR – IWW at levels of abundance in keeping with their biotic potential
- Maintain the diversity and extent of native plant communities throughout their range in the UMR – IWW
- Maintain viable populations of native macroinvertebrate species throughout their range in the UMR – IWW at levels of abundance in keeping with their biotic potential
- Maintain the diversity and extent of native macroinvertebrate communities throughout their range in the UMR – IWW
- Maintain viable populations of native mussel species throughout their range in the UMR – IWW at levels of abundance in keeping with their biotic potential
- Maintain the diversity and extent of native mussel communities throughout their range in the UMR – IWW

(Sheet 2 of 3)

Table 4 (Concluded)
Biota (cont.)
• Maintain viable populations of native fish species throughout their range in the UMR – IWW at levels of abundance in keeping with their biotic potential • Maintain the diversity and extent of native fish communities throughout their range in the UMR – IWW • Maintain viable populations of native amphibians and reptiles throughout their range in the UMR – IWW at levels of abundance in keeping with their biotic potential • Maintain the diversity and extent of native amphibian and reptile communities throughout their range in the UMR-IWW • Maintain viable populations of native birds throughout their range in the UMR – IWW at levels of abundance in keeping with their biotic potential • Maintain the diversity and extent of native bird communities throughout their range in the UMR – IWW • Maintain viable populations of native mammals throughout their range in the UMR – IWW at levels of abundance in keeping with their biotic potential • Maintain the diversity and extent of native mammal communities throughout their range in the UMR – IWW • Prevent the introduction and dispersion of exotic invasive species • Reduce the extent and abundance of exotic invasive species • Reduce the adverse effects of invasive species on native biota
(Sheet 3 of 3)

Objectives by river reach

The science Panel further segregated and stratified objectives by the four river reaches defined in DeHaan et al. (2003) that were used in the UMR – IWW environmental objectives workshops (Figure 2). This classification divides the UMR – IWW according to similar geomorphic, hydrologic, and navigational features. These reaches are:

Reach 1 – Mississippi River Pools 1 through 11.
Reach 2 – Mississippi River Pools 12 through 22.
Reach 3 – Mississippi River Pool 24 to confluence with Ohio River.
Reach 4 - Illinois River.

Given the marked differences in climate, geomorphology, hydrologic regime, habitats, and navigation and floodplain uses of the UMR – IWW between the river reaches, some objectives apply only to certain reaches. For example, the objective to reduce wind fetch in open-water areas applies only to the parts of the river system that are impounded by the navigation dams. Maintaining adequate dissolved oxygen in backwaters during winter ice cover only applies to the northern reaches of the system, although the objective of maintaining adequate dissolved oxygen in backwaters is relevant to the entire UMR – IWW. The objective to increase the area of floodplain without levees applies to the river reaches with levees.

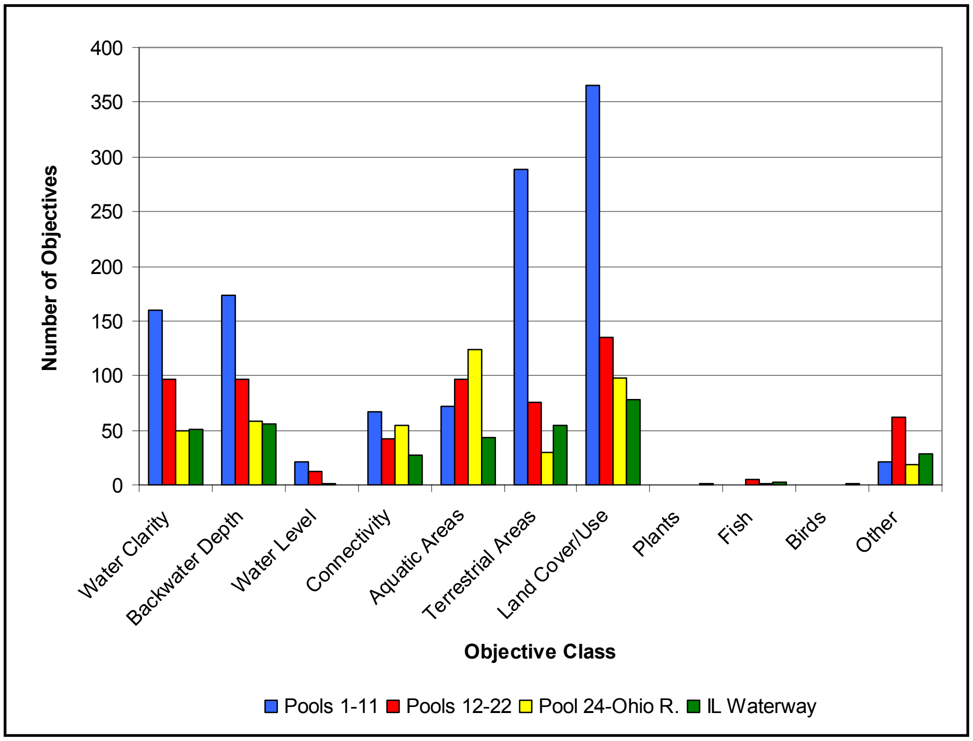

Figure 2. Regional distribution of UMR – IWW environmental objectives (DeHaan et al. 2003)

Most of the objectives apply throughout the UMR – IWW. Objectives for biota all call for maintaining viable populations of native species at levels of abundance that are consistent with their biotic potential, and for maintaining the diversity and extent of native communities throughout their range. Reducing nitrogen export from the UMR – IWW to the Gulf of Mexico applies to the entire system.

Most management actions are specific to river reaches, given their potential for effectiveness and the appropriateness of their application in differing parts of the river system. Queries of the relational database (described previously) can identify management actions that contribute to attaining objectives within each river reach (see Section 5, Appendix E).

4 Importance of Models to Adaptive Management

The Upper Mississippi River-Illinois Waterway is a large, complex, and human-dominated ecosystem comprised of interacting, interdependent subsystems linked together by exchanges of energy, materials, information, and money. Humans, other organisms, the navigation system, and the regional economy are all integral components of a broadly defined "UMR – IWW ecosystem." Although usually described, assessed, and evaluated separately, the economy, social conditions, political systems, and the environment are functionally interdependent. While recognizing the need for integration across these complex human and environmental systems, the Panel, following its charge, focused on the role of conceptual and operational models in environmental and ecological impact assessment. The Panel also addressed the potential contribution of these kinds of models to adaptive management and informed decision-making.

The Panel's discourse regarding models began with deliberations regarding the formulation, purpose, and application of conceptual models. A general conceptual model for the Upper Mississippi River was developed. Example applications for island construction and water-level management follow from this generalized model. The discussion continued through the Panel's consideration and evaluation of the role of quantitative models in supporting management goals and objectives specific to larger river systems, particularly the Upper Mississippi and Illinois Rivers. A number of relevant hydrodynamic, hydraulic, and ecological operational models were identified and are listed in Table 5. The chapter concluded with discussions relevant to the use of both conceptual and numerical models in support of adaptive environmental management.

Collaboration among multiple stakeholders is becoming increasingly important in natural resources management. A number of approaches for collaborative planning and management have emerged in recent years (Blumenthal and Jannik 2000). Among these approaches, adaptive management (Holling 1978, Walters 1986) is becoming widely applied. Management approaches that involve diverse participants in assessment, learning, planning, and management can lead to more flexible, adaptive institutions and sustainable outcomes (Lee 1993, Gunderson et al. 1995). For example, "citizen science" (Lee 1993) aims to involve stakeholders, scientists, and managers in a continuing discussion concerning ecosystem conditions valued by stakeholders and those ecosystem conditions that can be achieved and sustained. Importantly, adaptive management uses models extensively (e.g., Walters 1997) to increase stakeholder understanding and

Table 5
Existing and Needed Environmental Models for the UMR – IWW

Model	Source/Citation	Factors and Processes	Spatial Scales	Type of Model	Model Needs
Hydrologic and hydraulic processes					
TABS 2-D numerical hydraulic model	Corps Districts, unpublished	Current velocity, direction, stage by discharge level	Navigation pool or smaller study areas	Numerical simulation, linked to GIS	Complete for entire UMR-IWW
Hydraulic effects of navigation traffic (NAVEFF, NAVSED)	Corps ERDC, various reports	Hydraulic effects (velocity, drawdown, wake waves, sediment resuspension) of commercial towboat and barge traffic	Habitat area	Numerical simulation, linked to GIS	
Hydraulic effects of recreational boating traffic	Corps ERDC, Knight, Parchure in press	Hyudraulic effects – waves, sediment resuspension	Habitat area	Numerical simulation, linked to GIS	
Wind fetch, wave height	Rogala, USGS UMESC unpublished	Wind speed, wind fetch, wave height	Navigation pool	Numerical simulation, linked to GIS	Complete for specific areas of interest
UNET hydraulic model	Corps Districts, unpublished	Stage: discharge	Navigation pool, entire system	Numerical simulation, can be linked to GIS	Make link to GIS
Pool drawdown models	Corps Districts, unpublished	Current velocity, direction, stage, by discharge level and drawdown depth	Navigation pool	Numerical simulation, linked to GIS	Complete for specific areas of interest
'Micro' hydraulic models (Davinroy, CEMVS)		Stage:discharge, flow distribution, sediment processes	Habitat area, selected study areas	Small-scale physical hydraulic models	Complete for specific areas of interest
Large scale physical hydraulic models (Lower Pool 4, Pool 26, etc.)		Stage:discharge, flow distribution, sediment processes, effects of navigation traffic	Navigation pool, habitat area, selected study areas	Large-scale physical hydraulic models	
Floodplain inundation model	Wlosinski 2001 posted on UMESC web site	Stage:discharge frequency and duration by river mile	Habitat area, navigation pool, river reach	Look-up table, can be linked to GIS	Make link to GIS
Seamless fine scale aquatic-terrestrial elevation and hydrologic models					Develop
Sediments/Water Quality					
Tributary sediment, N, P yields	USGS UMESC web site, DeHaan and Soballe	Sediment, N, P annual yields of major tributaries	Tributary watershed	Empirical regression, linked to GIS	Refine models for smaller watersheds
Sediment budget Pools 11-26	Nakato in WEST Inc. 2000	Suspended sediment transport, fate	Navigation pool, river reach	Numerical simulation	Complete for entire UMR-IWW
Sediment budget Illinois River	Demissie et al. 1992, 2002	Suspended sediment transport, fate	Tributary watershed, river reach, navigation pool	Numerical simulation	
Wind-driven sediment resuspension	USGS UMESC unpublished, Rogala and Gaugush	Wind speed, wind fetch, wave height, water depth, sediment characteristics	Habitat area, navigation pool	Numerical simulation, linked to GIS	Complete for specific areas of interest
Sediment transport and channel response model		Sediment transport, geomorphic processes	Tributary watershed, river reach, navigation pool	Numerical simulation, linked to GIS	Develop
Nutirent dynamics					Develop
Ecosystem models					
Carbon model Pool 19	Sparks et al. unpublished	Photosynthetic production, secondary production	Habitat	Numerical simulation	Complete and validate

(Continued)

Table 5 (Concluded)

Habitat models					
Backwater winter fish habitat	USGS UMESC unpublished, Rogala and Gaugush	Under-ice current velocity, water depth, water temperature, dissolved oxygen	Habitat area, navigation pool	Empirical regression, linked to GIS	Complete for specific areas of interest
Aquatic plant occurrence	USGS UMESC unpublished, Yin	Submersed aquatic plant occurrence, as affected by depth, substrate type	Navigation pool	Empirical regression	Complete for specific areas of interest
Habitat Needs Assessment Query Tool	DeHaan et al. 2000	Potential species habitat, Potential species in habitat areas	Habitat area, pool, system	Look-up tables linked to GIS	Update with 2000 land cover
Habitat Evaluation Procedures (HEP)	FWS, Corps ERDC WES	Habitat suitability for selected species	Habitat area for a plant or animal community	Empirical/subjective, can be linked to GIS	Modify or construct; Make link to GIS
Wildlife Habitat Appraisal Guide (WHAG)	Corps ERDC-WES	Waterfowl/wetland habitat	Habitat area for waterfowl	Empirical/subjective, can be linked to GIS	Make link to GIS
Aquatic Habitat Appraisal Guide (AHAG)	Corps ERDC-WES	Fish habitat, based on MoFish (Missouri DOC)	Habitat area for fish	Empirical/subjective, can be linked to GIS	Make link to GIS
Hydrogeomorphic Approach to Wetland Function	Corps ERDC WES	Rating of wetland functions, e.g., floodwater retention	Wetland area	Empirical/subjective, can be linked to GIS	Wetland classification and functional curve development
Population models					
Larval fish entrainment models	Bartell et al. 2000	Hydraulic (water entrainment), larval fish entrainment mortality, equivalent adults lost, recruitment foregone, and production foregone	UMRS, habitat area	Numerical simulation, linked to GIS	Complete for specific areas of interest
Leslie matrix fish population models	Bartell 2000 unpublished	Population response to entrainment mortality – several fish species	Habitat area, navigation pool	Numerical simulation	Complete for specific areas of interest
Mussel impacts model	Bartell and Miller 2000	Mussel response (behavior, growth) to vessel-induced stress	Microhabitat	Numerical simulation	
Zebra mussel veliger drift	Illinois Natural History Survey 2000	Zebra mussel veliger drift, settlement	River reach	Numerical simulation	
RAMAS mussel population model	Corps St. Paul District 2000 unpublished	Population growth, potential for local extinction	Navigation pool	Numerical simulation	
Fingernail clam distribution	USGS UMESC unpublished, Burkhardt	Fingernail clam occurrence, density, wind fetch, water depth, current velocity, sediment characteristics	Habitat area	Numerical regression, linked to GIS	Publish
Aquatic plant growth	Bartell, Best unpublished	Submersed aquatic plant growth and reproduction (suspended sediment, water depth, temperature)	Habitat area	Numerical bioenergetics, linked to GIS	Publish; Complete for specific areas of interest
Aquatic plant breakage by vessel wakes and wind waves	Nair and Bartell, unpublished	Submersed aquatic plant breakage in current	Habitat area	Numerical simulation, linked to GIS	
Regression model Pool 8	Claflin 1977	Hydrologic regime, plant growth, fish growth	Navigation pool	Simulation	Complete for specific areas of interest
Other species and guilds					Develop
Floodplain vegetation succession					Develop
Biological Production					Develop
Microbial activity					Develop
Other models					
Conceptual model of the UMRS	Lubinski 1993	All	Natural and anthropogenic	Conceptual	
AEA	AEA Committee 1997	River reach (Pools 4 – 22), Navigation pool	Hydrologic regime, sedimentation and dredging, plant growth and succession, patterns of habitats, fish abundance, and shipping	Numerical simulation	
Recreational boating traffic forecast and allocation model	Carlson et al. 2000	All	UMRS, navigated area	Empirical regression	

awareness. When applied in a planning and decision-making context, these management models should be usable and understandable by diverse participants, and should be easily modified to accommodate unanticipated situations and explore new ideas (Carpenter et al. 1999).

These models are routinely used to describe and analyze general patterns of system behavior. However, models can also be viewed as caricatures of reality that stimulate creative problem-solving, focus discussion and clarify communication, and contribute to collective understanding of complex problems (Holling and Chambers 1973; Holling 1978; Scheffer and Beets 1994; Walters 1997; Janssen 1998). New approaches for simulating behavior of individuals, societies, and ecosystems are rapidly emerging, revealing some startling insights into the effectiveness of long-held assumptions about ecosystem management (Rauch 2002; Carpenter et al. 1999). Models can be used to develop concepts, educate, simulate processes, test hypotheses, forecast future conditions, conduct planning, assess the results of monitoring, and identify additional information and research needs. Recent understanding concerning the dynamics of complex systems is creating new tools for environmental modeling and resource management (e.g., Dale 2003, Costanza et al. 1993). In the context of UMR – IWW river management, models can usefully contribute to all of these management and assessment activities.

The Panel further recognized the importance of conceptual and operational models as key management tools that:

- Provide quantitative, and if necessary qualitative, assessments of ecological risks posed by the diverse and disparately scaled environmental stressors relevant to the Upper Mississippi River basin.
- Assist scientists and managers in the formulation of decision alternatives and management plans critical to adaptive management in the broader context of sustainability.
- Estimate the outcomes of management decisions, including likelihood and degree of success (e.g., restored or created habitat units, fish species diversity, aquatic plant distribution and abundance), as well as risk of failure (e.g., habitat degradation, local extinctions, introduction of invasive species).
- Help scientists and managers in the design of effective monitoring plans needed to support adaptive management and to evaluate sustainability.
- Permit modeled explorations of ecological sustainability in advance of monitoring results.

Conceptual Models

The Panel endorsed and encouraged greater use of conceptual models as valuable tools for managing complex ecological systems, such as the Upper Mississippi River. The following sections outline the purpose of conceptual models, describe their general formulation for risk assessment and environmental management, and present example applications relevant to the Upper Mississippi River.

Description

In general, a conceptual model for a complex ecological system identifies controlling factors, ecosystem structure, and ecosystem resources (Thom 2001) that are important in the system; and changes that may occur. Those changes may be desirable (e.g., restoration and management) or undesirable (i.e., degradation). The model defines the subset of system components that are germane to the modeling objectives and specifies the functional interrelationships among the selected components that determine ecosystem condition in the presence and absence of the effectors of change (Thom 2001). There can be considerable variation in how a conceptual model is developed for any particular ecosystem, including how to best describe structural components, controlling elements, and determine functional interrelationships.

Purpose

Conceptual models help simplify complex environmental systems and organize the salient information about such systems in relation to a particular management or assessment problem. These models distinguish the important structural and functional attributes of complex systems necessary to address specific problems (i.e., problem identification). They identify the key functional interconnections among system components and illustrate how changes in one or more components can propagate throughout the system to indirectly affect other system components. A conceptual model also can indicate sources of uncertainty that limit understanding of the system of interest. In adaptive management, conceptual models typically are used as a tool to formulate management actions, to assess their effects, and to aid in communication among diverse stakeholders (Thom 2001). Conceptual models are accepted as key components of adaptive management and can help guide active and passive adaptive management (Walters 1997). Conceptual models are also considered essential to the design of effective monitoring programs that provide an empirical basis for management and decision-making (Manley et al. 2000).

A Conceptual Model of the Upper Mississippi River Ecosystem

The Panel developed a general conceptual model of the UMR – IWW ecosystem (Figure 3). The model structure reflects the Panel's understanding of the critical components of this large-scale, complex environmental system in relation to continuing challenges in assessing ecological risks posed by multiple and disparately scaled environmental stressors. The general model structure also identifies the key components and linkages needed to address important management opportunities consistent with adaptive management within a broader framework of ecological sustainability.

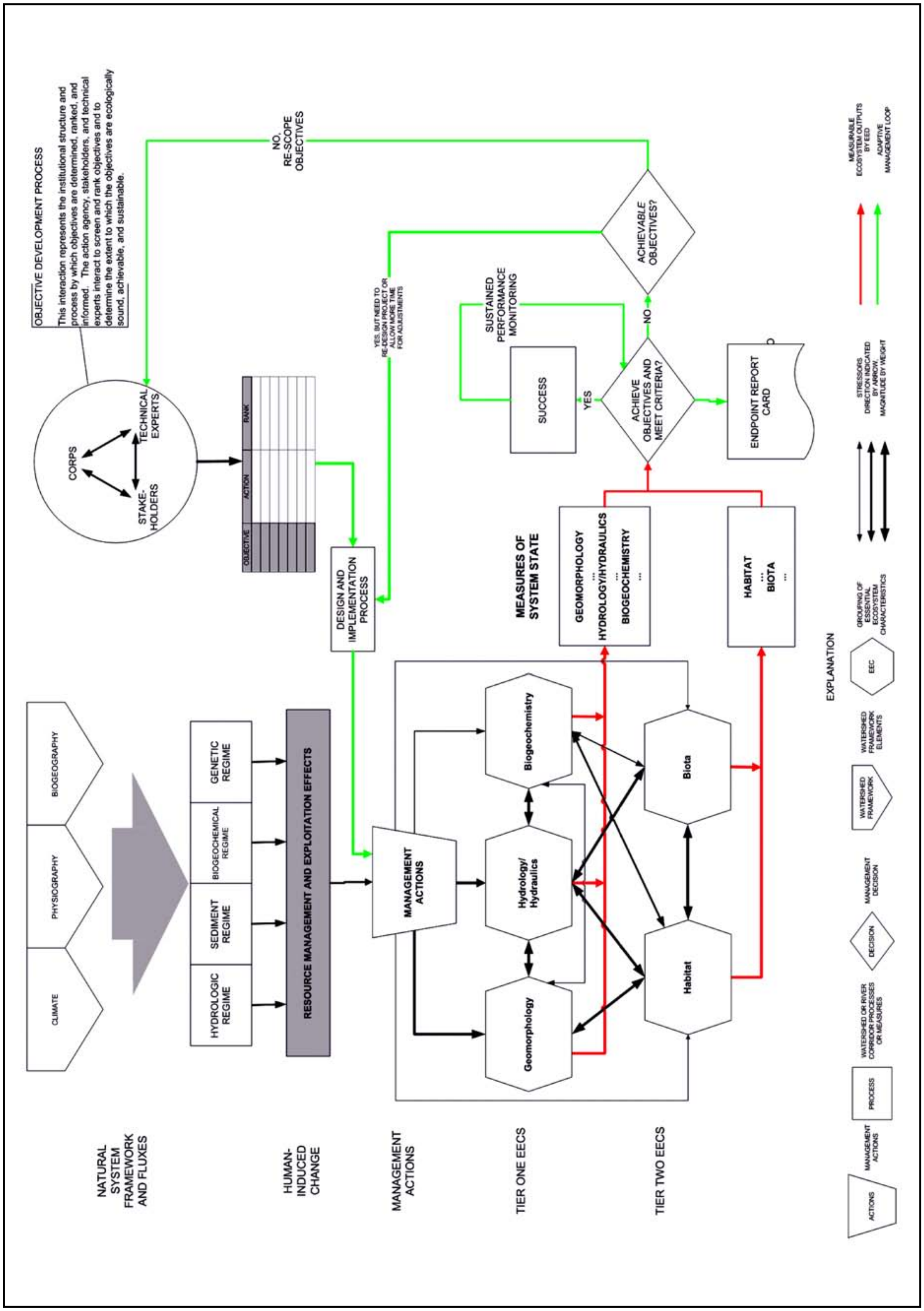

Figure 3. General conceptual model of the Upper Mississippi River

Concepts and terminology borrowed from ecological risk assessment (i.e., USEPA (1992, 1998)) facilitate the description of the UMR – IWW conceptual model. Three fundamental components of the risk assessment framework typically include: drivers, stressors, and endpoints. Drivers are broadly defined categories of larger scale human or natural disturbance that produce measurable changes (desired or undesired) in the ecological system of interest. In the typical ecological risk assessment model, stressors are physical, chemical, or biological change that can affect an ecosystem or ecosystem component. The effect can be considered negative or positive (U.S. Army Engineer Research and Development Center and Harwell Gentile and Associates 2001). In ecological risk assessment, drivers and stressors are agents of change; endpoints identify, in general or in detail, the environmental or ecological changes of interest. Broadly defined endpoints might include changes in terrestrial primary production as a function of regional changes in climate (e.g., CO_2 fertilization) or acres of riparian wetlands lost to agriculture. The UMR – IWW ecosystem conceptual model includes broadly defined categories of environmental features termed essential ecosystem characteristics (EECs). The EECs originate from an expansion of the USEPA risk assessment methodology (Harwell et al. 1999); they identify ecological components thought to be critical in sustaining ecological systems (e.g., energy flow, material cycling) and those aspects of ecosystems valued by various stakeholder interests.

Drivers and EECs are organizing principles in a conceptual model; stressors and endpoints are the ecosystem components that become the focus of direct management attention. Drivers and stressors are for the most part directly measurable and are determined by the ecosystem to be modeled; EECs and endpoints are more user-defined in the context of assessment or management goals and objectives. Endpoints are specific characteristics within the EECs that are selected to represent ecosystem responses to management actions.

The Panel's generic conceptual model of the UMR – IWW builds upon the typical consideration of drivers, stressors, and endpoints, but alters some concepts to achieve a more useful description. The structure presented here (Figure 3) reflects the committee's understanding of the critical components of the ecosystem, and it is intended to address primarily the need to communicate complex ecological interactions to the public and resource managers. Figure 3 identifies important drivers, stressors, and endpoints relevant to risk assessment and adaptive management in this large-scale and complex ecosystem. The following section describes this generic model. Specific applications to island creation and water level management are provided as examples.

In this formulation, the general nature of the UMR – IWW ecosystem is determined primarily by the natural physical framework and larger scale hydrology of the watershed. 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 the biota (including genetic information) in this ecosystem.

The climatic driver encompasses large-scale fluxes of energy and water into the UMR – IWW watershed. Climate is clearly an important driver of this large river system. Regional climate variation (e.g., floods, drought) largely determines the pattern of water flows that define the system hydrology. Alterations in climate could dramatically change the hydrologic and ecological conditions within the system and can occur at spatial-temporal scales relevant to planning and management. However, these changes are largely beyond the influence of management actions and, in the context of the conceptual model, climate is considered an environmental context for assessment and management. Climate is considered as a boundary condition (i.e., beyond the influence of practical management actions) in this conceptual model.

The physiographic driver includes geology, soils, and topography that are relevant for at least two differing scales. At the scale of the watershed, physiography exerts strong control over hydrologic, sediment, and geochemical fluxes into the river system. At the scale of the river valley, physiography exerts direct control on geomorphic and hydrologic responses of the river, for example by controlling valley width or floodplain elevation. In the absence of human influence, the physiographic driver would be considered invariant over planning time frames of decades to centuries. Physiographic changes in the watershed due to human influences -- for example, drainage of agricultural lands or an increase in impervious surfaces -- can affect these fluxes over planning scales. These changes can be accommodated within the conceptual model, but because the area of interest in this study is limited to the river and its floodplain, changes in watershed physiography are treated as boundary conditions.

The biogeographic driver defines the distribution and abundance of organisms that inhabit the drainage basin. This driver also includes the natural flux of genetic information in and out of the system due to migrations, mutations, and extinctions involving the endemic species, as well as introduced species. The native biota results largely from historical and geographic controls on the distributions of species, although these assemblages of organisms have been altered by human actions that have introduced invasive species and caused local extinctions of species native to the UMR – IWW ecosystem. In addition, the biogeographic driver emphasizes the spatial distribution of organisms within the watershed. The biogeographic driver in the watershed is treated as a boundary condition and the abundance and distribution of organisms within the river system are considered implicitly in the general conceptual model (Figure 3).

As subsets of the larger scale drivers just described, more detailed drivers are defined as regimes that describe time series of fluxes of water, sediment, chemicals (and associated energy), and genetics (that is, species) into the UMR – IWW system. Fluxes into the river system are controlled in large part by the climatic, physiographic, and biogeographic contexts of the watershed. The fluxes can be altered by management actions directed at hydrologic features of the system, for example regional-scale land-use change, water level management, or construction of impoundments. This conceptual model considers changes in the watershed as boundary conditions as they are generally outside the scope of UMR – IWW management decisions.

The four regimes above can be considered the fundamental ecosystem drivers that can be altered (or filtered) by management or resource-exploitation actions to cause stresses to the river ecosystem. This schema differs from some conceptual models in which human actions are defined as the fundamental drivers or stressors (for example, Harwell et al. (1999)). In this case, the Panel defined drivers as the fundamental controlling forces and fluxes that structure ecosystems. This emphasizes the role of fundamental processes that structure ecosystems, whether natural or unnatural. Human actions for management or resource exploitation serve as filters (or modifiers) that alter the driver regimes. The term stressor is used to denote perturbations that alter the rate or nature of physical, chemical, or biological regimes (in keeping with Barrett and others (1976); see Appendix A, “Glossary”).

The Panel classified ecological endpoints into two broader categories (“tiers”) of essential ecosystem characteristics. The two tiers reflect differing perceptions of ecological structure and function as they might be understood and valued by different stakeholders. Each tier of EECs can be further subdivided into measurable endpoints that can be examined in a monitoring program (Figure 3; also see Chapter 6). The Tier 1 EECs consist of categories of geomorphology, hydrology/hydraulics, and biogeochemistry. The Tier 1 EECs are linked to measurable endpoints that may have important scientific information content and value in informing management, for example, of sediment concentrations or dissolved oxygen. Such technically defined EECs might not be generally recognized as being inherently valuable by the public. The importance of the Tier 1 EECs and their associated endpoints is described by linkages to Tier 2 EECs, which define characteristics identified as valuable by many stakeholders. Tier 2 EECs are habitat and biota. Many (but not all) pathways identified in the conceptual model link human actions to Tier 1 EECs, which can subsequently affect the habitat EEC and the biota EEC. The habitat EEC delineates physical habitat (for example, spatial and temporal distribution of water depth and velocity), as well as habitat provided by biota, (e.g., vegetation). Hence, vegetation characteristics generally show up in the habitat EEC rather than the biota EEC. Endpoints identified from Tier 2 EECs relate directly to stakeholders’ views concerning desirable ecological conditions, goods, and services provided by the UMR – IWW.

Arrows in the conceptual model illustrate the direction and relative importance of process linkages among drivers, stressors, management actions, EECs, and endpoints. In this sense, the arrows represent stressors that transfer perturbations in material or energy fluxes among EECs. In the generic model (Figure 3), most of the linkages pass through Tier 1 EECs. One exception includes the pathways emanating from biogeography. These are meant to indicate long-term genetic and biogeographic controls on the distribution and abundance of organisms that inhabit the system. Pathways from biogeography are considered to more directly influence the habitat (e.g., vegetation) and biota EECs, with pathways and feedbacks of secondary importance to the Tier 1 EECs. The conceptual model indicates that the Tier 1 and Tier 2 EECs are interdependent; the comparative importance of these interactions is indicated by the relative width of the lines defining them; stronger interactions are indicated with thick lines and weaker interactions are indicated with thinner lines.

Figure 3 demonstrates numerous feedbacks that indicate the complex relations among EECs. For example, hydrology/hydraulic characteristics affect geomorphology by interacting with sediment transport processes; geomorphology exerts a feedback control on hydraulics by altering channel morphology. Habitat has a strong connection to biota by influencing the environment inhabited by organisms, but the biota also can create and modify habitat, especially by controlling vegetation. In general, the more lines and arrows depicted on a diagram, the greater the complexity and inherent uncertainty. A complex conceptual model generally indicates that a high degree of difficulty will be encountered in creating useful predictive numeric models for management and assessment.

The generic model also includes management influence components related to objective development and adaptive management. In the upper right- hand portion of the conceptual model diagram, the objective-setting process is indicated as a three-way interaction among the Corps of Engineers, stakeholders (broadly defined to include input from resource management agencies and the concerned public), and technical experts. The diagram is not meant to define the roles of each explicitly, but simply to indicate the interaction of these three generic groups. In the UMR – IWW, objectives have been determined, in part, through a stakeholder-driven process; input from technical experts is meant to inform the process through evaluating the objectives with respect to ecological feasibility and sustainability.

Now that an initial set of objectives for the UMR – IWW ecosystem has been established, the navigation study process will proceed to formulation of alternative management plans (combinations of management actions). The alternative plans will be evaluated and compared, with regard to cost (efficiency), effectiveness (degree to which they would attain the objectives), non-monetary benefits, completeness, and acceptability (to stakeholders). A recommended plan will be selected, and following approval, will be implemented.

The adaptive management loop illustrated in the lower right portion of the model (Figure 3) depicts how measured results following the implementation of management actions are evaluated to see if changes to the system meet the planning objectives and are sustainable. Monitoring and evaluation of ecosystem state provide the data for this decision. This management process also provides for the preparation of a report card on endpoints for the stakeholders and managers (see Chapter 6). If the planning objectives and sustainability criteria have been met, the project can transition into a phase of low-intensity and continued monitoring. Performance monitoring is meant to continually evaluate changes in ecosystem state in relation to management actions and uncontrollable stressors (e.g., climate change). If planning objectives or sustainability criteria have not been achieved, the project objectives can be re-evaluated to determine whether, given the updated information on ecosystem response, the objectives are achievable and/or sustainable. This step is a "reality check" that determines whether objectives are reasonable or should be redefined. If it is determined that the objectives are not achievable or sustainable, this information is communicated to the three groups of stakeholders for reconsideration. If the objectives are deemed achievable, but were not achieved in the initial implementation of the project, the new information on system state response is fed back to the design and implementation process to guide adaptive redesign, or maintenance, or – in the case of slower ecological adjustments – to perhaps trigger additional monitoring and evaluation.

The general conceptual model is intended to illustrate how management actions propagate through EECs, the complexity of the interactions, the general direction of ecosystem response, and a sense of the level of uncertainty involved. Two example applications of conceptual models are presented to illustrate how such models may be developed and applied.

Island construction model

Numerous islands were created when the river was impounded to form the UMR – IWW navigation pools (e.g., USGS (1999), West Consultants, Inc. (2000)). However, erosion in subsequent years has reduced the number and spatial extent of these islands, and has thus diminished habitat quality and availability. The example management scenario involves the construction of islands using dredged material and rock revetments (Figure 4). The main stressor of this management action includes altered hydrologic regime, wind fetch, topography and redistributed sediment, which propagate to the geomorphology EEC. There will be strong interaction with the hydrology/hydraulics EEC because depth, velocity, and wind-driven waves will be altered by the constructed island. In turn, these stressors will feed back to geomorphology through sediment erosion, transport, and deposition. The net result of these interactions will determine the long-term stability of the created islands. The islands can indirectly alter the spatial and temporal patterns of water circulation and concentrations of suspended sediments. For example, water clarity may increase towards the downstream or leeward side of the island, or resuspension of sediment as the islands erode may have the opposite effect upstream. These stresses would be reflected in the biogeochemistry, and may be further propagated to biota as changes in, for example, dissolved oxygen and primary productivity.

The most substantial stressor from Tier 1 to Tier 2 in this example would probably be changes in hydroscape (i.e., the spatial and temporal distribution of water, resulting in the patterns of depth and velocity that define much of physical aquatic habitat) as a result of geomorphic and hydraulic changes. Altered hydroscape characteristics determine aquatic and terrestrial habitat availability around the islands. In turn, hydroscape would affect vegetation characteristics in the habitat EEC. Altered habitat quality and quantity would propagate directly to biota. Additional possible feedbacks include how alteration of vegetation-induced roughness might affect hydraulics, and how some biota could affect vegetation distributions (for example, grazing on submersed aquatic vegetation).

Island Construction Case Study

Island erosion in the regulated UMR – IWW System has been well documented (USGS 1999;West Consultants, Inc. 2000). Resultant impacts including loss of plants, morphometric structure, and bathymetric diversity are recognized in many areas, but are only well documented in a few areas.

Restoration projects (i.e., management actions) have been formulated to construct islands in specific areas to counteract erosion processes. The first island construction projects were not intended to replace former islands; rather, they

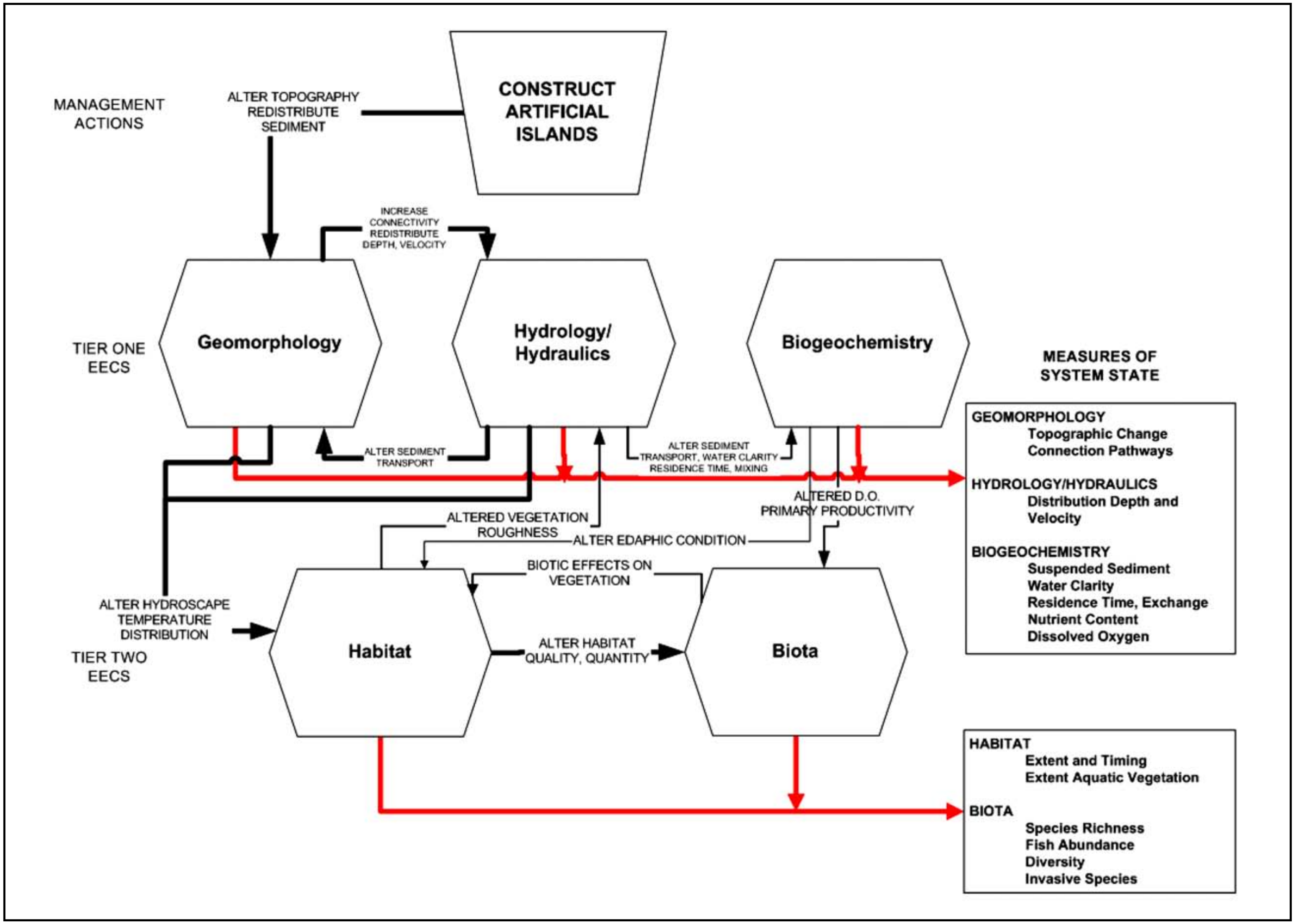

Figure 4. Conceptual model for island creation for the UMR-IWW system

were designed to reduce erosion in windswept, open-water areas, which caused losses of aquatic plants. Later projects were positioned along natural topographic gradients (in shoaling and filling areas) or where islands had been present previously. In either case, the islands were hardened to reduce erosion.

The results have been mixed. The first well documented project, Weaver Bottoms in Pool 5, did not achieve the desired results because impacts beyond wave action (i.e., tributary inputs) contributed to the degradation of the area, but were not adequately considered in project design. Another early project in Pool 7 placed islands to deflect flow and waves in a large open backwater. They effectively created a current shadow where plants grew downstream, but had little effect beyond their immediate footprint.

The next generation of island projects followed the configuration of formerly existing islands (Figure 5), even though these islands were artifacts of impoundment and thus the restoration was not to a sustainable condition. The island configuration was unstable, so they were hardened to resist erosion. As experience was gained, bank armoring became more passive (e.g., sacrificial berms) or natural (e.g., plantings) and rock armoring was reduced. These later projects have been more successful in creating larger areas that benefit from the influence of the relatively modest footprint of the constructed island.

Figure 5. Island habitat restoration in lower Pool 8, Stoddard, Wisconsin

Project design for islands has achieved a very advanced level that includes expanded objectives, better design criteria, and better prediction of effects. The incorporation of two-dimensional hydraulic models and a wind fetch model into the island planning process improved design and evaluation considerably. A bioresponse model for mallard ducks that incorporates these and other environmental parameters has also been developed. However, monitoring and evaluation need to continue in order to refine the understanding of important mechanisms affected by these projects, and also in a greater variety of habitats where local problems and construction materials differ.

Water-level management model

The specific water-level management considered in this example application is a drawdown of pool water levels, which is intended to encourage growth of vegetation at the shallower margins of main channels, side channels, and backwaters (Figure 6). The main stressor from water-level management is lowered pool stage, which propagates through the hydrology/hydraulics EEC. With the exception of the changes in topography as an additional stressor, the structure of this conceptual model is similar to that for artificial island construction. The interactions of geomorphology and hydrology/hydraulics EECs represent adjustments of the physical system as the lowered pool level alters water depths, current velocities, and sediment transport. This complex adjustment has the potential to accelerate sedimentation in some areas and thus decrease physical connectivity to backwaters. Geomorphology and hydrology/hydraulics effects could also propagate to some degree to the biogeochemistry EEC in the form of changes in water clarity and physical mixing.

The primary effect on Tier 2 EECs would be through changing the hydroscape of backwaters and other shallow, marginal areas to facilitate the establishment of emergent vegetation. Vegetation effects would be addressed in the habitat EEC and could include a feedback to hydrology/hydraulics EEC in the form of vegetation-induced decreases in current velocities and corresponding increases in sedimentation rates. Increased vegetation would increase habitat by providing increased food and shelter for fish and wildlife. Biogeochemical increases in dissolved oxygen and primary productivity would also propagate to the biota EEC. Potential measures of changes in ecosystem state for Tier 1 and Tier 2 EECs are indicated on the diagram.

Water level management case study

Water levels are managed for many reasons on the UMR – IWW. The first, and most obvious, is to maintain a 9-ft-deep navigation channel for commercial navigation. Less obvious is a 4-ft increase in water level on the Illinois River produced by flow diversions from Lake Michigan. These actions, while initially beneficial to newly created aquatic environments, eventually degraded the system to a level where remedial actions were required to restore formerly productive aquatic habitats.

Wildlife biologists on the Illinois River realized that much of the reason for a widespread loss of backwater wetlands was extreme water level fluctuations associated with upland development. An associated increase in suspended sediments also blocked light penetration and degraded substrate quality. Isolating backwaters with low levees or reclaiming leveed farmland for wildlife management proved to be highly successful surrogates of the natural hydrograph. Within these management units (called moist soil management areas) refuge managers had an increased capacity to optimize water levels to produce desired wetland communities. Managers can vary the timing of drawdowns to produce submersed, emergent perennial, or emergent annual plant species depending on the ambient hydrology or their management objectives for a given year.

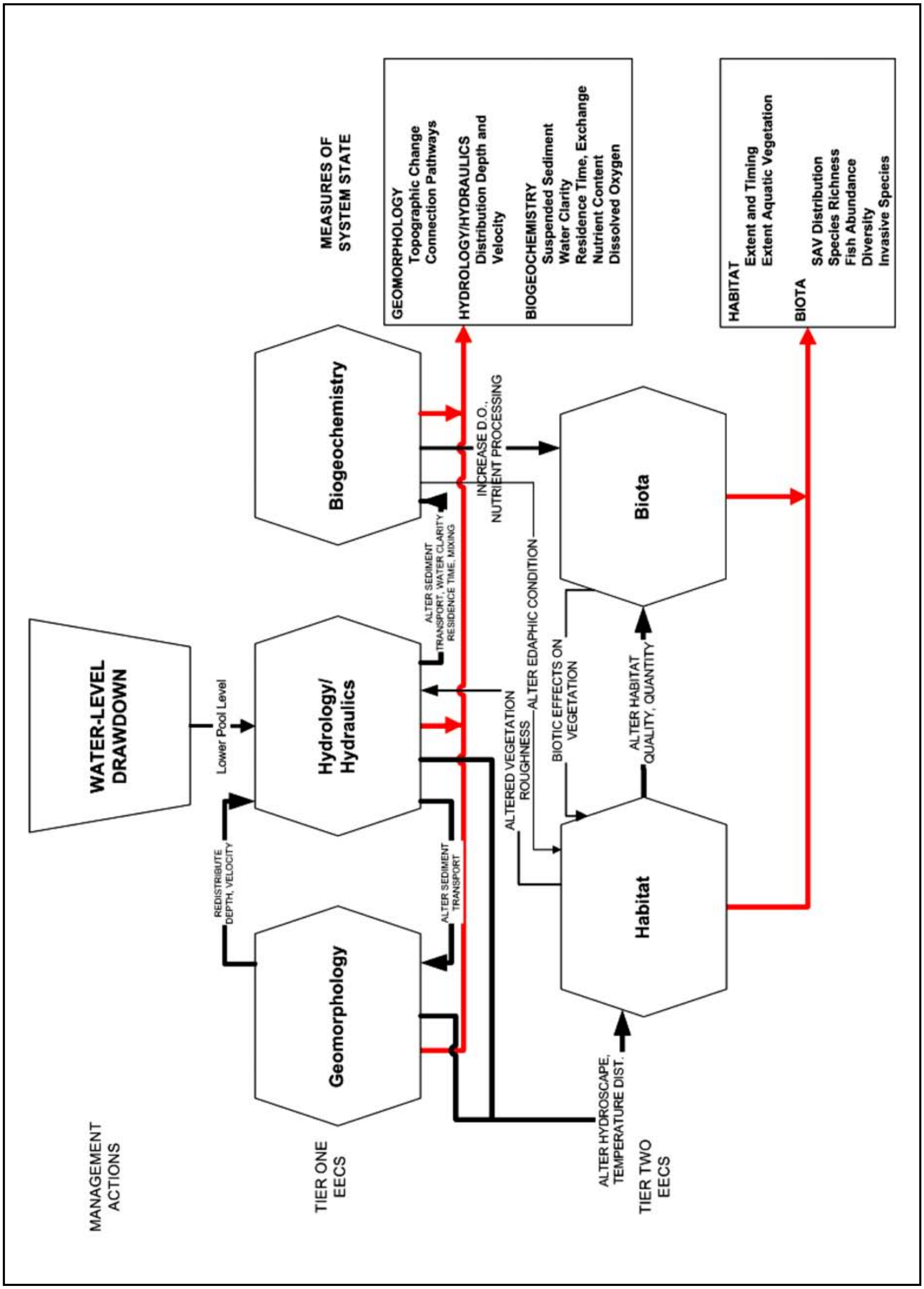

Figure 6. Conceptual model of water level management (drawdown) for the UMR-IWW system

While moist soil management proved to be a very successful wetland management technique, it has several drawbacks. First, the levees restrict movement of animals, primarily fish, that cannot traverse the barriers imposed by the levees. Second, the management units have a high front-end cost of construction and a continual cost for operations and maintenance. A less costly and more robust water level management scheme was needed.

Natural resource managers have long wanted to conduct pool-scale drawdowns to achieve the benefits of the moist soil management (i.e., sediment compaction, emergent plant growth, improved water quality) over larger areas. In the mid-1990s, resource managers approached the St. Louis District, who conducted drawdowns up to 6 ft in Pools 24-26 as part of their routine operating procedures, to see if they could maintain low river stages for periods of up to 60 days. The District responded with a plan called Environmental Pool Management, where in some years they try to hold drawdowns as long as possible without impeding navigation. In other years or seasons, they try to hold water levels high to maximize water depths. They have had considerable success in the last several years in exposing sediments and expanding emergent plant beds by several thousand acres in each pool.

The next evolution of pool scale water level management was in Pool 8 where a feasibility study investigated the possibility of 1- to 3-ft drawdowns (Figure 7). The situation differs from the St. Louis District, though, in that routine drawdowns in the St. Paul District are regulated to 1 ft or less. Drawdowns of the scale proposed required overdraft dredging to accommodate commercial traffic during the drawdown. Consultation with the public also raised concerns over recreational access (i.e., boat ramps and marinas). The study process ended with a recommendation for a 1.5-ft drawdown at a cost of about $1 million. The drawdown conducted during 2002 was considered a great success with initial plant responses being very encouraging. The monitoring results are still being evaluated. Plans for similar drawdowns in Pools 5 and 9 during 2003 were canceled because of concerns over archeological resources and recreational impacts. In fact, impacts to recreation are becoming the biggest barrier to water level management plans.

Future plans call for increased investigations for water level management. A comprehensive review of problems and opportunities was conducted by a UMR – IWW Navigation Study work group. Their analysis revealed that 12 pools are likely candidates for successful drawdowns, although no pools were eliminated from consideration. The navigation study economic work group is evaluating the financial impact of a 3-month closure to navigation from Pool 25 north to accommodate extended system-wide drawdowns.

Numerical (Predictive) Models

As the preceding examples suggest, conceptual models can assist risk assessors, environmental managers, decision-makers, and the public delineating the nature and scope of the problem (or opportunity), by identifying the

Figure 7. Pool 8 environmental drawdown

necessary and important structural and process-level components required to meaningfully address the issues of concern. They can also specify component and process interactions and interdependencies that might provide insights concerning accurate assessment or effective management. However, in many cases, net positive or negative effects on an EEC cannot be inferred from simple conceptual models because of offsetting processes. In these cases, quantitative process models are needed to calculate the net effect. Moreover, once the number of interacting components and processes exceed four or five, the human mind experiences increasing difficulty in understanding the implications of such interactions from inspection of a schematic illustration (i.e., conceptual model). Under these circumstances, the conceptual model can be used as a guide to develop a corresponding operational model (or models) that translates the qualitative understanding derived from an illustration to numerical values that address management or assessment needs. Deliberations on the roles and status of computational models in management and assessment issues relevant to a sustainable Upper Mississippi River-Illinois Waterway ecosystem are discussed below.

Existing models for the UMR – IWW

A diverse collection of models has been developed to describe and to forecast future hydrodynamic, geomorphological (sediment), and ecological conditions in the UMR – IWW. Table 5 lists selected models developed for use in UMR – IWW management and impact assessment. These existing models can be organized according to their focus on hydrology, hydraulics, sediments, habitat, and different levels of ecological organization (e.g., populations, communities, ecosystems). Most existing UMR – IWW ecological models address conditions occurring at the habitat area or navigation pool scale. Adaptive Environmental Assessment (AEA) models were developed to examine river ecological processes and management alternatives at two scales; a long river reach from Pools 4 through 22, and within a single navigation pool (Pool 8). Many of these models are based upon hydrologic or hydraulic models, reflecting the importance of physical processes to the ecosystem.

Interrelated hydraulic disturbance and biological response models were developed to assess the impacts of commercial navigation traffic for the UMR – IWW System Navigation Feasibility Study. These models, including NAVEFF, NAVSED, and other hydraulic models are used to simulate the hydraulic disturbances produced by navigating vessels. VALLA and POTAM are plant growth models used to simulate the response of submersed aquatic plants to light limitation produced by navigation-related sediment resuspension. The fish larval entrainment mortality impact model (NavLEM) estimates the effect of larval fish losses on equivalent adult fish, the prey fish forage base, and individual fish recruited to adult fish populations. Leslie matrix fish population models have been developed to examine the potential inter-annual effect of fish entrainment losses for selected fish populations. Two of the existing UMR – IWW assessment models are individual-based; one for unionid mussels (NavMSL) and another for submerged aquatic vegetation (NavSAV) that assess the impact of disturbance on organism bioenergetics, growth, and reproduction. Few models exist that simulate animal or plant populations within the UMR – IWW ecosystem. Except for the AEA models, the existing UMR – IWW ecological models are narrowly focused by components, processes, and scale.

Other predictive models

In addition to models developed explicitly for the UMR – IWW, other ecological and environmental models might have useful applications in support of adaptive environmental management. Ecosystem models that link physical and biological process models into a model system have been developed for study and management of other large rivers and estuaries; for example, the Florida Everglades, Biscayne Bay, Chesapeake Bay, Columbia River, Grand Canyon, Fraser River Canada, Rhine River in Europe, and the Murray River in Australia.

As an example of an aquatic ecosystem model that might be adapted for application in the UMR – IWW, the Comprehensive Aquatic Systems Model (CASM) provides a generalized framework for developing site-specific aquatic ecosystem models that simulate linked physical and chemical processes with biological components (Figure 8) (e.g., Naito et al. (2002); Bartell et al. (2000a, 2000b, 1999)). A comprehensive search of the technical literature should be performed to identify other ecological models (e.g., population, community, ecosystem, landscape) that could be used to address resource management issues in the UMR – IWW.

A hierarchical approach to model development

As indicated in Table 5, ecological and environmental processes important for adaptive resource management in the UMR – IWW are characterized by different spatial and temporal scales. Disparate scales in space and time of critical ecosystem process dictate a hierarchical approach to the development of a system model for planning and management activities directed to sustainability in the

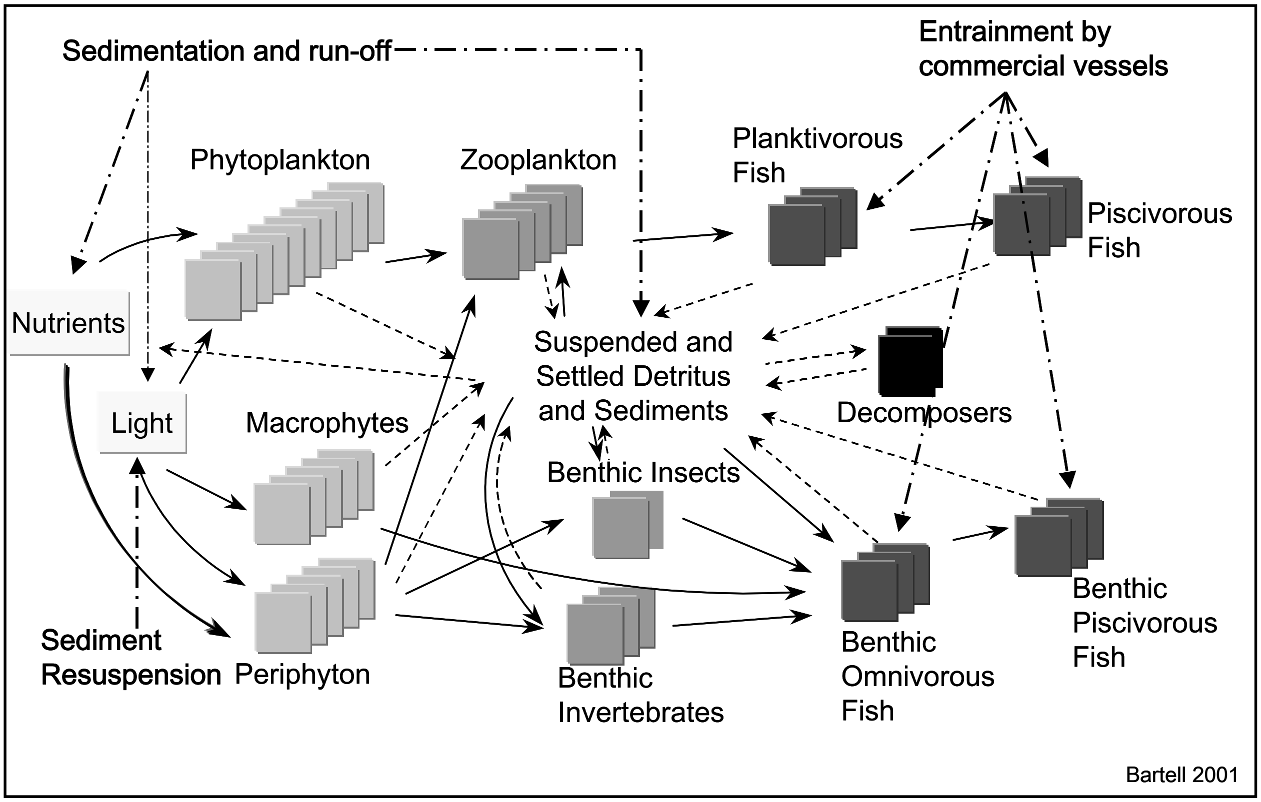

Figure 8. Comprehensive Aquatic Systems Model (CASM)

UMR – IWW. This approach to ecological modeling (e.g., Figure 9) dates at least to the hierarchical models proposed to describe the ecological production dynamics in lotic ecosystems (e.g., McIntire (1983)). In this strategy for model development, complex ecological systems can be decomposed into subsystems, each modeled at its appropriate scale (Allen and Starr 1982, O'Neill et al. 1986). Linkages between subsystems can be formulated to pass energy, materials, and information at relevant scales. The important point is to avoid the construction of an overly complex model that forces disparately scaled organisms (e.g., bacteria, fish) into a single model construct and that requires some compromise in scale selection.

Existing ecological models might be adapted to provide a useful set of models scaled appropriately to different management objectives. For example, Figure 10 schematically illustrates two differently scaled (time scales) models that could be constructed using the general CASM modeling approach. The benthic invertebrate model indicates the possibility of constructing a detailed multi-population model that operates on a daily time scale relevant to these organisms. The output (e.g., total benthic invertebrate biomass) available as prey for a less detailed benthic omnivorous fish population model can be integrated at a monthly time scale over larger spatial scales (i.e., 1 km^2). Other approaches to hierarchical model development should also be explored for development of an UMR – IWW system model.

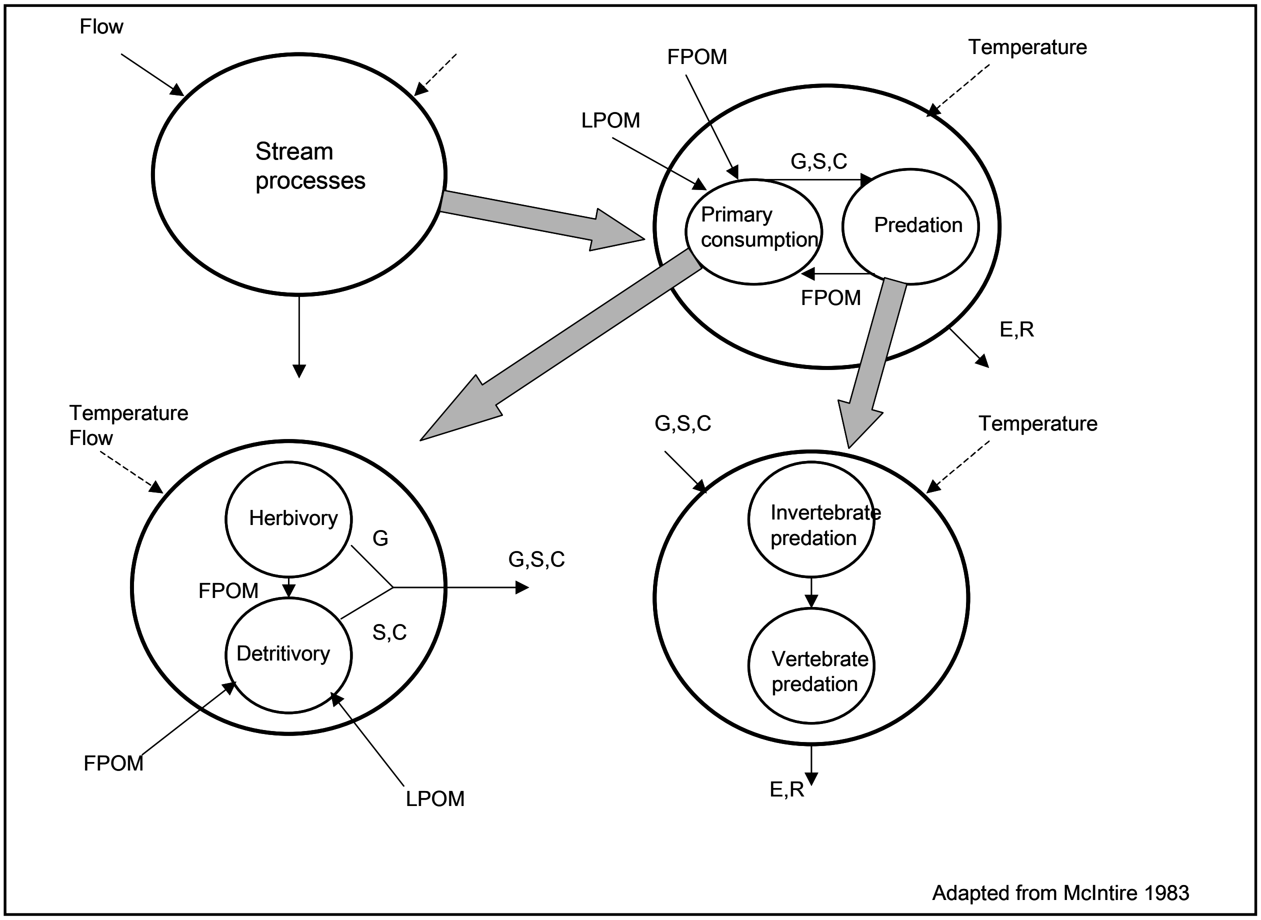

Figure 9. A hierarchical representation of consumption and predation for a lotic system (adapted from McIntire (1983); LPOM = large particulate organic matter, FPOM = fine particulate organic matter, G, S, C = grazers, shredders, collectors, E = egestion, R = respiration)

Importance of scale

Ecosystems and models describing them are defined using scales of time and space. The UMR – IWW ecosystem can be considered a hierarchical set of ecosystems starting from the spatial scale of the entire drainage basin, extending to smaller-scale ecosystems defined by geomorphic features and associated vegetation and animal communities (Figure 11). Within the UMR – IWW basin are a number of ecoregions, defined in the National Hierarchical Framework of Ecological Units (Bailey 1980; Bailey et al. 1994). The primary spatial scales in the UMR – IWW ecosystem are the river basin, tributary sub-basins or water-sheds, river reach, navigation pool, habitat area, and microhabitat (Lubinski 1993, Wilcox 1993). The navigation study and most river management are focused on the UMR – IWW channels and floodplains, but river management must include consideration of water and material flows from tributary watersheds to the mainstem rivers.

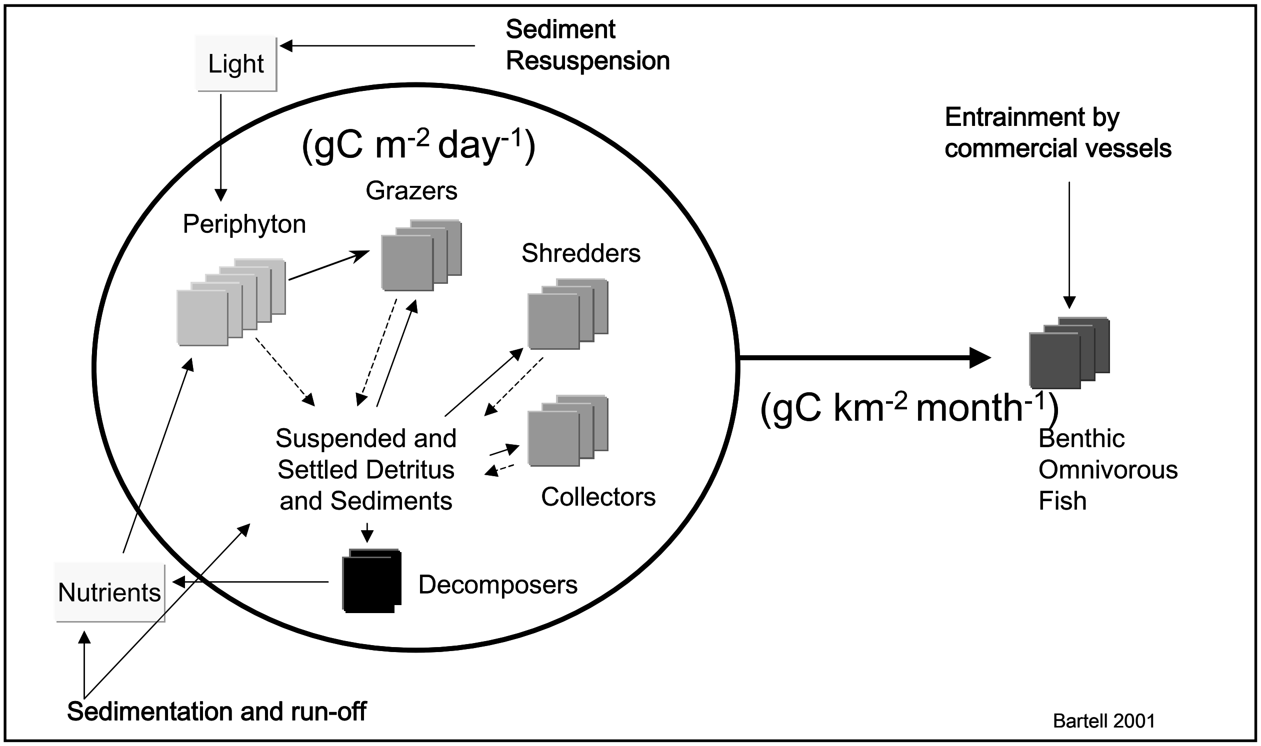

Figure 10. Example hierarchical models for benthic invertebrates and benthic omnivorous fish derived from the CASM (Naito et al. 2002; Bartell et al. 2000, 1999; gC = grams of carbon)

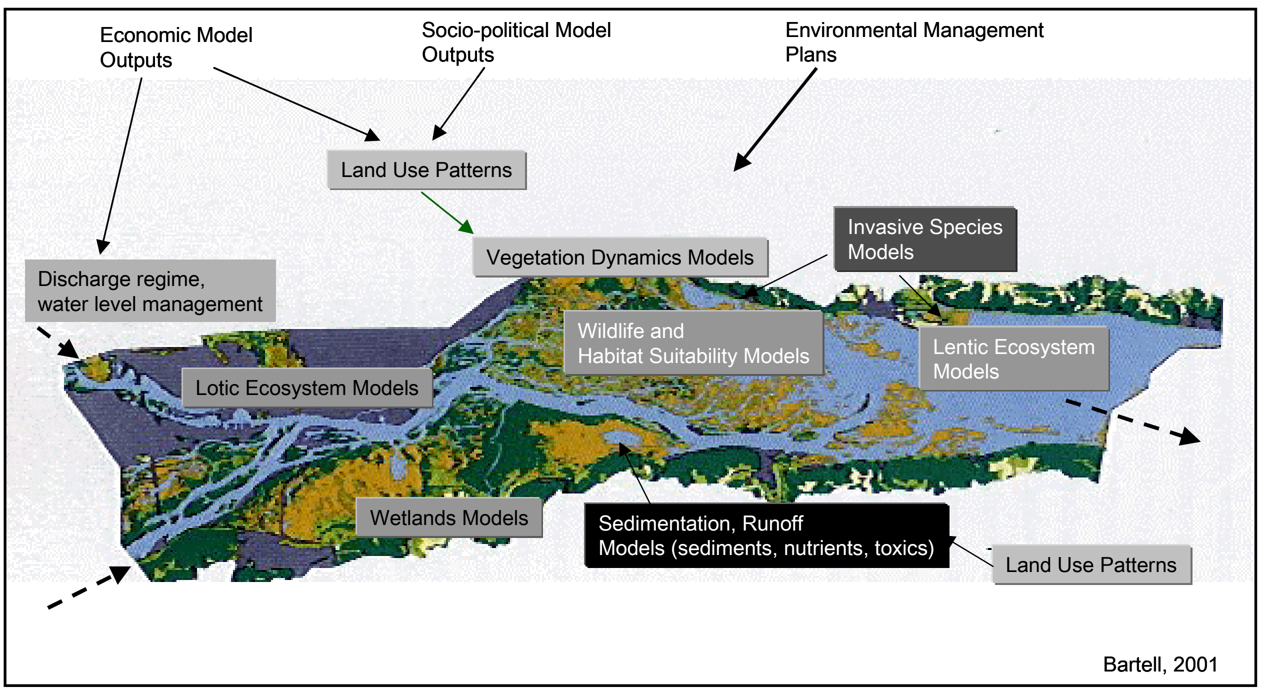

Figure 11. Illustration of processes acting at the navigation pool scale, and the kinds of models that can be used to simulate them

Processes shaping the UMR – IWW ecosystem act at different scales (Figure 11, Table 5). For example, human land use at the river basin scale has modified the hydrologic regime and sediment yields in the last century (Knox et al. 1975). At the habitat area scale, dissolved oxygen concentrations in shallow UMR – IWW backwaters vary hourly due to photosynthesis and respiration by algae. Many processes act over several spatial scales. Models simulating ecological processes must be designed and linked together with the appropriate time and spatial scales.

Figure 11 is a conceptual illustration of how different processes and factors act at the navigation pool scale, and how different ecosystem model elements can be selected from existing models or how models might be newly constructed to address these differently scaled attributes of the UMR ecosystem. Figure 12 illustrates the same concept using a river and floodplain cross-section diagram.

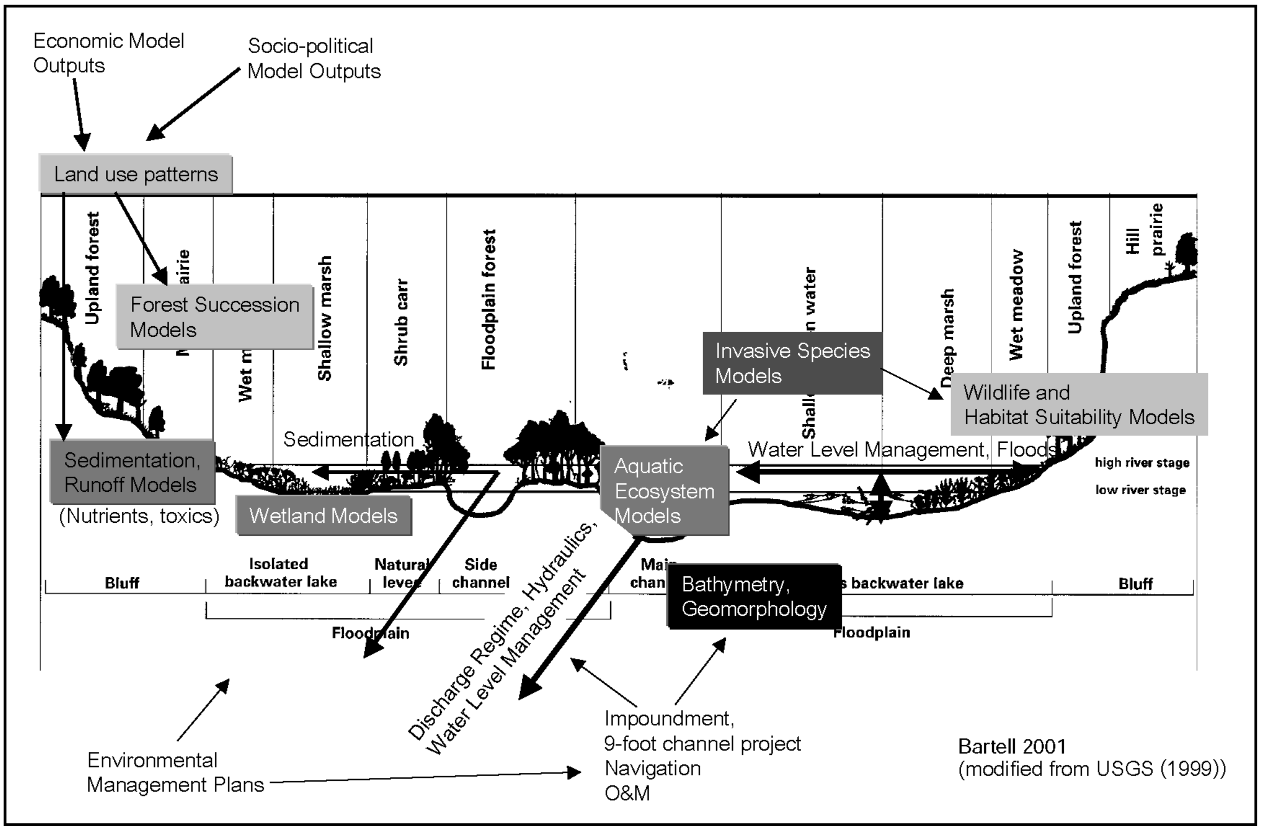

Figure 12. Illustration of processes acting in the river channel and floodplain, and the kinds of models that can be used to simulate them

Models needed and appropriate for use in UMR – IWW management

An integrated system of models is needed to support adaptive management of the UMR ecosystem. The models should be hierarchically organized according to scale and process to effectively represent the range of natural and anthropogenic drivers and stressors that determine the condition of the UMR ecosystem. Table 5 identifies some of the differently scaled models needed for planning and managing within the UMR.

At the river basin and tributary watershed scales, refined models for sediment and plant nutrient mobilization from the landscape and transport and fate processes in the stream drainage network could be linked with river and reservoir water quality models to simulate loading of materials from tributary watersheds and the subsequent ecological implications of these external loadings. An important and challenging element of this would be a model system that would simulate channel geomorphic response and sediment transport in the tributary rivers. Such a model system could be used to help formulate ecologically effective watershed management alternatives and to optimize investment in best management practices at a regional (e.g., geomorphic reach) scale. This kind of model system could provide a quantitative basis for setting attainable objectives and defining endpoints for sediment and nutrient loadings to the UMR system.

At the river reach scale, refinement and expansion of the existing sediment budget model for Pools 11 through 26 to the entire UMR – IWW is needed. Bed sediment transport should be included, given its importance to dredging requirements and formation of geomorphic features of the channels and floodplain. A model that quantifies the additional habitat made accessible to migrating fish moving upriver through navigation dams would provide a basis for planning effective fish passage improvements in the system. Population models of exotic species invasion and establishment could help in determining effective control measures. A model of plant consumption by populations of migrating waterfowl could provide a quantitative basis from which to plan for system-wide restoration of habitats to provide sufficient forage for these birds.

At the navigation pool and habitat area scales, a model of geomorphic response of the channels and floodplain to sediment loadings would provide an improved basis for forecasting future geometry of the system. A spatially explicit floodplain vegetation succession model could forecast future habitat distribution, location, and quality. Models of biological production, animal population dynamics, and limiting factors would enable refinement of the Habitat Needs Assessment Query Tool to plan for ecologically effective habitat protection and restoration projects. Biological production models linked to population models would allow setting realistic objectives for the abundance of selected fish species, and a means to assess the impacts of entrainment losses, harvests, and management actions related to modifying aquatic habitat.

At the microhabitat scale, microbial activity and nutrient dynamics greatly influence water quality and biological production (e.g., benthic insects, other macroinvertebrates) in the river ecosystem. Models of these processes could provide insight into the ecological effects of reduced nutrient loading from UMR tributaries.

5 Management Actions Available for River Management and Restoration

For purposes of this report, management actions are considered to be human activities intended to affect the condition of the river ecosystem. An initial list of management actions was compiled for the Navigation Study Interim Report (U.S. Army Corps of Engineers 2002, Appendix F). A variety of sources were used to identify the management actions, including EMP habitat project reports, Corps District navigation channel and natural resources management plans, U.S. Fish and Wildlife Service refuge plans, Upper Mississippi River Conservation Committee (2001), USDA watershed management literature, and Schnick et al. (1982). The U.S. Army Corps of Engineers, the Navigation Study Environmental Coordination Committee, and participants in the Navigation Study Environmental Stakeholders workshops reviewed and refined the list (Appendix D).

UMR – IWW management actions are implemented by many groups: the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the U.S. Department of Agriculture, the five UMR – IWW states, local units of government, private landowners, and non-governmental organizations.

Relationship of Management Actions to Goals and Objectives

Management actions that can be taken to achieve goals and objectives were linked to the objectives for condition of the UMR – IWW ecosystem in the Goals, Objectives, and Management Actions relational database (Appendix E). The management actions were rated from 0 to 3 as to their potential ecological effectiveness in achieving the objective with 0 = no effect, 1 = marginally effective, 2 = effective, and 3 = very effective. This rating is subjective, but enables management actions to be identified that might best contribute to each objective. More detailed planning and evaluation will reveal the most cost- and ecologically effective management actions for selected project areas and to attain differing objectives.

Management Actions by River Reach

Jurisdiction, weather, river discharge, staff, equipment, and funding are all perennial constraints to applying management actions. Management actions are generally applied where they can be effective, given the need as expressed by condition of the ecosystem, and where the technology is suitable given the conditions in each part of the river basin and reach of the river system. River reaches where each management action has been or has potential to be applied were identified in the Goals, Objectives, and Management Actions relational database.

Many management actions are applicable only in certain river reaches. For example, dustpan hydraulic dredging is conducted in reaches in which dredging equipment is suitable for high-volume output with in-channel placement of dredged material. Many of the management actions listed have been applied; others have potential to be applied (Appendix D). For example, pool-scale drawdown of navigation pools has been conducted to promote growth of aquatic plants in Pools 8, 13, 24, 25, and 26. There is potential to conduct growing season drawdowns (and some are presently scheduled) in other locations.

Scales of Application of Management Actions

The scales of application of listed management actions vary considerably in time and space because the drivers, stressors, endpoints, measurement methodology, and other factors vary in scale also. The scale of management actions ranges from widely and frequently applied routine management actions to large habitat restoration projects that might be constructed only once. Some management actions, such as navigation dam gate operation, are routine and are conducted daily at all the dams in the river system. Other management actions such as channel maintenance dredging, are also routine, but are conducted at specific locations (dredge cuts) at varying frequencies ranging from twice a year to once in decades. Some management actions (such as removal of invasive plants) are only implemented in selected areas as needed. Many management actions involve major construction that would be implemented infrequently and in selected areas as part of a habitat restoration project.

6 Evaluation and Monitoring

Evaluation is a critical part of the adaptive management process because it indicates whether performance is adequate and sustainable.

Determining Endpoints and Measures

Environmental systems indicators, or endpoints, are increasingly being incorporated into ecosystem level management and development planning as key elements in goal setting and performance assessment. An endpoint is a component of the system that may be ecologically important, is valued by humans, and is used to evaluate changes in the ecosystem. In a system-wide management plan, one or more endpoint objectives need to be associated with each objective. Measurement (quantification) of endpoints, will provide an assessment of status of that endpoint. Measuring endpoint values through time indicates trends or environmental performance that can be disseminated to stakeholders at regular intervals.

Endpoints need to be defined in numeric, rank, or binary terms that are informative both to management agencies and the public. That is, they should be easily understood by non-specialists and useable in agency programs with commonly available monitoring data. To meet this need, endpoints were selected that related to the values expressed by local people and to actions of managers. The environmental objectives workshop results reviewed in DeHaan et al. (2003) provided input from stakeholders and management agency staff regarding what endpoints are important to them.

Our criteria for what constitutes a desirable and effective endpoint came from a synthesis of the guidance in Harwell et al. (1999), Jackson et al. (2000b), National Research Council (2001), and Schiller et al. (2001). Three primary considerations or criteria were employed: policy and management relevance, technical merit, and practicality.

- **Policy and management relevance** is based upon the extent that a candidate endpoint addresses a societal issue or interest (e.g., recreation, biodiversity, water quality). A relevant endpoint should be clearly related to management actions and capabilities. Interested citizens and involved public groups with minimal technical expertise should be able to see how an endpoint relates to environmental quality. Ideally, environmental quality levels should be attributable to endpoint values.

- **Technical merit** is concerned with the relationship between an endpoint and a structural and functional property of the ecosystem. Each endpoint must be based on scientific principles and scientific concepts. There should be confidence by analysts that the endpoint will yield reliable information and be indicative of the environmental changes of interest. Consideration needs to be given to how vulnerable an endpoint value is to confounding influences over time or space. We need to be confident that indicator values reflect the anticipated information of interest and not random or unrelated variations. Finally for technical merit, it is best if standard methods are available for measurements so data collection can be executed in a routine and confident manner.

- **Practicality** relates to whether adequate data or feasible monitoring samples would be likely to yield accurate or reliable endpoint results. Are monitoring practitioners capable of routinely collecting the appropriate measurements in adequate amounts and quality? The costs and benefits of using the endpoint should be readily clear to program managers and the public, and monitoring costs need to be reasonable over many years of use and fluctuations in agency budgets. Further, we considered whether quality control, timely reporting, and data storage and distribution could be easily managed. For practicality reasons, the endpoint should be closely related and compatible with established monitoring programs if possible.

Endpoint identification process

The Panel developed and employed a structured five-step process for identifying endpoints. The process was started with three sources of information:

- A synthesized list of environmental objectives from a series of fall 2002 Objectives Planning Workshops in the study region (reported in DeHaan et al. (2003)).
- A spreadsheet analysis of environmental objectives grouped by EEC and management actions (U.S. Army Corps of Engineers, Science Panel and NECC meeting minutes).
- The criteria for endpoint selection: policy and management relevance, technical merit, and practicality.

First, each UMR-IWW environmental planning objective (stated system attribute) was considered against the three endpoint selection criteria. A YES or NO designation was made for each of the three criteria. Only attributes with three YES ratings were considered further. Second, the items with three YES answers were reviewed for redundancy and relative importance within each EEC. Third, additional endpoints were considered, in the event that they improved the characterization of environmental objectives. Fourth, the Panel reviewed and commented on the endpoint selections, and adjustments were then made in the final endpoint list (Table 6). Finally, each endpoint was documented by reporting the endpoint name, definition, the three selection criteria justifications and a set of recommended monitoring measurements (Appendix F).

Report Card

The customary means for assessing environmental quality and the progress of management efforts has relied on one of a few regulatory criteria. The most established basis for determining environmental quality has been to compare field measurements against mandated water quality criteria to determine if a water body meets standards. A water body was either in compliance or not, and the frequency of non-compliance was often the only temporal perspective employed. Starting in the 1980s, federal and state environmental management agencies began incorporating broader measures and criteria of environmental quality. Measures of community composition, species diversity, and ecosystem integrity began to be developed and implemented in assessing ecosystem health; often called bioassessment. A broader means of assessing environmental management performance emerged with the shift from single chemical criteria to managing for ecosystem health. Concurrently, the amount of public investment in environmental quality improvement rose sharply, and the need to demonstrate the resulting benefits followed. Lastly, government policies and legislation developed that require agency reporting of performance. The Federal Government Performance Results Act of 1993 is a prominent example.

Table 6
Selected Ecological Endpoints to Evaluate UMR – IWW Management Actions and Objectives

Biota
Abundance of Asian carps
Population of lake sturgeon
Abundance of waterfowl
Neotropical migrant birds
Freshwater mussel populations
Mast tree populations
Biogeochemistry
Water quality criteria
Nutrient concentrations in water
Fine sediment entering the system
Contaminated sediments
Geomorphology
Topographic connections
Topographic variability
Rates of bank erosion
Hydrology and Hydraulics
Water levels below dams
Water levels during growing season
Pool stage in winter
Dam operations
Habitat
Aquatic vegetation in shallow lentic waters
Natural terrestrial habitat on floodplain
Special aquatic sites
Islands with natural habitats

One developing form of reporting on ecosystem management performance is the environmental report card (Harwell et al. 1999, Young and Sanzone 2002). An environmental report card presents summary status information on ecosystem endpoints, and it communicates progress of management in improving ecosystem health. Being a communication tool, the report card should be easily understood by a range of audiences. It should communicate the status of the system in terms of endpoints, and reflect trends over time to judge progress. Finally, the method for assigning ratings or grades should be easily understood and clearly based on endpoint definitions and measures. The best formats for progress reporting should make it easy for users to understand the desired endpoint value, current status relative to the endpoint target, and trend in status through time.

There is no standard format for an environmental report card. However, some common elements of environmental performance reporting are seen in the report cards on ecosystem management by state and federal agencies in the Everglades, Chesapeake Bay, and San Francisco Bay. Performance reporting on the Everglades (McLean and Ogden 2000) and Chesapeake Bay (*http://www.chesapeakebay.net/index.cfm*) use one simple bar chart or line graph for each endpoint showing annual measurement values by year. These graphs also clearly show the desired endpoint value for stakeholders to readily judge status and trend.

Lubinski and Theiling (1999) developed a type of report card for the ecological status and trends for the Upper Mississippi River System (USGS 1999). They used dashboard-type dials indicating a range of ecological health from “Degraded” at the most impaired level or “Unimpaired” or “Recovered” at the “healthier” end of the scale. While useful for the broad categories considered:

- Viable native populations and habitats.
- Ability to recover from disturbance.
- Ecosystem sustainability.
- Capacity to function as part of a healthy basin.
- Annual floodplain connectivity.
- Ecological value of natural disturbances.

and the four river reaches considered:

- Upper Impounded Reach (Pools 1-13).
- Lower Impounded Reach (Pools 14-26).
- Unimpounded Reach (RM 201-0).
- Lower Illinois River (Peoria – Alton Pools).

The evaluation criteria were very general. They did not have the required resolution to serve as indicators or endpoints required in an effective adaptive management program.

An example of detailed endpoint criteria that could be evaluated using available monitoring data from the UMR – IWW is shown in Figure 13 for nutrient concentrations reported by Soballe and Wiener (1999). The low nutrient concentration endpoint specifies target levels for total phosphorus and nitrogen in river water. Figure 13 shows that both nutrient concentrations are above the specified endpoint concentrations. For nitrogen, the target level has been achieved during a few isolated months, and the trend is improving to the extent that in recent years nitrogen concentrations regularly approach target levels. In contrast, no trend for improvement is seen in average annual phosphorus levels, suggesting different or additional management effort will be needed. In the ecosystem management cases of the Everglades and Chesapeake Bay, the annual report card released to the public primarily consisted of a series of plots like Figure 13. Users would review a set of these to judge overall system status and management progress.

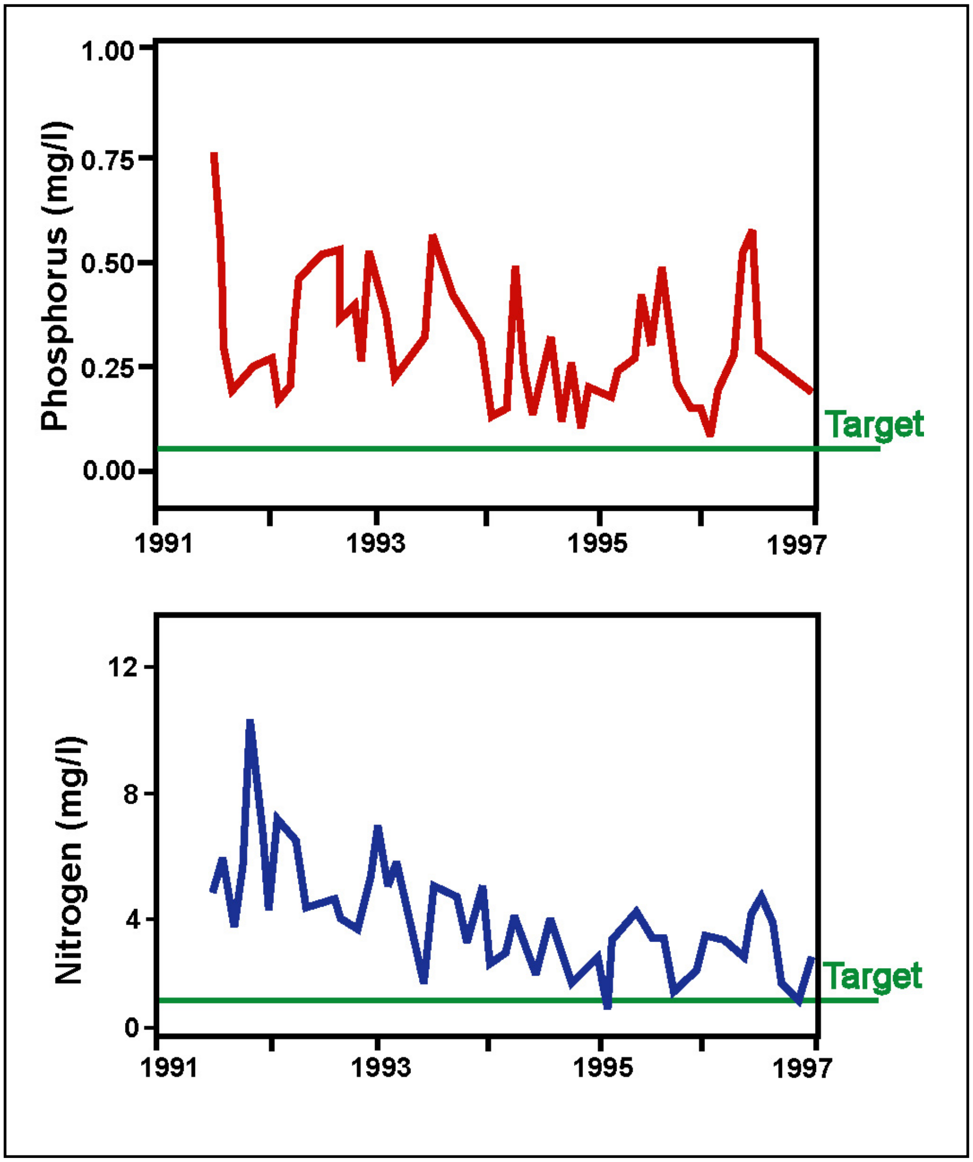

Figure 13. Mean annual nutrient concentrations in the main channel of the Mississippi River in relation to potential target levels (modified from Soballe and Wiener (1999))

An alternative reporting format is more analogous to school report cards than a series of trend plots. Table 7 shows a tabular reporting form for the UMR – IWW using the endpoints and essential ecosystem characteristics reported above. Two ratings are provided for each endpoint to show status and progress. Status is indicated by a color-coded rating using the system of McLean and Ogden (2000) for the Everglades. A grade of green means that the status of the endpoint has been reached or closely approaches its specified target; yellow means that the endpoint is short of the target state; and red means that the endpoint is seriously deficient. Judgment is needed to assign these ratings because they are approximate categorizations of endpoint measurements relative to endpoint criteria.

Table 7
Upper Mississippi River-Illinois Waterway Environmental Report Card Showing an Entry for Endpoint 7 Using Data Reported in Figure 13 (See Text for Entries and Color Rating Under "Status")

No.	ENDPOINT	EEC	Status	Progress	Comments
1	Abundance, exotic Asian carp	Biota			
2	Population of lake sturgeon	Biota			
3	Abundance of waterfowl	Biota			
4	Neotropical birds	Biota			
5	Mast tree abundance	Biota			
6	Water quality compliance	Biogeochemistry			
7	Nutrient concentrations	Biogeochemistry		Substantive improvement	*N improving but P consistently high*
8	Fine sediment input	Biogeochemistry			
9	Contaminated sediments	Biogeochemistry			
10	Greater topographic connections	Geomorphology			
11	Greater topographic variability	Geomorphology			
12	Flocculent backwater sediment	Geomorphology			
13	Decreased bank erosion	Geomorphology			
14	Stabilize water levels	Hydrology & Hydraulics			
15	Summer low water	Hydrology & Hydraulics			
16	Maximum winter pool stage	Hydrology & Hydraulics			
17	Flexibility of dam operations	Hydrology & Hydraulics			
18	Aquatic vegetation cover	Habitat			
19	Terrestrial habitat on the floodplain	Habitat			
20	Special aquatic sites	Habitat			
21	Islands with natural habitats	Habitat			
22	Maintain crop land	Habitat			

Progress can be assessed using another set of ratings as done by the Association of Bay Area Governments (2001) on San Francisco Bay ecosystem management. A progress rating term is entered to capture the general pattern in endpoint values over time. A rating of FULL progress indicates that the endpoint target state has been realized or will be shortly (recent values within 75-100 percent of endpoint range show in series presented). A rating of SUBSTANTIVE progress is entered when the time series shows clear progress (50-75 percent target value change) toward the endpoint target. Finally, SOME is entered when minimal progress (0-25 percent) is seen, and NEGLIGIBLE when there is no progress or a decline in performance.

The Panel recommends that a UMR – IWW report card use both a tabular progress report as in Table 7 with time series charts like Figure 13 for some or all endpoints. Planners may also determine that, considering the importance of location and scale in ecological function and condition, regional report cards may be required for some or all endpoints (e.g., status and trends indicators). An overall text comment on the set of endpoints should summarize status and progress for each endpoint and for the overall system. A final note on interpretation is needed for ecosystem management assessment. Unlike a school report card, poor ratings or even deteriorating endpoint status does not necessarily imply management failure. Factors outside management control can determine endpoint values in some or many years. In the case of nutrient concentrations used here, UMR – IWW management cannot control upland land use practices and tributary basin runoff inputs of nutrients. Nevertheless, knowing that some endpoints fall short of target values is important for judging system health and trend even when the involved managers cannot largely influence causes. It is the context of status and trend across all endpoints that is intended to give a full appreciation for where the UMR – IWW stands in any year, and how management programs may or may not be improving the system.

7 Learning and Adaptation

Learning and adaptation are the elements of an adaptive management process that close the feedback loop and begin the iterative process over again. In this phase of the process, information (in the form of monitoring data, results of experimental manipulations, and predictive models) is issued to either confirm existing beliefs, or provide new descriptions of system status and function. While much of the technical learning takes place within the scientific community, different kinds of information need to be "learned" at all levels of the decision-making process. A scientist, for example, may determine that a new and different combination of physical and hydraulic variables is much better at explaining the response of aquatic vegetation to newly constructed islands. The use of that knowledge by habitat project designers to increase vegetation response is one kind of adaptation. If that change produces a much more favorable cost/benefit ratio, it leads to learning by program managers, so that they can allocate resources more effectively. Still further, if progressive iterations of the new design at numerous sites warrant a modification to vegetation goals and objectives that affects other uses of the system, policy makers must learn how and why in order to weigh policy alternatives. When uncertain ecosystem responses are possible, successful learning may be as valuable as restoration itself.

Learning

The use of conceptual and predictive models in learning was discussed extensively in Chapter 3. Here, the application of two other types of information relative to potential future adaptive management on the UMR – IWW are briefly discussed.

Synthesis of monitoring data

The first major synthesis of LTRMP data was reported in 1999 (USGS 1999). Lubinski and Theiling (1999) made an initial attempt at defining major criteria that determine the overall health of large, river-floodplain systems like those of the UMR – IWW, and used those criteria to evaluate four different reaches. However, the authors acknowledged that the evaluation process was far from complete. The next LTRMP synthesis report, as well as any produced by an adaptive management program following the feasibility study, should be designed to be an effective tool within the comprehensive adaptive management process. The criteria for measuring river ecosystem health should be closely matched to the essential ecosystem characteristics and endpoints of a conceptual model that has been reviewed and accepted by the public and scientific community. Further, the focus of future monitoring syntheses should be on a specific set of scientifically derived endpoints and measures that are closely linked to the essential ecosystem characteristics of the conceptual model (see Harwell et al. (1999)).

Evaluation of experimental manipulations

The enhanced value of scientifically designed and adequately monitored, large-scale experimental manipulations derives from the inferences that can be drawn from their results. For example, it should be possible after a pool elevation drawdown to not only know how plant composition and distribution at a selected site changed, but what the likely results would be if the duration or timing of the drawdown were modified in the future. The Panel is aware of the dilemma that has grown around the dual desire within the Environmental Management Program to fully support habitat rehabilitation by minimizing costs for project monitoring while learning as much as possible from the projects. Clearly there will be limited "learning" returns from the extensive monitoring of projects that are primarily intended to repeat well-known and tested management actions. However, innovative and untested actions should be considered not just important learning opportunities but perhaps the only learning opportunities that exist, and therefore they should be supported with strong scientific designs and monitoring programs.

Adaptation

The concept of adaptation is relatively simple. Disciplined adaptation, however, within a program that addresses the desires of many different stakeholders, is a difficult process to implement and control.

In addition to the many other problems associated with implementing adaptive management discussed in previous chapters of this report, there is also the question of "When to adapt?" While the acquisition of some information, such as from a controlled experiment or a monitoring program, can be planned, other information arrives unexpectedly. Furthermore, the time in which certain ecosystem components respond to management actions may also vary considerably. Acquiring knowledge about the response of the UMR – IWW to a one-in-200-year flood, for example, cannot be predicted.

Adaptive management on the UMR – IWW requires both an ability to change on a regular, predictable schedule, and also, if necessary, in rapid response to unpredicted events. Given what we know about year-to-year variability of large river conditions, it seems realistic to consider establishing a regular system status review at intervals of 5 to 10 years, similar to the schedule that has been adopted for LTRMP synthesis reports. However, a rapid response decision-making mechanism should also be considered as a vital element of a future adaptive management process.

Finally, we encourage the Corps and UMR – IWW stakeholders, as they develop a more and more integrated goal-setting process, to consider the importance of well-thought-out, long-term goals, and, in addition, the need to take a conservative approach to changing those goals from one interval of adaptation to another. If stated well, a long-term ecosystem goal should not be subject to fads or political whim. The restoration of desirable conditions for many of the ecosystem elements of the UMR – IWW is likely to require decades rather than years. Success will require unwavering commitment as well as vision.

8 Recommendations

Adaptive Management

We recommend that planning for a formal Adaptive Management approach on the UMR – IWW be accelerated and expanded to include multiple organizations and programs.

Corps and stakeholder documents acknowledge that important features of the UMR – IWW ecosystem continue to degrade in spite of current levels of habitat rehabilitation. A formal Adaptive Management program offers the most promise of stabilizing and reversing this degradation as quickly and effectively as possible by maximizing the use of available scientific information. Progress will be most rapid if this Adaptive Management approach builds upon and enhances the existing programs of partner agencies and organizations. The work must be collaborative, driven by a common set of goals and objectives reviewed at regular intervals by all participants. Constraints of policy and legislative authority will likely continue to limit the scope of activities the Corps will be able to pursue, so it is essential that other agencies and organizations, with responsibilities for addressing different elements of river ecosystem health, be full participants to fill these gaps. These concepts are fundamental to Adaptive Management.

Adaptive management can include both active and passive strategies. Active adaptive management should continue to include actions that have already been tested, such as drawdowns and island creation, as well as more innovative and perhaps untested actions such as those intended to increase fish passage opportunities. Passive adaptive management can be more reactive, including necessary responses to natural events such as droughts, floods, and climate change. The iterative nature of adaptive management, in contrast to more centralized "command and control" management, will foster greater emphasis on large-scale experimental manipulations that, together with adequate monitoring, will result in planned learning and rapid application of information to resource problems.

When stakeholders are uncertain about the outcomes of management actions, the actions should be considered hypotheses and addressed from the perspective of rigorous experimental design and decision analysis. Uncertainty should be recognized and then analyzed formally, and monitoring designs used to fill key gaps in information and understanding.

To foster comprehensive and formal adaptive management, we encourage continued discussion of alternative institutional arrangements. Effective institutional arrangements can facilitate enhanced learning from management actions by: (1) establishing open channels of communication and data sharing, (2) standardizing methods, and (3) recognizing time expended to evaluate project performance as a contribution to project cost-sharing. Perhaps more importantly, effective institutional arrangements can and should promote project planning that includes formal steps to identify the key questions addressed through project implementation. Effective institutional arrangements should also facilitate regular review of all recent information to assess progress toward the stated objectives.

The experiences gained through adaptive management on other systems (i.e., Everglades, Glen Canyon, and Chesapeake Bay) should be used to provide guidance in all applicable areas of river management, from goal setting to measuring performance. An effective institutional arrangement can promote learning from management of other systems by facilitating professional exchanges (i.e. such as temporary tours of duty of agency personnel, intersystem conferences, etc.) that cut across agency or organization boundaries.

The links that connect scientific measures of system condition to system objectives, and the relationships between stressors and essential ecosystem characteristics need to be clearly articulated, widely communicated, and generally accepted. Frequent reference to the conceptual model and the adaptive management framework, through common dialogue, will be required to ensure that managers and stakeholders stay engaged in the adaptive management process, keeping in mind why certain elements of the ecosystem are considered essential, and discussing the use of measures and related data in evaluating progress toward objectives.

Goals and Objectives

We commend the Corps and the UMR – IWW partners for collaboratively developing and supporting a vision of economic and ecosystem sustainability for the UMR – IWW, but recommend continued clarification and integration of the ecosystem goals and objectives developed so far through stakeholder input. Further we note the need to begin, also collaboratively, a structured process for rigorous and quantifiable evaluation of unavoidable trade-offs between the ecological and economic values of the system.

Clearly, planning for river management should be based on integrated goals and objectives that together represent desired future conditions of the UMR – IWW at several spatial scales. The goals and objectives resulting from the stakeholder workshops reflect the desires of many interest groups in terms that span a wide range of concerns. The stated goals are ecologically sound, but valuable to managers only if they are clearly linked to specific actions. The objectives, as presented to the Panel, were somewhat ambiguous, thus detracting from their value for directing an operational management process.

Some of the ambiguity in the objectives may result from their disconnection from a hierarchical structure. Thus, linkages between goals and objectives are somewhat vague. The linkages need to be clear, so that in the future when progress on a specific objective is evaluated, the overall context of that objective is understood. Strong linkages between the goals and objectives will also promote consistency of program priorities over time. Future work to integrate the existing objectives will be more effective if scientists and stakeholders are given the opportunity to discuss them together.

Generally, the goals and objectives are focused mostly on the structural features of the river ecosystem. Few objectives appeared to recognize the value of the ecological services that the river provides. The full value of an ecosystem can only be understood, and its resources managed, in the context of these goods and services. The goal of sustainable resource management for the UMR – IWW can only be met by ensuring that these goods and services are generated by the ecosystem in perpetuity, guaranteeing their availability to all future generations. Sustaining the ecological health of the UMR – IWW, and the range of goods and services that it generates, will require a collaborative approach to management that seeks conditions for the river biota and the human users that are "adequate for all," rather than "optimum for a few." This implies a fundamental grasp of river ecosystem dynamics and functions and recognizes the ecological importance of a highly variable and diverse mosaic of structures and processes that may not be especially attractive to humans. Whole-system restoration will require constant maintenance and intervention with no guarantee that the resulting system will ever completely provide the same level of ecosystem goods and services as a self-maintaining, healthy ecosystem.

In order to evaluate future tradeoffs objectively, the collective understanding that exists about the river ecosystem will ultimately have to be expanded to include socio-economic conditions and values. The discussion of such trade-offs was beyond the explicit responsibilities assigned to the Panel, but we note that on other systems, substantial progress has been made in this area over the last two decades. The sooner a satisfactory process to evaluate trade-offs can be initiated, the sooner stakeholders will be able to integrate and advance economic and ecosystem goals and objectives in concert with each other.

Modeling

We recommend that conceptual and simulation modeling be formally established as vital steps in the adaptive management process to: 1) record the current state of the system; 2) create a holistic "virtual" reference system, based on goals and objectives expressed by stakeholders; and 3) predict system-level outcomes of alternative actions and policies.

The desired future condition of the UMR – IWW ecosystem cannot be based solely on "natural" (i.e., historic or pre-disturbance) conditions, because so much of the system has been altered. The broad variety of goals and objectives that have been expressed by stakeholders may be thought of as pieces of a puzzle. A systemic vision of the desired future river is critical to understanding whether the identified pieces will be "enough" to construct the whole puzzle. A strategy that includes conceptual modeling of the future desired system, as well as the existing system, can yield an enhanced view of how the system as a whole should be structured, and how the individual pieces are expected to interact with each other.

During the process of adaptive management, a "virtual" reference system can act as the perceived "ideal" and holistic standard against which future progress can be measured, and a progressively enhanced understanding of comprehensive ecosystem function and response to human activities can be developed. Attention to achieving desirable conditions at multiple scales (both spatial and temporal) is vital for a system as large and complex as the UMR – IWW. The process of conceptual modeling can be designed to evaluate local, pool, and reach conditions.

Models can and should be used to develop concepts, simulate processes, refine hypotheses, forecast future conditions, conduct planning, assess the results of monitoring, identify additional information needs, and inform stakeholders. Existing ecological models can be adapted to provide a useful set of tools scaled appropriately to different management objectives. Models simulating ecological processes must be designed and linked together with the appropriate time and spatial scales. Integrated models are needed for management of the UMR – IWW. The models should be hierarchically organized according to scale and process to effectively represent the range of natural and anthropogenic factors that shape the condition of the UMR – IWW ecosystem. Hierarchical model development should lead to the development ultimately of a UMR – IWW ecological modeling system consisting of modules, which can operate independently or interactively depending on specific application requirements.

Models for sediment and water-borne nutrients, mobilized from the landscape, and their transport and fate processes in the stream network need to be linked with river and reservoir water quality models to simulate loading of materials from tributary watersheds. An important element of these refinements must be the capability to simulate channel geomorphic response and sediment transport in the tributary rivers. Such integrated models will be needed to identify ecologically effective watershed management alternatives, and to optimize investment in best management practices regionally. This kind of integrated model system should be developed to provide a quantitative basis for setting attainable objectives and endpoints for sediment and nutrient loadings to the UMR – IWW.

The selected ecosystem model framework should be flexible, and have the ability to link with Geographic Information Systems to generate spatially explicit simulations and visualization products. A model of the UMR – IWW ecosystem and environment should be part of a Decision Support System (DSS) supporting informed management decision-making. The DSS should enable the calculation of the benefits (both monetary and non-monetary) of ecosystem services affected by alternative management actions.

Implementing of conceptual and simulation models will challenge the institutional framework of the UMR – IWW. Modeling will require participation of many individuals and institutions to provide the necessary expertise. Because more decisions will depend heavily on model results, the models will have to be developed collaboratively and transparently to ensure all stakeholders adequately understand the models and have open access to modeling assumptions, tools, and results.

Management Actions

We recommend that management actions available for implementation on the UMR – IWW focus on the attainment of goals and objectives at the system level--with appropriate attention to risk and uncertainty as key considerations in the Adaptive Management process.

Lack of knowledge of how the original ecosystem once functioned makes selective management (e.g., for selected species) speculative and unlikely to be successful in achieving sustainability at an ecosystem level. Management needs to focus on the attainment of accepted goals and objectives as components of the desired future condition. It is critical that restoration actions be planned and implemented at the system level, based on an improved understanding (through continued research) of contributing ecological processes across species and locations. Expanding the scope of available management actions (e.g., changes in land use in the basin) should be considered in ultimately providing environmental benefits beyond what can be accomplished only in the river corridor. However, such an expansion of capabilities is beyond the scope of the Navigational Feasibility Study, and will likely require substantial changes in existing institutional arrangements on the UMR – IWW.

The outcomes of management actions in complex ecosystems will always be uncertain. Models and monitoring programs developed to support decision-making are also fraught with uncertainty. Therefore, we recommend that sensitivity and uncertainty analyses be conducted to identify the key sources of uncertainty that will potentially impact the effectiveness of specific management actions. Resources should then be allocated to obtain any critical information identified in this process and to develop and revise models as needed to reduce uncertainty to acceptable levels and increase the value of the adaptive management process.

To the extent possible, the feasibility and effectiveness of all management actions should be evaluated in relation to the goals and objectives they are meant to address. The example, already under way, of evaluating the probabilities associated with drawdowns on various navigation pools demonstrates the value of predicting how effective an action is likely to be. Such evaluations can be especially valuable in forecasting threshold levels of effort required for alternative management actions.

Monitoring and Evaluation

We recommend the development of a UMR – IWW Ecosystem Report Card procedure and appropriate monitoring program to regularly evaluate system condition and progress toward attainment of objectives.

Managers of the UMR – IWW are fortunate to have available the extensive data sets created under the LTRMP and related studies. The value of the LTRMP can be improved once an Ecosystem Report Card is developed and relevant end-points and measures are incorporated into the monitoring program. The Report Card needs to be developed to accurately and frequently reflect condition of the river ecosystem in the context of its desired future condition. Endpoints with quantitative, time-bound, and spatially explicit metrics should be selected for many aspects (objectives) of the desired future condition of the UMR – IWW to enable monitoring and tracking of progress toward attaining broad goals for the condition of the UMR – IWW ecosystem.

We also suggest that the UMR – IWW be inventoried to identify specific areas that can be classified as "internal references" that could be studied and assessed to determine blends of processes that are sustainable within the present ecosystem. Where lacking, critical information on natural ecosystem processes in the Mississippi River may also be inferred by incorporating findings from studies conducted on similar, but unregulated rivers.

Institutional arrangements should support the UMR – IWW Ecosystem Report Card process as an unbiased evaluation, accepted by all stakeholders. The Report Card should include evaluation of the progress of management actions toward improving system condition as well as system condition. As such, the Report Card will serve as a tool to promote accountability of agencies to stakeholders' input.

Adaptation and Learning

We recommend that selected future management actions be specifically considered as experimental manipulations, intended not only to achieve stated objectives and to enhance ecosystem health, but also to provide knowledge in a predictable and structured way.

Uncertainties exist at all levels of river science and management. Models may predict the results of management actions using the best and most up-to-date science available, but applications of model results are always subject to local and frequently unpredictable conditions. There appear to be many relatively low-cost opportunities to expand the context of river management actions to include scientific control and treatment features that would greatly accelerate learning, and therefore improve the effectiveness of all subsequent actions.

References

Adaptive Environmental Assessment Steering Committee. (1997). "Upper Mississippi River Adaptive Environmental Assessment, Phase I Report," Upper Mississippi River Basin Association, 408 St. Peter Street, St. Paul, MN.

Allen, T. F. H., and Starr, T. B. (1982). *Hierarchy - perspectives for ecological complexity*. University of Chicago Press, Chicago, IL.

Association of Bay Area Governments. (2001). "Bay-Delta Environmental Report Card 1999-2001," San Francisco Estuary Project, *http://www.abag.ca.gov/bayarea/sfep/reports/*.

Bailey, R. G. (1980). "Description of the ecoregions of the United States. Miscellaneous Publication 1391. U.S. Department of Agriculture, Washington, DC.

Bailey, R. G., Avers, P. E., King, T., McNab, W. H., eds. (1994). "Ecoregions and subregions of the United States (map)," U.S. Geological Survey, Washington, DC. Scale 1: 7,500,000; colored. Accompanied by a supplementary table of map unit descriptions compiled and edited by W. H. McNab, and R. G. Bailey. Prepared for the U.S. Department of Agriculture, Forest Service.

Barnett, A., Eroschenko, V. P., Fox, G. F., Fry, D. M., and Gorsline, J. (1984). "Avian endocrine responses to environmental pollutants," *Journal of Experimental Zoology* 232, 683-689.

Barrett, G. W., Van Dyne, G. M., and Odum, E. P. (1976). "Stress ecology," *Bioscience* 26, 192-194.

Bartell, S. M., Campbell, K. R., Best, E. P. H., and Boyd, W. A. (2000a). Ecological risk assessment of the effects of the incremental increase of commercial navigation traffic (25, 50, 75, and 100% increase of 1992 baseline traffic) on submerged aquatic plants in the main channel borders," Upper Mississippi River-Illinois Waterway Navigation Study. Interim Environmental Report ENV-17. Rock Island District, U.S. Army Corps of Engineers, Rock Island, IL.

Bartell, S. M., Campbell, K. R., Lovelock, C. M., Nair, S. K., and Shaw, J. L. (2000). "Characterizing aquatic ecological risks from pesticides using a diquat dibromide case study III. Ecological process models," *Environmental Toxicology and Chemistry* 19, 1441-1453.

Bartell, S. M., Lefebvre, G., Kaminski, G., Carreau, M., and Campbell, K. R. (1999). "An ecosystem model for assessing ecological risks in Québec rivers, lakes, and reservoirs," *Ecological Modeling* 124:43-67.

Bayley, P. B. (1995). "Understanding large river-floodplain ecosystems." *Bioscience* 45, 153-158.

Blumenthal, D., and Jannink, J. L. (2000). "A classification of collaborative management methods," *Conservation Ecology* 4(2), 13. [online] URL: *http://www.consecol.org/vol4/iss2/art13*.

Cairns, J., Jr. (1990). "Lack of theoretical basis for predicting rate and pathways of recovery," *Environmental Management* 14, 517-526.

Carpenter, S. R., Brock, W. A., and Hansen, J. (1999). "Ecological and social dynamics in simple models of ecosystem management," *Conservation Ecology* 3(1). [online] URL: *http://www.consecol.org/Journal/vol3/iss2/art4/index.html*.

Christensen, N. L. (1997). "Managing for heterogeneity and complexity on dynamic landscapes: heterogeneity, ecosystems and biodiversity". *The ecological basis of conservation*. S. T. A. Pickett, R. S. Ostfeld, M. Shachak, and G. E. Likens, ed., Chapman and Hall, New York.

Claflin, T. (1977). "Regression simulation model users manual, navigation pool No. 8, final report," University of Wisconsin, La Crosse.

Coffey, M., Phillips, K., Berg, C., Harshbarger, J., and Green, T. (2000). "Middle Mississippi River Sturgeon Preliminary Contaminants Investigation, Illinois, Missouri, and Iowa," U.S. Fish and Wildlife Service Regional Identification Number 3F25, Divisional Identification Number 9730003. U.S. Fish and Wildlife Service, Rock Island Field Office.

Colburn, T., Dumanoski, D., and Myers, J. P. (1996). *Our stolen future: Are we threatening our fertility, intelligence, and survival?: A scientific detective story.* Penguin Books, New York.

Costanza, R. (1992). "Towards an operational definition of ecosystem health." *Ecosystem health: New goals for environmental management.* R. Costanza, B. G. Norton, and B. D. Haskell, ed., Island Press, Washington, DC.

Costanza, R., Wainger, L., Folke, C., and Maler, K.G. (1993). "Modeling complex ecological economic systems. Toward an evolutionary, dynamic understanding of people and nature," *BioScience* 43(8), 545-555.

Dale, V. H., ed.. (2003). *Ecological modeling for resource management*. Springer-Verlag, New York.

DeHaan, H. C., McVay, N. M., Theiling, C. H., and Soileau, R. S. (2003). "Upper Mississippi River-Illinois Waterway System Environmental Objectives Planning workshops," U.S. Army Corps of Engineers, Rock Island, IL.

DeHaan, T., Fox, J., Korschgen, C. E., Theiling, C. H., and Rohweder, J. J. (2000). "Habitat needs assessment GIS query tool for the Upper Mississippi River System," U.S. Geological Survey Upper Midwest Environmental Science Center, LaCrosse, Wisconsin. Contract report prepared for the U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

Fish and Wildlife Interagency Committee. (2003). "Pool plans, Upper Mississippi River Navigation Pools 11 – 22 (review drafts)," Rock Island Field Office, U.S. Fish and Wildlife Service. Rock Island, IL. *http://midwest.fws.gov/RockIsland/activity/FWICWebpage/index.htm*

Fish and Wildlife Work Group. (2003). "Environmental Pool Plans, Upper Mississippi River, Pools 1-10. (review draft March 2003)," River Resources Forum. St. Paul District, U.S. Army Corps of Engineers. St. Paul, MN.

Floodplain Management Review Committee. (1994). "A blueprint for change, Part V: Science for floodplain management into the 21st century," Report of the Floodplain Management Review Committee to the Administration Floodplain Management Task Force, U.S. Government Printing Office, Washington, DC.

Gardner, R. H., Kemp, W. M., Kennedy, V. S., and Petersen, J. E., eds. (2001). "Scaling relations in experimental ecology." *Complexity in ecological systems*. Columbia University Press, New York.

Green, W. E. (1960). "Ecological changes on the upper Mississippi River Wildlife and Fish Refuge since inception of the 9-foot channel." U.S. Department of the Interior, Fish and Wildlife Service Annual Refuge Report, Winona, MN.

Grumbine, R. E. (1994). "What is Ecosystem Management?" *Conservation Biology* 8, 27-38.

Gunderson, L. H., and Holling, C. S., eds. (2002). "Panarchy – understanding transformations in human and natural systems," Island Press, Washington, DC.

Gunderson, L. H., Holling, C. S., and Light, S. S. (1995). "Barriers and bridges to the renewal of ecosystems and institutions," Columbia University Press, New York.

Harwell, M. A., Meyers, V., Young, T., Bartuska, A., Grassman, N., Gentile, J. H., Harwell, C. C., Appelbaum, S., Barko, J., Causey, B., Johnson, C., McLean, A., Smola, R., Tamplet, P., and Tosini, S. (1999). "A framework for an ecosystem integrity report card," *BioSciences* 49(7), 543-556.

Harwell, M. A., Long, J. F., Bartuska, A. M., Gentile, J. H., Harwell, C. C., and Meyers, V. (1996). "Ecosystem management to achieve ecological sustainability: The case of South Florida," *Environmental Management* 20(4), 497-521.

Holling, C. S., and Chambers, A. D. (1973). "Resource science: the nurture of an infant," *BioScience* 23, 3-21.

Holling, C. S., ed. (1978). *Adaptive environmental assessment and management*. Wiley, New York.

Interagency Floodplain Management Review Committee (Galloway Report). (1994). "A blueprint for change: Sharing the challenge: Floodplain management into the 21st century," Report of the Floodplain Management Review Committee to the Administration Floodplain Management Task Force, U.S. Government Printing Office, Washington, DC.

Izaak Walton League of America and Natural Resources Defense Council. (1994). "Restoring the big river: A clean water act blueprint for the Mississippi," Izaak Walton League of America and Natural Resources Defense Council, Minneapolis, MN and Washington, DC.

IUCN (World Conservation Union). (1980). *The world conservation strategy*. IUCN/UNEP/WWF, London, UK.

Jackson, L. E., Kurtz, J. C., and Fisher, W. S. (2000). "Evaluation guidelines for ecological indicators," EPA/620/R-99/005. U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC.

Janssen, M. (1998). *Modeling global change: The art of integrated assessment modeling.* Edward Elgar, Lyme, CT.

Karr, J. R., and Dudley, D. K. (1981). "Ecological perspective on water quality goals," *Environmental Management* 5, 55-68.

Knox, J. C., Bartlein, P. J., Hirschboeck, K. K., and Muckenhirn, R. J. (1975). "The response of floods and sediment yields to climatic variation and land use in the Upper Mississippi Valley," University of Wisconsin-Madison Institute for Environmental Studies Report 52, Madison, WI.

Lee, K. N. (1993). *Compass and gyroscope*. Island Press, Washington, DC.

Lettenmaier, D. P., Hooper, E. R., Wagoner, C., and Faris, K. B. (1991). "Trends in stream quality in the continental United States, 1978–1987," *Water Resources Research* 27, 327–339.

Lubinski, K. (1993). “A conceptual model of the Upper Mississippi River System ecosystem.” U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, WI, EMTC 93-T001, (NTIS #PB93-174357).

Lubinski, K. S., and Theiling, C. H. (1999). “Assessments and forecasts of the ecological health of the Upper Mississippi River System floodplain reaches.” *Ecological status and trends of the Upper Mississippi River System 1998: A report of the Long Term Resource Monitoring Program*. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI, LTRMP 99-T001, 16-1 – 16-12.

Manley, P. N., Zielinski, W. J., Stuart, C. M., Keane, J. J., Lind, A. J., Brown, C., Plymale, B. L, and Napper, C. O. (2000). “Monitoring ecosystems in the Sierra Nevada: The conceptual model foundation,” *Environmental Monitoring and Assessment* 64, 139-152.

Martin, L. R., and Stakhiv, E. Z. (1999). “Sustainable development: Concepts, goals, and relevance to the civil works program,” IWR Report 99-PS-1. Water Resources Support Center, U.S. Army Corps of Engineers, Alexandria, VA.

McIntire, D. 1983. *Dynamics of Lotic Systems*. T. D. Fontaine and S. M. Bartell, ed., Ann Arbor Science, Ann Arbor, MI.

McLean, A., and Ogden, T. (2000). “Baseline report for the comprehensive Everglades restoration plan,” U.S. Army Corps of Engineers, Restoration Program Office, West Palm Beach, FL.

Naito, W., Miyamoto, K., Nakanishi, J., Masunaga, S., and Bartell, S. M. (2002). “Application of an ecosystem model for ecological risk assessment of chemicals for a Japanese lake,” *Water Research* 36, 1-14.

Nakato, T. (2000). “Sediment budget.” *Upper Mississippi River and Illinois Waterway cumulative effects study. Volume 1: Geomorphic Assessment*. Report by West Consultants, Inc. to the Rock Island District, U.S. Army Corps of Engineers, 151-172.

National Research Council. (2001a). “Ecological indicators for the Nation,” Committee to Evaluate Indicators for Monitoring Aquatic and Terrestrial Environments, National Research Council, National Academy Press, Washington, DC.

__________. (2001b). “Inland navigation system planning: The Upper Mississippi River-Illinois Waterway,” National Academy Press, Washington, DC.

O’Neil, L. J., and Bartoldous, C. (2002). “Selected definitions for ecological evaluation,” Glossary for Corps training courses, U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. Unpublished.

O'Neill, R. V., DeAngelis, D. L., Waide, J. B., and Allen, T. F. H. (1986). *A hierarchical concept of ecosystems*. Princeton University Press, Princeton, NJ.

Pastorok, R. A., Bartell, S. M., Ferson, S., and Ginzburg, L. R. (2002). *Ecological modeling in risk assessment: Chemical effects on populations, ecosystems, and landscapes*. Lewis Publishers, Boca Raton, FL.

Poff, N. L., Allen, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., Sparks, R. E., and Stromberg, J. C. (1997). "The natural flow regime: A paradigm for river conservation and preservation," *BioScience* 47, 769-784.

Rauch, J. (2002). "Seeing around corners," *The Atlantic Monthly*. April. 35-48.

Richter, B. D., Mathews, R., Harrison, D. L., and Wigington, R. (2003). "Ecologically sustainable water management: Managing river flows for ecological integrity," *Ecological Applications* 13, 206-224.

Robinson, A., and Marks, R. (1994). "Restoring the big river: A clean water act blueprint for the Mississippi," Izaak Walton League, Minneapolis, Minnesota and Natural Resources Defense Council, Washington, DC.

Rogers, K. (1998). "Managing science/management partnerships: A challenge of adaptive management," *Conservation Ecology* 2(2): R1 [online]. URL: *http://www.consecol.org/vol2/iss2/resp1*

Rogers, K. H. (1997). "Operationalizing ecology under a new paradigm: an African perspective." *The ecological basis of conservation*. S. T. A. Pickett, R. S. Ostfeld, M. Shachak, and G. E. Likens, ed., Chapman and Hall, New York.

Scheffer, M., and Beets, J. (1994). "Ecological models and the pitfalls of causality," *Hydrobiologia* 276, 115-124.

Schiller, A., Hunsaker, C. T., Kane, M. A., Wolfe, A. K., Dale, V. H., Suter, G. W., Russell, C. S., Pion, G., Jensen, M. H., and Konar, V. C. (2001). "Communicating ecological indicators to decision makers and the public," *Conservation Ecology* 5, 19, URL: *http://www.consecol.org/vol5/iss1/art19*

Schnick, R. A., Morton, J. M., Mochalski, J. C., and Beal, J. T. (1982). "Mitigation and enhancement techniques for the Upper Mississippi River System and other large river systems," U.S. Fish and Wildlife Service. Resource Publication 149.

Smith, R. A., Alexander, R. B., and Lanfear, K. J. (1993). "Stream water quality in the conterminous United States — status and trends of selected indicators during the 1980's," U.S. Geological Survey, Water Supply Paper 2400, Reston, VA.

Smith, R. A., Alexander, R. B., and Wolman, M. G. (1987). "Water-quality trends in the nation's rivers," *Science* 235, 1607–1615.

Soballe, D., and Wiener, J. (1999). "Water quality." *Ecological status and trends of the Upper Mississippi River System 1998: A report of the Long Term Resource Monitoring Program*. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI. April. LTRMP 99-T001.

Sparks, R. E., Bayley, P. B., Kohler, S. L., and Osborne, L. L. (1990). "Disturbance and recovery of large floodplain rivers," *Environmental Management* 14(5), 699-709.

Theiling, C. H., Korschgen, C., Dehaan, H., Fox, T., Rohweder, J., and Robinson, L. (2000). "Habitat needs assessment for the Upper Mississippi River System: Technical Report," U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, Wisconsin. Contract report prepared for the U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO. *www.umesc.usgs.gov/habitat_needs_assessment/emp_hna.html*

The McKnight Foundation. (1996). *The Mississippi River in the Upper Midwest: Its economy, ecology, and management*. The McKnight Foundation, Minneapolis, MN.

The Nature Conservancy. (1998). "Illinois River site conservation plan," The Nature Conservancy of Illinois. Illinois River Project Office, Lewistown, IL.

Thom, R. M. (2001). "Development of a conceptual model for the Columbia River navigation channel improvement project reconsultation process," *Sustainable Ecosystem Initiative Columbia River Project,* Available online 15 May 2003 at URL: *http://sei.org/columbia/downloads/ronthom.PDF*.

Upper Mississippi River Basin Commission. (1980). "Upper Mississippi River main stem, level B study: Final report," Upper Mississippi River Basin Commission. Bloomington, MN.

__________. (1982). "Comprehensive master plan for the management of the Upper Mississippi River System," Upper Mississippi River Basin Commission, Minneapolis, MN.

Upper Mississippi River Conservation Committee. (1993). "The Upper Mississippi River; America's river faces its greatest threat -- a call for action from the Upper Mississippi River Conservation Committee," Upper Mississippi River Conservation Committee, Rock Island, IL.

__________. (1995). *Proceedings of the Fifty-First Annual Meeting of the Upper Mississippi River Conservation Committee*. March 15 - 17, 1995, Dubuque, Iowa. Upper Mississippi River Conservation Committee, Rock Island, IL.

__________. (2001). "A working river and a river that works," Upper Mississippi River Conservation Committee, Rock Island, IL.

Upper Mississippi River Conservation Committee. (2002). “A preliminary description of habitat objectives (and estimated costs) needed to achieve a desired level of ecosystem integrity on the Upper Mississippi River System,” Upper Mississippi River Conservation Committee, Rock Island, IL.

Upper Mississippi River Summit. (1996). “Interagency planning committee established under Upper Mississippi River Basin Association (UMRBA) auspices to work toward integrated management of the river system,” UMRBA, St. Paul, MN.

U.S. Army Corps of Engineers. (1990). “Guidance for conducting civil works planning studies (Planning Guidance Notebook, PGN),” Engineering Regulation (ER) 1105-2-100, CECW-P, HQUSACE, Washington, DC.

__________. (2000). “Upper Mississippi River and Illinois Waterway Cumulative Effects Study Volume 1: Geomorphic Assessment. Volume 2 Ecological Assessment,” Prepared by West Consultants, Inc., Bellevue, Washington for U.S. Army Corps of Engineers, Rock Island District, Rock Island, IL.

__________. (2002). “Interim report for the restructured Upper Mississippi – Illinois Waterway Navigation Study,” Rock Island District, Rock Island, IL.

U.S. Army Engineer Research and Development Center and Harwell Gentile and Associates. (2001). “Conceptual models for coastal Long Island ecosystems: Fire Island to Montauk Point reformulation study,” Draft report. Vicksburg, MS.

U.S. Environmental Protection Agency. (1992). “Framework for ecological risk assessment,” EPA 630-R-92-001. Risk Assessment Forum, Washington, DC.

__________. (1997). “National study of chemical residues in fish;” Vol I EPA 823-R-008a. “The incidence and severity of sediment contamination in surface waters of the United States;” Vol 1: National sediment quality survey. EPA 823-R-97-006.

__________. (1998). “Guidelines for ecological risk assessment,” EPA 630-R-95-002F. Risk Assessment Forum, Washington, DC.

U.S. Fish and Wildlife Service. (1995). “Fish and Wildlife Interagency Committee HREP fact sheet set,” U.S. Fish and Wildlife Service, Rock Island, IL.

U.S. Geological Survey. (1999). “Ecological status and trends of the Upper Mississippi River System 1998: A report of the Long Term Resource Monitoring Program,” LTRMP 99-T001, U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI.

U.S. Water Resources Council. (1983). “Economic and environmental principles and guidelines for water and related land resources implementation studies,” Washington, DC.

Walters, C. (1986). *Adaptive management of renewable resources*. Macmillan, New York.

Walters, C. (1997). "Challenges in adaptive management of riparian and coastal ecosystems," *Conservation Ecology* 1:1 [online]. *http://www.consecol.org/vol1/iss2/art1*

Walters, C. J., and Holling, C. S. (1990). "Large-scale management experiments and learning by doing," *Ecology* 71, 2060-2068.

West Consultants, Inc. (2000). "Upper Mississippi River and Illinois Waterway Cumulative Effects Study; Volume 2: Geomorphic Assessment," ENV Report 40-2, Report to the U. S. Army Corps of Engineer District, Rock Island, IL.

Wilcox, D. B. (1993). "An aquatic habitat classification system for the Upper Mississippi River System," Long Term Resource Monitoring Program Technical Report EMTC 93-T003, U.S. Geological Survey Upper Midwest Environmental Science Center, Onalaska, WI.

World Commission on Environment and Development. (1987). *Our common future*. Oxford University Press, Oxford, England.

Young, T. F., and Sanzone, S., eds. (2002). "A framework for assessing and reporting ecological condition," Report EPA-SAB-EPEC-02-009, U.S. Environmental Protection Agency, Science Advisory Board, Washington, DC.

Appendix A
Glossary

Adaptive Management (AM) – An approach to natural resource management that monitors of project outcomes and uses the monitoring results to make revisions and refinements to ongoing management actions. (adapted from National Academy of Science (2002)).

Benefits – Outcomes of management actions described in terms of relative value (adapted from O'Neil and Bartoldus (2002)).

Components – Discernable or distinct parts that exist in the ecosystem, and together with other components, constitute or encompass the entirety of the ecosystem. Components may be organisms, physical features, patterns, or processes.

Disturbances – Natural occurrences that cause rapid and extensive change, relative to the scales of the ecosystem. Disturbances can be biotic and abiotic, and take place at different frequencies of occurrence, duration, intensity, and spatial extent.

Drivers – Natural fundamental forces and fluxes that structure ecosystems.

Economic Coordinating Committee (ECC) – An oversight team of economic interests in the UMR – IWW region concerned with the economic development impacts of the UMR – IWW expansion. The group is composed of entities such as the Midwest Area River Coalition 2000 (MARC 2000), Upper Mississippi, Illinois, and Missouri River Association (UMIMRA), and farm groups such as the corn and soybean growers associations.

Endpoints – Selected components of the ecosystem that may be ecologically important, valued by humans, and used to evaluate changes in the ecosystem.

Essential Ecosystem Characteristics (EEC) – Categories of major components in the ecosystem that link the interests of society and science and are used to organize components into meaningful classes.

Function – The biological, physical, and chemical processes that occur in natural systems (O’Neil and Bartoldus 2002).

Goals – Articulation of societal values and desired future ecosystem conditions. Goals are generally broad in nature and further defined by more specifically stated objectives, and implemented with management actions directed toward endpoints (adapted from Harwell et al. (1999)).

Hydroscape – description of the spatial and temporal distributions of water depth and velocity that define much of physical aquatic habitat.

Management Actions – Human activities that are intended to affect endpoints and attain objectives.

Navigation Environmental Coordinating Committee (NECC) – An oversight committee composed of the five UMR – IWW states and federal natural resource agencies and environmental non-governmental organizations such as Mississippi River Basin Alliance (MRBA), American Rivers, and the Izaac Walton League, among others.

Objectives – A clear statement of desired future conditions of an ecosystem or an endpoint.

Pattern – A characteristic, repeatable, or predictable occurrence of ecosystem components. Sometimes referred to as structure. Pattern is seen in both biotic and abiotic components.

Performance criteria – Criteria for the endpoints, e.g., acceptable range, thresholds, or limits; based on scientific understanding of desired ecological conditions (adapted from Harwell et al. (1999)).

Process – The biological, physical, and chemical flows of energy and material between and among components of ecosystems (adapted from O'Neil and Bartoldus (2002)).

Services – Humanly valued outputs resulting from functions of natural systems.

Significant – Likely to have a material bearing on the decision-making process. Significance is based on institutional, technical, and public recognition. Resources and effects of alternative management actions are evaluated for significance (U.S. Water Resources Council 1983).

Stressors – A physical, chemical, or biological perturbation to a system that is either a) foreign to that system, or b) natural to the system but applied at an excessive (or deficient) level (Barrett et al. 1976).

Structure – The spatial and temporal occurrence and arrangement of components of an ecosystem; the physical manifestation of patterns and processes (adapted from O'Neil and Bartoldus (2002)).

Appendix F
Ecological Endpoints to Evaluate Upper Mississippi River – Illinois Waterway Management Actions and Objectives

Proposed Endpoints and Measures

BIOTA: Abundance of Asian Carps

Endpoint Definition. Maintain the current low numbers of Asian Carp (*Cyprinidae* spp.) north of Pool 19 in the Upper Mississippi River. Current carp species from Asia in the system are: grass carp (*Cttenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and black carp (*Mylopharyngodon piceus*).

Policy and Management Relevance. Exotic and invasive species can have profound undesirable effects on ecosystems and natural resources of direct human use. Common carp (a European exotic species) have been present in the UMR – IWW for more than a century, and are one of the most abundant aquatic species. Other more recent exotics have caused significant ecological and economic consequences. Minimizing exotic species impacts is a significant concern of natural resource agencies, biologists, commercial fishermen, sportsmen, and municipal and industrial plant managers. Limiting further expansion of exotic species and the emergence of new species is a broadly supported environmental management objective.

Technical Merit. Exotic species interactions with native species has been a leading cause of extinctions, food web disruption, and shifts in community composition. Exotic species have also caused large alterations of the physical environment (e.g., sediment resuspension by common carp feeding), increased water clarity (zebra mussel filter feeding), and restructuring of whole ecosystems (littoral to pelagic dominance). The record of predicting which species may be introduced and which might attain nuisance levels has been poor. Many ecological and economic consequences of these species had not been anticipated, but may not have been avoidable regardless. The choice of a group of Asian carps represents the pervasiveness of exotic species in the system, and their potential effects on the ecosystem. This group of fish includes a herbivore, two plantiviores, and a molluscivore, respectively, capturing a broad range of connections to the natural river system food web.

Practicality. The Asian carps are large and relatively long-lived fish that can occupy a wide range of lotic and lentic habitats and traverse distances as large as the UMRS. These fish can now be considered permanent inhabitants within the Mississippi River basin. The fish occur commonly in routine fishery sampling in the Lower Illinois, Middle Mississippi, and Lower Pooled Reaches of the Upper Mississippi River. They have achieved nuisance status in the catch of commercial fishermen.

Measures. (1) Annual number of confirmed range expansions in the system; (2) Catch per unit effort in standardized fishery monitoring sampling where established.

BIOTA: Population of Lake Sturgeon

Endpoint Definition. Maintain a viable population of lake sturgeon (*Acipenser fulvescens*) in the upper Mississippi River system.

Policy and Management Relevance. The lake sturgeon is formally recognized as a species of concern in some states, and it is a highly managed species due to its past and present value in the commercial fishery. The state of Missouri stocks lake sturgeon. Limited sport harvest of this fish is allowed in the region, and public interest is high because of the atypical nature of these fish. The endpoint of having a population of this fish in the upper Mississippi River system is clear and easily recognized by the public.

Technical Merit. Lake sturgeon are members of the rheophilic guild of large river fishes. This species and other large river rheophilic fish occupy main and side channel habitats with deep water and often strong current. Lake sturgeon require access to long stretches of river since migrations to spawning, rearing, and overwintering habitats can be extensive. Spawning conditions can be restrictive since hard substrates free of sediment accumulations are used. Population threats include migration barriers posed by dam and navigation structures, power plant cooling water impingement and entrainment, overexploitation, degradation of spawning habitats, and direct impact of ship propellers. Consequently, the continued presence of this species in the system requires uninterrupted access to extensive river reaches and availability of clean rock substrate in deep channel waters.

Practicality. Lake sturgeon are rarely seen or captured by sport fishermen or the public, and there are sparse records of the fish in the long-term monitoring of the U.S. Geological Survey. However, the presence of the fish, especially young individuals, indicates the persistence of a population. Commercial fishermen are able to collect them in higher abundance during certain river conditions and times of year. Sighting information can be readily collected from the commercial catch and routine fish monitoring.

Measures. (1) Number of captures in monitoring and research programs; (2) Number of captures by commercial fishermen; (3) Number stocked and recapture rate and location.

BIOTA: Abundance of Waterfowl

Endpoint definition. Increase the overall abundance of waterfowl using habitats of the UMR – IWW above current levels.

Policy and Management Relevance. The UMR – IWW is critical to migratory waterfowl of the United States because more than 40 percent of this national resource relies heavily on UMR – IWW wetlands and aquatic habitats. Migratory waterfowl have been in decline in the UMR – IWW since the 1950s, and they are the focus of local, national, and international wildlife management programs. Finally, these birds support important seasonal recreational harvest and wildlife observation.

Technical Merit. The UMR – IWW supports spring and fall concentrations of ducks that feed on plants and invertebrates in or on aquatic substrates. Both diving (e.g., canvasback, *Aythya valisneria*; lesser scaup, *Aythya marila*; greater scaup, *Athya affinis*) and dabbling ducks (e.g., mallard, *Anas platyrhynchos*; blue-wing teal, *Anas discors*) are supported. Waterfowl species occur sporadically in a wide range of shallow-water habitats, but food availability is highest and most easily obtained in clear, vegetated waters in protected areas and backwaters. Seasonal abundance indicates the prevalence and productivity of preferred habitats.

Practicality. Waterfowl are being monitored using standard census methods. Many factors external to the UMR – IWW affect waterfowl numbers but patterns of abundance related to habitat conditions within the UMR – IWW are apparent. Losses of waterfowl below current levels could be caused by external factors but this would remain a loss to an important and publicly noted UMR – IWW resource.

Measures. (1) Use-days during migration period; (2) Nest counts; (3) Transect sampling counts in select habitats or managed areas.

BIOTA: Neotropical Migrant Birds

Endpoint Definition. Increase the total numbers of neotropical migrant birds, especially rare conservation priority species.

Policy and Management Relevance. Neotropical migrant birds are a Federal trust resource, protected by the Migratory Bird Treaty Act. Numerous agency and non-government organization efforts are directed at the conservation of all birds, including shorebirds, waterfowl, raptors, and migrant and resident landbirds. The National Refuge System units on the UMR – IWW were established with migratory bird consideration in their authorizing language. The USFWS established the Breeding Bird Survey (BBS) to monitor trends in bird populations, and many organizations and individuals participate in annual Christmas bird counts. Region 3 of the USFWS has prepared a list of songbirds that include 17 neotropical migrants as conservation priorities due to rare or declining trends.

Technical Merit. Birds exhibit numerous traits that make them good ecological indicators at regional and national scales. Across the 17 species identified as conservation priorities, the extent and condition of HNA habitat classes of bottomland forest, marsh/wet meadow, grassland, and scrub-shrub habitat would be indicative of their potential UMR – IWW habitat.

Practicality. Although birds are attractive as ecological indicators because they can be readily sampled and their taxonomy is well-known, habitat-specific data on the occurrence and relative abundance of most non-waterfowl bird species are not yet available for most areas on the Mississippi River. However, data sets exist with the U.S. Army Corps of Engineers, the states, and the U.S. Geological Survey that remain to be analyzed. Standardized survey routes and point counts specific to riverine and floodplain habitats would be needed to supplement available data for the region.

Measures. Numbers and nesting success estimates for selected species, as guild representatives, for selected habitats.

BIOTA: Freshwater Mussel Populations

Endpoint Definition. Increase freshwater mussel abundance and species diversity to maintain viable populations of native fauna.

Policy and Management Relevance. Freshwater mussel abundance is directly related to societal goals for healthy biotic communities, good water quality, and aquatic habitat improvement articulated in recent public surveys (HNA & LTRM). About 40 percent of the UMR – IWW native species have been extirpated and 20 percent of the remaining species are at risk of extinction. Two remaining species are listed as Federally endangered.

Technical Merit. Mussels are good indicators of ecosystem health because they are relatively long-lived and sessile, and depend on good water quality and physical habitat. Adult mussels are eaten by muskrats, otters, and raccoons; young mussels are eaten by ducks, wading birds, and fish. Freshwater mussel populations are under stress throughout most of their range from poor water quality, habitat degradation, overharvest, and recently, the exotic and invasive zebra mussel. Additional threats are posed by other unintentionally introduced species such as the black carp, a molluscivore, which is being evaluated by the aquaculture industry to control snail populations in ponds.

Practicality. Quantitative mussel survey techniques have improved with technology and diving surveys are now routine for the research and consulting community for dredging and other development activities. Other methods to detect freshwater mussels such as hydroacoustics are improving and may help focus more expensive dive surveys. Size distribution, abundance, and diversity metrics are commonly reported across researchers, and an Upper Mississippi River Mussel Coordination Team has recently been established to promote and pursue a comprehensive monitoring program.

Measures. (1) Mussel beds per river reach (to be defined); (2) Number of species per bed; (3) Density of mussels in beds.

BIOTA: Mast Tree Populations

Endpoint Definition. Increase forest species composition and diversity by reestablishing the once prominent mast species component of the forest community.

Policy and Management Relevance. The floodplain forests of the UMR – IWW are currently dominated by mixed silver maple communities that occur in even aged stands between 50 and 70 years old, whereas historic records indicate forests were formerly more diverse in species and age composition. There is limited regeneration of silver maple or other trees. Mast-producing tree communities occur on less than 10 percent of the UMR – IWW floodplain. Currently, the Corps retains forest management authority on all project lands including those subject to the successive Cooperative Agreement between the U.S. Fish and Wildlife Service and the States on General Plan Lands. The USFWS is responsible for forest management on other Federal lands. The primary focus of UMR – IWW forestry programs is to enhance wildlife habitat. Forest management programs are reviewed annually by interested agencies and stakeholders. Also, two goals supported by UMR – IWW stakeholders are to (1) maintain viable populations of native species in situ; and (2) represent all native ecosystem types across their natural range of variation.

Technical Merit. Hard mast such as acorns, pecans, and hickory nuts are important food sources for wood duck, mallard, squirrel, deer, beaver, blue jay, and other wildlife. Mast-producing trees commonly refer to oaks, pecan, hackberry, walnut, and hickory, some of which provide species-specific benefit to migrant landbirds. With alternative growth forms to the dominant silver maple, these trees provide structural diversity in the forest canopy.

Practicality. Forests have been monitored under the Long Term Resource Monitoring Program component of the Environmental Management Program. The Corps of Engineers also supports forest inventory activities in the St. Paul and Rock Island Districts. The status of forest inventory and monitoring on state and private lands in the floodplain is unknown. Establishment of additional monitoring plots, restoration of transect monitoring under LTRM, or other approaches should be straightforward if necessary to design, estimate, and implement.

Measures. (1) Forest community composition; (2) Importance value of mast trees; (3) Regeneration indices.

BIOGEOCHEMISTRY: Water Quality Criteria

Endpoint Definition. Achieve and maintain compliance with prevailing water quality criteria at all times and places in the UMR – IWW. Prevailing criteria will be those applicable to a location despite variations among state criteria.

Policy and Management Relevance. Compliance with state water quality criteria is a regulatory requirement, but in certain instances requirements are reduced or waived. Also, in practice, waters out of compliance often cannot be attributed to any one cause, which may complicate identifying and correcting problems. Major public investments in municipal waste treatment and private treatment of industrial waste have resulted in large improvements in water quality in many river reaches. However, non-point nutrient and chemical inputs continue to degrade water quality across the UMR – IWW, and several government programs are now targeting funds for agricultural practices that reduce nutrient and chemical inputs to waterways.

Technical Merit. Standard methods for water sampling and testing are available, and sources of most pollutants are known. Point and non-point source control practices are well-known for most types of pollutants.

Practicality. Water quality assessment and monitoring are widespread and routine environmental management activities in the United States. States and the U.S. Environmental Protection Agency maintain a central database for water quality data (STORET), and the U.S. Geological Survey regularly collects and archives water quality data (WATSTORE). Consequently, assessing status via water quality is routine and historical data will be available for assessing trends.

Measures. (1) Percent observations not meeting quality criteria in a fixed series of annual water samples; (2) Number of occasions and locations observed to be out of compliance in a year.

BIOGEOCHEMISTRY: Nutrient Concentrations in Water

Endpoint Definition. Low water concentrations of nitrogen and phosphorus measured as nitrate nitrogen less than 1 mg/l and phosphorus less than 0.1 mg/l.

Policy and Management Relevance. Elevated nutrient concentrations result in problematic algae and plant growth, high algal turbidity, and the potential for oxygen and nutrient toxicity stress to aquatic life. Stakeholder objectives reported in DeHaan et al. (2003) regularly desired bottom visibility of 1 m or more, making low nutrient concentrations necessary. The primary nutrients of concern are nitrogen and phosphorus coming from agricultural and urban land runoff, and stakeholder workshops commonly indicated an interest in reducing runoff inputs to the UMR – IWW by 25 percent. These public interests suggest nutrient concentration in a range that would be considered low in the United States.

Technical Merit. Smith et al. (1993) use a nitrate concentration of 1 mg/L N as indicative of agricultural and urban runoff effects. Using STORET and WATSTORE databases, Smith et al. (1987) estimated that the middle 50 percent of U.S. waters range in nitrate from 0.20 to 0.89 (median 0.41) mg/L. A low concentration of 1 mg/l N would be achieved by more than 75 percent of U.S. waters, indicating this water concentration should be attainable for most waters of the UMR – IWW in time. In fresh waters, phosphorus is most commonly the critical nutrient relative to problematic algae or plant growth. The U.S. Environmental Protection Agency specifies that phosphorus concentrations remain under 0.1 mg/L to prevent excessive algae and plant growths in flowing waters. Smith et al. (1987) computed that the middle 50 percent of U.S. waters ranged in phosphorus from 0.6 to 0.29 mg/L (median 0.13) in the 1970s with stable or declining concentrations since that time (Lettenmaier et al. 1991, Smith et al. 1993). Therefore, most U.S. waters exceed the low concentration given here as an endpoint, suggesting this will be a challenging water quality objective for the UMRS.

Practicality. Nutrient measurement and monitoring are widespread and routine environmental management activities in the United States. Standard methods for water sampling and testing are available. Point and non-point source control practices are well-known for nutrients although major inputs to the UMR - IWW would be expected from lands well outside the area.

Measures. (1) Percent observations not meeting low concentration criteria in a fixed series of annual water samples; (2) Number of occasions and locations observed to be high in a year.

BIOGEOCHEMISTRY: Contaminated Sediments

Endpoint Definition. Evaluate the chemical constituents and their concentration, toxicity, and mobility in contaminated sediments and apply BMPs to manage them.

Policy and Management Relevance. The Clean Water Act and the Comprehensive Environmental Response, Compensation, and Liability Act, and their implementing regulations, including State regulations, reflect national and regional policy to identify, investigate, remediate, or otherwise manage contaminants released into the environment. Contaminant releases can lead to contaminated sediment problems (USEPA 1997). Fish consumption advisories have been issued by each of the five UMR – IWW border states for the Mississippi and Illinois Rivers in part as a result of exposure to contaminants associated with sediments (USEPA 1992).

Technical Merit. Contaminated sediments can cause human, fish, and wildlife health problems (Colburn et al. 1996), and may also contribute to economic losses. Health problems include mortality by acute toxicity or cancer, physiological dysfunction and altered reproductive success by chronic exposure (Barnett et al. 1984, Coffey et al. 2000). Some fish advisories are associated with locations with fine sediments known to be contaminated with polychlorinated biphenyls (PCBs), hydrocarbon compounds, or heavy metals such as mercury. These contaminants enter biological pathways via direct ingestion of sediments by filter-feeding organisms, ingestion of contaminated food items, or release of contaminants to the water column. Isolating, stabilizing, or removing contaminated sediments would reduce or eliminate the availability of their toxic constituents to the UMR-IWW food chain. Well-known contaminant "hot spots" are located near some of the larger municipalities in the region.

Practicality. Common techniques and established scientific protocols exist for monitoring contaminant concentrations in sediment and fish tissue, water quality, and health biomarkers such as endocrine disruption. The regulations for Natural Resource Damage Assessment Regulations (Department of Interior 43 CFR Part 11, as amended by 61 CFR 20559) provide a phased assessment process to determine if, to what degree, and through what mechanism injuries to natural resources have occurred. This or a similar process could be used to screen and prioritize locations and site-specific actions to manage contaminated sediments in the Mississippi River system.

Measures. (1) Reduction or elimination of selected contaminant levels in indicator fish species tissues; (2) Reduction or elimination of anomalies in indicator fish species health metrics (e.g., intersex sturgeon in the Middle Mississippi River).

BIOGEOCHEMISTRY: Fine Sediment Entering the System

Endpoint Definition. Reductions in fine sediment loading to the UMR – IWW from current levels.

Policy and Management Relevance. Fine sediments that are easily resuspended by wave and boat action result in highly turbid water that reduces the occurrence and extent of desirable aquatic plants; produces unstable sediments of low value for invertebrates; and adds inorganic material to the water, interfering with filter feeding organisms like mussels and mayflies. Clear waters, submerged aquatic plants, and benthic productivity supporting fish and waterfowl rank high in sentiments recorded in stakeholder workshops reported in DeHaan et al. (2003). Minimizing the prevalence of fine sediment in the system would contribute to these aims.

Technical Merit. Fine silts and clay are easily transported downstream through tributary streams to the mainstem Illinois and Mississippi Rivers, where they settle in slow-flowing backwaters and secondary channels. In many locations these fine sediments are readily resuspended in windswept backwaters and impoundments or where boat activity disturbs the sediment. If current sediment delivery rates are maintained, sediment resuspension rates will remain high. Suspended sediment input to the river system can be accurately measured with available data on larger tributaries. While the precise upland sources and mainstem disturbance and transport dynamics of fine sediment are complex, the fate and impacts of fine sediment suspension and deposition are understood.

Practicality. Standard methods for measuring suspended sediment in water are available, and indirect measures (Secchis disk readings, turbidity meters) can be used once relations with fine sediment concentrations are established. Relevant time series data are available from the LTRMP and likely in the STORET and WATSTORE databases. Methods for reducing sediment yield from agricultural and urban lands are well-known, and estimated benefits in sediment yield per unit land are available. However, fine sediment input to the UMR – IWW is diffuse, so promoting low inputs will be difficult.

Measures. (1) Estimated annual loading from tributary discharge and water sample data; (2) Measurements from sediment traps in standardized locations; (3) Wind fetch and duration models; (4) Sediment resuspention models; (5) Substrate typing.

GEOMORPHOLOGY: Topographic Connections

Endpoint Definition. Optimize topographic connections between backwaters, floodplain, and the main channel, consistent with natural processes and variability.

Policy and Management Relevance. This statement reflects stakeholders' opinions that aquatic connections and aquatic habitat conditions just after pool closure were desirable in the context of the currently degraded managed system. Floodplain isolation is an increasingly prominent problem in a southern direction from Rock Island, Illinois. The endpoint would contribute to desired hydrologic, physical habitat, and biogeochemical aspects of backwaters, floodplain, and other off-channel water bodies.

Technical Merit. This endpoint addresses specific aspects of topographic variability that would conduct surface water between parts of the UMR – IWW ecosystem. Topographic connections are channel-like features characterized by width, depth, orientation, elevation, and adjacency to desired habitats. The spatial characteristics of the channels determine which areas are connected to the main channel at which discharges. Topographic connections include features that connect backwaters to the main channel, and the floodplain to the main channel. Such connections are necessary to maintain fluxes of water, sediment, energy, and biota among parts of the river-corridor ecosystem.

Practicality. The endpoint is practical to the extent that it is deemed affordable by stakeholders and society to restore. The endpoint is not physically sustainable without engineering intervention to dredge and maintain the topographic connecting features. The engineering techniques for dredging and excavating connections are well-known; increased topographic connections may be achieved using the same engineering techniques employed to increase topographic variability. System-wide topographic data collection has long been desired, but it has been impractical using traditional methods. More practical remote sensing tools have been tested, but their current cost at the scale of the entire UMR – IWW is prohibitive.

Measures. Progress on the endpoint requires measurement of the topographic/bathymetric change in project areas as channels are excavated combined with understanding of the magnitude and frequency of discharge that will be conducted by the channels. Evaluation will require monitored cross sections and/or continuous high-resolution bathymetric and topographic mapping related to water-surface elevations, and compared to similar early post-closure datasets (if they exist).

GEOMORPHOLOGY: Topographic Variability

Endpoint Definition. Increased topographic variability within the channel and floodplain, consistent with natural processes and variability including islands, backwaters, and floodplain ridge and swale topography.

Policy and Management Relevance. This endpoint reflects the strong belief by stakeholders that the ridge/swale topography that existed shortly after the closing of the navigation pools produced a highly desirable suite of physical habitats, including a large number of islands and backwaters. Loss of topographic variability since pool closure has been the inevitable result of pooling of the system and disturbance of the sediment budget; hence, this endpoint cannot be considered physically sustainable without human intervention. Sustainability can only be accomplished through investment in active engineering to redistribute sediment from low points to high points and to harden the topography to prevent continued deterioration and redistribution.

Technical Merit. The availability of physical aquatic habitat is controlled by hydrologic factors and topographic factors. The two combine to form the *hydroscape*, the temporal and spatial distribution of depth, velocity, and substrate. Topographic variability, including sub-aerial and sub-aqueous parts of the landscape, is a fundamental measure of the geomorphic and habitat potential of a landscape.

Practicality. The endpoint is practical to the extent that it is deemed affordable by stakeholders and society. The engineering techniques for dredging and island construction exist and are well-documented; some topographic variability may also be achieved by water-level management techniques to consolidate loose sediment in backwaters. Floodplain habitat treatments can be coordinated with channel maintenance activities.

Measures. The endpoint can be measured by comparing planform maps of the managed ecosystem with post-closure maps to evaluate island and backwater spatial characteristics. Evaluation of topographic variability in the vertical dimension will require monitored cross sections, continuous high-resolution bathymetric mapping, and/or continuous high-resolution flood-plain elevation data that can be compared to similar early post-closure datasets (if they exist). Variability can be assessed through a large number of spatial metrics.

GEOMORPHOLOGY: Rates of Bank Erosion

Endpoint Definition. Bank erosion processes that are permitted to form important micro-habitats and topographic diversity in locations where bank erosion does not threaten infrastructure or critical habitats.

Policy and Management Relevance. This endpoint addresses the concern that bank erosion leads to loss of terrestrial habitat, threatens land and infrastructure, and contributes to loss of topographic variability (i.e., island erosion). The endpoint recognizes that bank erosion is a natural process of rivers, and contributes to topographic variability and rejuvenation of aquatic and terrestrial habitats. On a highly managed river, however, bank erosion can be accelerated by riparian land use, navigation, recreational boating, and wind-driven waves, thereby threatening infrastructure and engineered habitats. The rate of bank erosion and allowable locations therefore need to be controlled to maximize contribution to ecological processes and minimize economic loss. The endpoint is highly related to policy requirements to minimize loss of private land and risk to infrastructure. The endpoint also addresses sustainability of engineered habitats like artificial islands.

Technical Merit. Bank erosion risks to infrastructure are evident. Ecological benefits of bank erosion accrue where bank erosion is balanced by deposition of new terrestrial or aquatic habitat. These sites provide for frequent hydrologic connection to vegetated areas and new sites for primary succession. Erosional sites provide steep, concave-up and overhanging banks, and deliver large woody debris to the channel. The engineering challenge is to accommodate this low level of dynamic instability within a system managed overall for stability.

Practicality. Techniques to stabilize banks using hard-rock structures are well-established; techniques to control a slow rate of bank erosion are less well-established but worth exploring. Approaches to identifying optimal sites for stabilization and bank erosion are available.

Measures. (1) Surveyed or photogrammetric maps and topographic cross sections to measure plan form erosion rates; (2) Bathymetric/topographic maps to document and evaluate topographic variability resulting from dynamic bank erosion.

HYDROLOGY & HYDRAULICS: Water Levels Below Dams

Endpoint Definition. Achieve more gradual fluctuations in water levels immediately downstream of dams caused by changes in discharge rates, gate designs, and hydropower peaking operation.

Policy and Management Relevance. Rapid fluctuations in water levels and current velocity downstream of dams often occur much faster than natural river flow changes. Rapid river flow changes impact shallow-water aquatic life, wetland and marginal plant communities, and human river uses along shorelines and in boats.

Technical Merit. Rapid water level changes in rivers downstream of dams have a significant biotic impact associated with quickly changing habitat conditions. Organisms can be trapped by fast dewatering, displaced by abrupt increases in velocities, and exposed by predation by quickly deepening water depths. Impacts caused by rapid flow fluctuations are commonly associated with hydroelectric dams but all variable release dams can cause rapid fluctuations in tailwaters.

Practicality. Rapid water level changes are often mitigated by changing gate settings gradually (ramping) and coordinating river-wide release rates to avoid the need for fast dam release changes. Dam facilities may need to be modified and automated for greater control of water release rates. Dam releases are routinely monitored by facility operators and commonly reflected in downstream river gauges.

Measures. (1) Moving variance of 15-min stage measurements at select dams; (2) Variance in river gauge measurements in downstream reaches.

HYDROLOGY & HYDRAULICS: Water Levels During Growing Season

Endpoint Definition. Provide low-water periods during the growing season to restore aquatic vegetation.

Policy and Management Relevance. This objective has been pursued in all UMR Corps of Engineers Districts in response to the following goals supported by UMR-IWW stakeholders: (1)maintain viable populations of native species in situ; and (2) represent all native ecosystem types across their natural range of variation. Although the Corps manages water levels primarily to benefit commercial navigation, the Fish and Wildlife Coordination Act (F&WCA) requires them to operate the pools as though navigation occurred year-round above Rock Island. This is colloquially referred to as the "Anti-drawdown law," and has been applied throughout the Rock Island and St. Paul Districts. It was added as an amendment to the F&WCA to protect denning furbearers and overwintering fish. At the recent request of partner agencies, the Corps has adopted experimental drawdowns within authorized pool operating bands and slightly below those bands following NEPA compliance and agency approval to enhance germination of emergent aquatic plants.

Technical Merit. Recreation or simulation of growing season stage-discharge relationships conducive to sediment exposure, oxidation, compaction, and moist soil plant germination results in increased resistance of those sediments to resuspension following inundation, thereby increasing water clarity and light penetration beneficial to aquatic plants, both submersed and emergent. Aquatic vegetation abundance and diversity are critical to the system's value to fish and migratory birds.

Practicality. Water level management is a common practice on reservoir systems and wetland management units to alter and control species composition of plant, invertebrate, and vertebrate communities beneficial to desirable wetland assemblages. It has been successfully practiced at several spatial scales on the UMR – IWW. It is also relatively easy to monitor using field and remote sensing techniques.

Measures. (1) Areal distribution of aquatic plants; (2) Species composition in plant beds.

HYDROLOGY & HYDRAULICS: Pool Stage During Winter

Endpoint Definition. For each pool, winter water surface elevation that is relatively high but practical to maintain should be identified as a target stage to improve fish habitat.

Policy and Management Relevance. Agency resource managers classified deep backwaters used by fish for overwintering as the most threatened type of habitat in the UMR – IWW in the workshop series reported by Theiling et al. (2000). Quality fish overwintering habitats are quiet waters that are deep enough to maintain adequate oxygen levels under prolonged ice cover. The accessibility of these habitats to fish in winter can be limited by ice cover in shallow channel and connecting waters. Raising winter stage will deepen both backwaters and channels, and it will also increase the volume of off-channel habitats for fish overwintering.

Technical Merit. Winter ice cover often restricts fish and water movements between the river channel, side channels, and floodplain water bodies because ice can reach 1 m in thickness. Thick ice cover also limits oxygen input to the water, and when snow-covered, there is little or no oxygen production by photosynthesis by plants and algae. With prolonged ice and snow cover, organic material decomposition can reduce dissolved oxygen levels to near zero causing direct fish mortality (known as winterkill; Theiling et al. (2000)). Maintaining water movement through side channels and connecting waters minimizes stressful water conditions under snow cover, and open water passages allow fish movements (West Consultants, Inc. 2000). Sedimentation has reduced water depths in off-channel habitats in many reaches of the UMRS, especially the southern portion of the Mississippi River and the Illinois River. High pool stage will mitigate the loss of floodplain water depths and help maintain connections.

Practicality. This endpoint is specifically defined to be practical; that is, striving for high winter water levels within a range compatible with water supplies and other river uses. The feasibility of monitoring pool stage is clear since data of this type are already being collected in a routine manner.

Measures. (1) Percent daily observations meeting a specified high stage range; (2) Average winter water stage from daily recordings.

HYDROLOGY & HYDRAULICS: Dam Operations

Endpoint Definition. Allow natural resource managers to establish target water regimes within constraints of the waterway system.

Policy and Management Relevance. Section 665a of the Fish and Wildlife Coordination Act of 1958 directs the Department of the Army "…to give full consideration and recognition to the needs of fish and other wildlife resources and their habitat dependent on such waters,…" and to operate and maintain pool levels between Rock Island, Illinois and Minneapolis, Minnesota "as though navigation was carried on throughout the year." The partner agencies on the Upper Mississippi have used various coordination forums to engage alternative water level management scenarios downstream of Rock Island as well, and in 1995 generated a fact sheet in pursuit of a Corps Continuing Authorities project to relocate the navigation control point from mid-pool to the dam at Lock and Dam 25. Inasmuch as this was a cost-shared project, the States of Missouri and Illinois, as non-Federal sponsors clearly demonstrated their support for this management activity.

Technical Merit. The Corps and its resource management agency partners seek additional flexibility in dam operations to alter aquatic habitat features and influence vegetation patterns beneficial to fish and wildlife. Approximately half of the navigation pools on the UMR – IWW are managed at a "hinge point" as opposed to a dam point. This mode of dam regulation necessitates untimely drawdowns during moderate discharges. Objectives to increase flexibility have been stated and studies have been completed to identify real estate and operational requirements to change operating modes.

Practicality. This endpoint is, in essence, a land management and policy feature, and fully within the scope of existing authorities for both navigation and resource management. Limits to implementation are real estate issues, seepage and increased drainage district pumping costs, and availability of cost share sponsors where necessary, if pursued at full federal funding.

Measures. Performance measurements for this endpoint would be: (1) Percentage of time each facility was controlled at either hinge or dam point and the acreage of selected cover types achieved; (2) Percent time that a particular function such as spawning or brood-rearing was achieved for a target organism group or community.

HABITAT: Aquatic Vegetation in Shallow Lentic Waters

Endpoint Definition. Shallow and still waters should have aquatic vegetation present in easily detectable abundance.

Policy and Management Relevance. Vegetated habitats support key ecological functions (e.g., primary productivity) and recreational resources, especially sport fishes and waterfowl populations. Clear waters, submerged aquatic plants, and benthic productivity supporting fish and waterfowl rank high in sentiments recorded in stakeholder workshops reported in DeHaan et al. (2003). Finally, absence of aquatic plants in shallow still waters will usually be associated with some form of environmental degradation such as high turbidity, unstable substrate, rapid erosion, and others.

Technical Merit. Prior to development of the navigation system, the area of vegetated aquatic water was very limited (Green 1960) and mostly restricted to the margins of backwater lakes and secondary channels. Although vegetated waters remain a minor component of the total habitat area of the UMR – IWW (Theiling et al. 2000), almost all shallow still waters should support aquatic plants. Common impediments to aquatic plant presence and growth are high turbidity from elevated sediment inputs, fine sediment deposits attributable to elevated sedimentation, wind and wave erosion caused by open impounded waters, and local eutrophication from elevated nutrient input.

Practicality. Management practices beneficial to aquatic vegetation growths are among the most common actions in the UMRS: runoff input reduction, sediment stabilization, erosion control, turbidity reduction, water level management, etc. In some locations there are also data and models to estimate the locations where aquatic plants should be able to grow. Updates of habitat status can be achieved with regular aerial photography and GIS processing.

Measures. (1) Portion of shallow lentic waters with aquatic vegetation; (2) Ratio of vegetated and unvegetated habitat in representative shallow lentic water.

HABITAT: Natural Terrestrial Habitat on Floodplain

Endpoint Definition. Through protection or restoration, provide at least one significant area of natural terrestrial floodplain habitat on each side of the main channel in each pool.

Policy and Management Relevance. Terrestrial plant communities are an important component of a large river floodplain ecosystem. As early as the 1850s, land use on the floodplains resulted in the large-scale conversion of forest, prairie, and wetland communities into agricultural lands. Prairie grasslands and hardwood forests (oaks and other mast-producing species) constituted a major portion of the valley land area along the Mississippi and Illinois Rivers. These habitat types support a high diversity of bird species, amphibian, and mammal species (West Consultants, Inc. 2000). Natural floodplain plant communities also serve as an important source of organic material for the aquatic food web at times of flood flows. Finally, natural forest and prairie areas have high recreational value of the UMR – IWW because they support direct uses such as wildlife viewing, hiking, and hunting.

Technical Merit. Prairie grasslands and forest stands were a major component of the pre-settlement floodplain landscape but they are not common today. Inundation by impoundment, alteration within leveed zones, and conversion to crops have largely eliminated natural dry and upland habitats. GIS analyses of habitat distributions in the river valleys provide good data on current locations and areas of terrestrial habitats on the floodplain. However, species compositions within these habitats can be different from natural communities (Theiling et al. 2000). Plant community types are responsive to local patterns of soil moisture and flood frequency, and the influence of competing species, especially invasive exotic plants. Analyses of pre-impoundment land cover (Theiling et al. 2000) showed a common pattern of dense floodplain forests bordering river channels and backwaters, and oak savannas and prairies between aquatic habitats and upland bluffs in much of the river system. Fire was once an important determinant of plant community composition in the more dry areas of the system.

Practicality. Restoration and management practices are available to maintain blocks of natural terrestrial plant communities. The availability of public land for plant community management and restoration varies greatly by reach and pool. However, limited blocks of natural plant communities can be developed by working with local organizations and landowners.

Measures. (1) Number of pools with at least one significant area of natural terrestrial floodplain habitat on each side of the main channel; (2) Land areas by pool with natural terrestrial vegetation.

HABITAT: Special Aquatic Sites

Endpoint Definition. Protect and restore special aquatic sites such as mud, sand, and gravel bars, and pool/riffle complexes.

Policy and Management Relevance. This objective is supported by regulatory requirements of the Clean Water Act, and represents stakeholder recognition of the habitat types necessary to support a variety of organisms and life stages. It is directly tied to the stakeholder goal to represent all native ecosystem types across their natural range of variation.

Technical Merit. Mudflats are important foraging areas for shorebirds. Sand and gravel shallows provide spawning and early life stage fish habitat. Sand or gravel islands provide critical nesting habitat for species of management concern, such as the interior least tern. The navigation system was designed to overcome pool/riffle features as navigation hazards, and they were subsequently reduced in area and abundance to ensure safe, reliable navigation.

Practicality. There is substantial evidence that these habitats can be created through common restoration practices. Monitoring changes in the areal extent of specific habitat types as landcover classes is commonplace, as is measuring temporal and spatial variability due to discharge stage.

Measures. Areal estimates of the maximum extent of and seasonal availability of special aquatic habitats.

HABITAT: Islands With Natural Habitats

Endpoint Definition. Protect, restore, or create islands.

Policy and Management Relevance. Island protection and restoration have been actively pursued through the Environmental Management Program and through the Corps' Channel Maintenance Program. A direct effect of construction and operation of the navigation system, islands were wholly submerged by impoundment or eroded away by wind and navigation-created wave action. This objective supports the stakeholder goal to represent all native ecosystem types across their natural range of variation.

Technical Merit. The prevailing principle behind island creation or restoration has been to place fill on original island alignments. Most often these features are desired in the lower ends of each pool. Island creation blocks wind and reduces sediment resuspension, thereby increasing water clarity and light penetration beneficial to aquatic plants, both submersed and emergent.

Practicality. Monitoring changes in the areal extent of specific habitat types as landcover classes is commonplace. Temporal and spatial variability due to discharge stage can be measured using hydraulic modeling or remote sensing.

Measures. Areal extent of islands and the landcover on them.

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Appendixes B-E are provided on attached CD.

14. ABSTRACT

This report summarizes the considerations and recommendations of an Environmental Science Panel that was convened in early 2003 to provide guidance to the U.S. Army Corps of Engineers and Upper Mississippi River (UMR) – Illinois Waterway (IWW) stakeholders regarding the restructured UMR – IWW System Navigation Feasibility Study. Between January and April of 2003, the Corps organized four Panel workshops to review and contribute to Navigation Study progress and to begin work on several specific tasks. Those tasks required considerations of not only procedural steps anticipated during the remainder of the Navigation Study, but also issues related to the future establishment of an adaptive management process on the UMR – IWW. At the conclusion of the workshops, the Panel made the following recommendations:

- Planning for a formal Adaptive Management approach on the UMR – IWW should be accelerated and expanded to include multiple organizations and programs.
- Ecosystem goals and objectives developed so far through stakeholder input should be clarified and integrated. A structured process for evaluation of the unavoidable trade-offs between the ecological and economic values of the system should be established.

(Continued)

15. SUBJECT TERMS

Illinois Waterway System	UMR
IWW	Upper Mississippi River System

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14. (Concluded)

- Conceptual and simulation modeling should be established as vital steps in the adaptive management process in order to:
  1) Record the current state of the system.
  2) Create a holistic “virtual” reference system.
  3) Predict system-level outcomes of alternative actions and policies.
- Management actions available for implementation on the UMR – IWW should focus on attaining goals and objectives at the system level—with appropriate attention to risk and uncertainty.
- A UMR – IWW report card system and appropriate monitoring system should be developed to evaluate system condition and attainment of objectives.
- Selected future management actions should be considered as experimental manipulations, which will achieve stated objectives, enhance ecosystem health and provide knowledge in a predictable and structured way.