MONITORING AND ADAPTIVE MANAGEMENT – A PROSPECTIVE TOOL FOR ENVIRONMENTAL MANAGEMENT

Author: Larry Canter
c/o Environmental Impact Training
PO Box 9143
Horseshoe Bay, TX 78657-9143
USA
Phone/Fax: 830.596.8804
Email: envimptr@aol.com

Co-Author: Eric Hollins
c/o Woolpert, Inc.
4141 Rosslyn Drive
Cincinnati, Ohio 45209
USA
Phone: 513.272.8300
Email: eric.hollins@woolpert.com

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Abstract

Adaptive management (AM), when accompanied by focused monitoring, can be seen as a prospective tool for water resources planning, including long-term planning for the Ohio River navigation system. Because of numerous environmental and institutional features which are conducive to AM, such a program could be used to facilitate the continued, long-term operations of the navigation system in an environmentally sustainable manner. Potential key elements of an AM program include, but are not limited to, the assemblage of information on historical and current conditions, prediction of future conditions resulting from multiple projects and uses, involvement of a spectrum of stakeholder groups, use of quantitative or qualitative models, delineation of management objectives and a range of management options, development of a scientifically-designed monitoring program, and use of a decision-making framework that is responsive to the interpretation of data and inputs from various stakeholder groups and peer advisors. In addition, collaborative agreements will be needed along with adequate budgetary and personnel resources. Regarding these key elements, several foundations for them already exist. For example, several organizations and agencies already have formal and coordinating responsibilities related to Ohio River management. Further, quantitative and qualitative models also are available, and extant or planned monitoring programs are focused on aquatic ecology, environmental mapping and assessment, mussels monitoring at multiple locations, and permit-related monitoring. Several initiating actions are needed to facilitate an AM program for the Ohio River system; they include authorization for a lead agency or organization, delineation of a stakeholder group, and allocation of collaborative funding and personnel. Follow-on implementation actions include information and data surveys, establishment of a management board and peer review committee, detailed planning for monitoring, and annual usage of a decision-making framework related to adapting the management of natural resources and/or stressor actions. Finally, integrating AM and monitoring into everyday decision-making related to the Ohio River navigation system could provide a flexible and useful tool for meeting expanding public expectations regarding ecosystem and resource sustainability.

Descriptor words: adaptive management, monitoring, cumulative effects, navigation system, stakeholder groups, and decision-making framework

Introduction

An emerging theme for strategic-level impact studies is the use of targeted monitoring and an adaptive management approach to address large-scale issues and long future timeframes that may involve both policy and scientific uncertainties. Adaptive management (AM) refers to a relatively new concept that recognizes that scientific uncertainties and unforeseen environmental changes are inevitable when long-term plans, programs, or policies are implemented in particular environmental settings. AM has been applied, or is being considered for application, in environmental management efforts related to several large-scale water resources projects and programs of the U.S. Army Corps of Engineers (Corps). For example, it is included in the Comprehensive Everglades Restoration Plan in Florida, the Upper Mississippi River Basin navigation study in the Midwest, and the Coastal Louisiana project; and it has been proposed for the Missouri River Basin ecosystem management program.

Applying AM concepts to the Ohio River system acknowledges uncertainties and offers a systematic way for the Corps, other federal agencies, and stakeholders to explore the relationships and trade-offs between river ecology, navigation, recreation and other uses. A post-ORMSS (Ohio River Mainstem Systems Study) AM program could include periodic reviews of navigation traffic relative to the Corps' traffic growth scenarios and adjustments in planned investments for lock extensions and maintenance and rehabilitation. Such a program could also include monitoring of environmental indicators and adjustments to navigation traffic management and environmental policies, as appropriate (Canter and Swor, 2004). Accordingly, AM and its incorporated monitoring emphasis represents a prospective tool for environmental management of the Ohio River system.

Included herein are sections related to the situational context for considering AM as a tool for the Ohio River system; features of the Ohio River system that are conducive to implementing an AM program; the key elements of such a program; and existing Ohio River system stakeholder groups, scientific models, and monitoring programs which could serve as a foundation for planning and implementing such a program. The penultimate section delineates several key actions which are needed to establish and implement an AM program. The final section includes the conclusions from this review.

Situational Context for AM of the Ohio River System

Although many institutional and policy factors could be identified as conducive to an AM program for the Ohio River system, two are of particular importance. The first is the increasing attention being given to monitoring and AM by the Council on Environmental Quality (CEQ). The second relates to a recent National Research Council (NRC) report which advocates the position that the Corps should more aggressively incorporate AM in water resources planning.

NEPA-Focused Encouragements

Although AM and monitoring have developed slowly and only recently begun to receive widespread attention, concepts related to this approach can be found in the original language of the National Environmental Policy Act (NEPA), which includes policy

'…to create and *maintain* conditions under which man and nature can exist in productive harmony…' (Section 101(a) of NEPA). Section 102(2) (B) calls for 'methods…which will insure that presently unquantified environmental amenities and values may be given appropriate consideration…' Section 102(2)(C) specifies that EISs (environmental impact statements) shall address 'the relationship between local short-term uses of man's environment and the *maintenance* and enhancement of long term productivity…' Finally, the CEQ is to define and *analyze* changes in the environment and interpret their causes (Section 204(6)) (NEPA, 1969; Carpenter, 1997).

The 1979 NEPA regulations of CEQ indirectly addressed elements of AM and monitoring as follows: "a monitoring and enforcement program shall be adopted and summarized where applicable for any mitigation" (Section 1505.2(c)) and "agencies may provide for monitoring to assure that their decisions are carried out and should do so in important cases" (Section 1505.3) (CEQ, 1978; Carpenter, 1997). It should be noted that the monitoring is related to mitigation measures and their implementation.

In a 1997 review of the 25-year history of NEPA, the CEQ addressed the potential for using AM in the NEPA process, concluding that a "major difficulty with the traditional environmental impact analysis process is that it is a one-time event; i.e., results from intensive research, modeling, and other computations or expert opinions are analyzed, the analysis of potential environmental impacts is prepared, mitigation measures are identified, and a document is released for public review" (CEQ, 1997b). Unfortunately, the NEPA process does not account for unanticipated changes in environmental conditions, inaccurate predictions, or subsequent information that might affect the original environmental protections. By incorporating the AM model into the NEPA process, the traditional "predict-mitigate-implement" model could be expanded to incorporate the "predict-mitigate-implement-monitor-adapt" model.

The CEQ's 1997 guidance on considering cumulative effects under NEPA highlighted monitoring and AM in the final step of an 11-step process. Specifically, when determining environmental consequences, it was noted that agencies should "…monitor the cumulative effects of the selected alternative and adapt management" (CEQ, 1997a).

The CEQ's NEPA Task Force utilized agency interviews and review of public comments in anticipation that the 1997 NEPA effectiveness study had fostered an understanding of the value of integrating AM into the NEPA process (CEQ, 2003). However, the Task Force discovered that AM was a relatively new concept for many NEPA practitioners. The 2003 study also found that some agencies had applied the term AM to programmatic impact studies, but without integrating the necessary 'monitor and adapt' components. The 2003 Task Force also concluded there was strong consensus among agencies that guidance was needed for incorporating AM into NEPA documents (CEQ, 2003). Chapters 2 through 4 of the 7-chapter report are relevant herein; namely, Chapter 2 relates to Federal and intergovernmental collaboration, Chapter 3 addresses programmatic studies, and Chapter 4 features monitoring and adaptive management. Case studies such as this one for the Ohio River system could be useful in developing such guidance.

In a NEPA-related matter, increasing attention is also being given to the implementation of Environmental Management Systems (EMS) as a follow-on to the completion of EISs or Programmatic EISs (PEISs). Monitoring and associated environmental compliance evaluations tend to be the focus of EMSs. Further, monitoring data from EMSs can be integrated into an AM program. Also, a CEQ attorney has recently provided a thorough review of the relationship between NEPA, mitigation monitoring, and EMS (Bolling, 2005).

NRC Report

The Corps recently took an initiative regarding the implementation of AM. Specifically, the Corps' requested that the NRC conduct a study based on the following charge (NRC, 2004):

> Review the Corps of Engineers' efforts in applying adaptive management concepts to project and program planning and operations, identifying adaptive management's potential and its limitations. The panel will consider the range of Corps of Engineers' responsibilities that relate to adaptive management concepts, including ecosystem restoration, flood damage reduction, and navigation enhancement. The panel will review the Corps' methods for implementing and practicing adaptive management and will identify barriers to implementing the concept. The panel will also recommend ways in which adaptive management might be usefully applied in Corps project planning and operations.

The resultant NRC report noted that AM is a multi-disciplinary, evolving concept whose core principles emphasize concepts such as uncertainty, surprise, and resilience. These concepts run counter to traditional engineering planning concepts of deterministic systems, precision, and model predictions. AM stresses the value of variability and extremes in sustaining healthy ecosystems. The Corps, on the other hand, has long sought to reduce hydrologic variability by providing reliable navigation channels, reducing high flows, and stabilizing coastal areas and beaches. Accordingly, the incorporation of AM in water resources planning will necessitate adaptive changes in operational styles, organizational accountability, and Corps guidance, staffing, and procedures.

The NRC report also identified the following opportunities for implementation of AM by the Corps (NRC, 2004):

- AM practices can be relevant and useful across a variety of scales and settings. In tracking experiences with AM, the Corps will benefit by a better understanding of the settings in which an adaptive approach—which may not always be appropriate—is merited and useful.

- AM may be particularly suited to large, complex ecosystem restoration projects, which entail large degrees of risk and uncertainty, multiple and changing objectives, and phased components. AM can be especially important in multi-phase activities, as it can promote adaptation of ends and means based on lessons learned that lead to model improvements to support future decisions.

- AM entails a spectrum of approaches. These range from "passive" programs, which focus on monitoring and evaluating outcomes from a particular policy choice, to more formal and rigorous “active” AM, which designs management actions to test competing models of system behavior so that models can be improved for future decision making. Ever-improving guidance could help provide advice concerning the degree to which AM is applicable to various types of projects. This could range from limited monitoring programs (passive) to more formal (active) AM programs with carefully-structured operational alternatives and ecosystem models.

- Although AM has been linked primarily with natural resources management, it can be used to manage other types of systems. AM concepts could thus be useful within the Corps’ navigation and flood management programs, as well as to its efforts in ecological restoration. Additionally, AM could be applicable in broader, but smaller scale settings such as small projects, infrastructure management (includes dam decommissioning), and permitting activities.

Conducive Features of the Ohio River System

The reality of changing conditions which AM recognizes is especially relevant to public works projects that are planned to last for multiple decades. For example, the Investment Plan for the navigation system on the Ohio River extends through the year 2060. Among many reasons AM is a potentially useful prospective tool for the Ohio River system are:

- The Ohio River system encompasses a large area which transcends conventional geopolitical boundaries and requires coordination among federal, state and local agencies, NGOs, etc.

- Ecological management policies and decisions should be based on integrated and scientific information that addresses multiple resources, such as that provided in the cumulative effects study for the ORMSS, rather than addressing single resources (Keiter and Adler 1998).

- AM recognizes the scientific uncertainty related to hydrodynamic and biogeochemical processes that occurs in large river systems such as the Ohio River. Accordingly, there may be opportunities to apply lessons learned from AM programs for other large river systems in the USA.

- AM does not postpone actions until enough is known, but enables learning and action despite limitations, even taking advantage of unanticipated events (Lee, 1999). Accordingly, momentum gained during the ORMSS can be a catalyst for a long-term AM program.

- AM can increase the ability to respond in a timely fashion to new information concerning the Ohio River system because stakeholders and other institutional structures are already in place.

- AM can reduce decision-making gridlock by making clear that decisions are provisional (NRC, 2002). The climate of trust developed by the Interagency

Working Group (IWG) during ORMSS meetings over several years could facilitate group decision-making in a future AM program.

- AM promotes monitoring that focuses on significant and detectable indicators of progress toward management objectives (NRC, 2004). Many indicators were identified during conduction of the ORMSS CEA; other indicators and indices are under development or are being studied by ORSANCO (Ohio River Valley Water Sanitation Commission) and other organizations.

- Because AM supersedes smaller spatial and temporal scales and individual projects, it focuses on the interconnectedness of resources, which is emphasized in the CEA study. Likewise, the holistic, multi- and interdisciplinary nature of AM would integrate the VECs (valued environmental components) used in the Ohio River study.

- AM is a useful prospective tool that accounts for the cumulative effects that occur in river basins that, like the Ohio River, are exposed to multiple stressors both from human activities and natural disturbances such as storms and floods.

- AM goes beyond piecemeal environmental mitigation to consider hydrological processes, sediment transport and other dynamics driving the river ecosystem (Light, 2001). The ORMSS CEA study has sought to integrate these processes.

- Finally, in addition to ecosystem applications, operation of existing locks and dams on the Ohio River could benefit from guidelines that incorporate AM.

Elements in an AM Program

There is no prototype for AM implementation or standard format that will assure success, because AM is context-specific. Further, the recognition and acceptance of uncertainty in AM enhances learning in ways that contribute to the uniqueness of each AM program. Nevertheless, several key elements are associated with AM, in general, and are applicable to an AM program for ORMSS (NRC, 2004; Canter and Swor, 2004; Gunderson, 1999; Light, 2001; and Walters, 1986). These key elements include:

- The assemblage of information on historical and current conditions of key indicators for environmental resources that are potentially subjected to impacts from a plan, program, or project; and the quantitative prediction or qualitative description of these anticipated impacts, along with impacts from other past, present, and reasonably foreseeable future actions (i.e., the cumulative effects), on the key indicators. Many factors should be included in the assessment and management process; examples include environmental, ecological, economic, historical, political, physical, social and cultural.

- Active involvement of a spectrum of stakeholders. Common ecological management goals should be socially defined through a collaborative vision process that involves all interested participants and that incorporates ecological, economic, and social considerations. Flexibility and commitment of stakeholders over a long timeframe are critical to the success of an AM program.

- Use of multiple quantitative models to generate hypotheses about the system under consideration. The models, however, cannot substitute for the realities of common sense and field testing. Large, complex systems, such as the Ohio River, are constantly changing and inherently uncertain with potential multiple futures.

- A range of management options linked to appropriate temporal and spatial scales. Because data rarely point to a single "best" management policy, the range of management options for each decision should be considered at the outset in light of stated objectives and models of system dynamics.

- A scientifically-designed monitoring program focused on measuring changes in key indicators of environmental resources subjected to potential cumulative effects. Monitoring should help distinguish between natural perturbations and perturbations caused by management actions.

- A strategic framework that includes periodic evaluations of the implementation of features of the Investment Plan, the monitoring data and other related policy information, and decision-making, as appropriate, relative to adapting management policies or measures for the environmental resources of concern. Through such a strategy, AM becomes an iterative process in which management objectives are regularly revisited and revised accordingly.

- Collaborative long-term agreements among pertinent federal, state, tribal, and local environmental agencies; and a program management board (or steering committee) comprised of representatives from these agencies. Given that most ecosystems and watersheds transcend conventional geopolitical boundaries, ecological management requires coordination among federal, state, tribal, and local governmental entities, as well as collaboration with other interested parties.

- Adequate budgetary and personnel resources. Given the finite nature of public funds and other resources, ecological management enables agencies to engage in careful targeting to select achievable goals and to allocate resources efficiently.

- A peer group of advisors with expertise in public policy analyses, the planning and conduction of environmental monitoring and research, and environmental decision-making.

- A commitment to continued learning.

Each of these elements will be addressed, as appropriate, in the continued development of an AM program for the Ohio River system.

Existing Foundations for Implementing an AM Program

This section highlights several extant stakeholder groups, scientific models, and monitoring programs related to the management of the Ohio River system.

Organizations with Responsibilities Related to Ohio River Management

No comprehensive entity for AM of the Ohio River system has been established, however, several organizations and agencies currently are involved in various aspects of Ohio River management. Development of the ORMSS CEA study provided opportunities to become acquainted with these organizations and their missions. To begin, the Corps is the federal agency responsible for the planning, construction, operation and maintenance of navigation structures along the Ohio River. Additionally, the role of the Corps has expanded in recent years to include ecosystem restoration. However, the Corps cannot typically carry out these projects by itself since current statutory authorities require non-federal cost sharing partners.

As part of the ORMSS, the Corps developed an IWG to help identify scientific information and provide guidance for the CEA process. The IWG consists of approximately 40 members representing the U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Environmental Protection Agency, and ORSANCO, along with several state resource agencies and NGOs. It may be appropriate for the IWG, which has coalesced over several years, to continue their involvement with the Corps by serving a similar role within an AM program. Examples of possible IWG activities include:

- Delineating and prioritizing key research needs relative to cumulative effects on environmental issues and natural resources

- Identifying scientific information on emerging issues, and

- Participating in various stages of the planning and implementation of a long-term strategy for environmental monitoring and AM for aquatic and riparian/floodplain resources.

Additional access to data and institutional knowledge is available though several IWG members who serve on the following specialized resource management teams:

- The Ohio River Fisheries Management Team (ORFMT), a group including representatives from fisheries resources agencies of the six states bordering the Ohio River. Activities of ORFMT have included coordination of state fishing regulations, development of management plans for sport fishes and species of special concern and, more recently, participation in developing an Asian carp management/control plan.

- The Ohio River Valley Ecosystem Team (ORVET) that consists of U.S. Fish and Wildlife personnel participating in eight subgroups relevant to Ohio River ecosystem management, including wetlands, migratory birds, fisheries resources, mollusks, endangered species, law enforcement, outreach, and cave/karst habitat. The ORVET has an extensive network of cooperators including universities, NGOs and state resource agencies.

Because of its long-term role in monitoring and management of the water quality of the Ohio River, ORSANCO would be important collaborator in an AM program. Since its creation in 1948 though an interstate compact aimed at controlling pollution and improving the river's water quality, ORSANCO's programs have grown to include extensive monitoring, spill prevention and detection, fish consumption and recreation advisories, TMDL (total maximum daily load) development, river cleanups and public outreach. Its multi-state governing body provides a forum for interstate issues and policies and opportunities for interactions with federal agencies and funding authorities. Other potential roles for ORSANCO will be delineated in the following subsections.

The Ohio River Basin Commission (ORBC) is another interstate group charged with coordinating and managing the water resources and related land resources of the Ohio River watershed. ORBC membership consists of gubernatorial representatives from nine participating states; the Commission also has a Citizens' Advisory Council. In addition to discussing and developing regional policies related to Ohio River resources, the ORBC seeks to encourage coordinated and cooperative actions among the participating states and federal agencies. Further, the Commission represents the interests of the Ohio River Basin before the U.S. Congress and federal agencies.

Models and Other Qualitative Tools

Computer models, various habitat indices, and other quantitative or qualitative tools are typically associated with successful AM programs. The development, evaluation, modification and eventual application of such models and tools distinguishes the directed learning characteristic of AM from the more evolutionary trial-and-error approach to ecosystem management. Further, applying these techniques to the AM process helps focus management options and identify alternatives for further evaluation and testing (Walters, 1997).

Lee (1999) and others have emphasized that an explicit baseline understanding and assumptions about an ecosystem being managed can provide a foundation for learning by AM. Such a system model helps to explain responses to management actions and to identify knowledge gaps and limits (NRC, 2004). Because cumulative effects are assessed for a spectrum of actions, and uncertainties are identified, the ORMSS CEA study, in effect, provides a model for the Ohio River system. Although qualitative in many respects, the CEA study offers future participants in an Ohio River AM program a comprehensive, integrated understanding of the VECs that comprise the river system.

It has been suggested that the "learning by doing" objectives of AM should begin with "a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies" (Walters, 1997). Such modeling can aid in problem clarification and enhanced communication among scientists, managers, and other stakeholders; policy screening to eliminate options that are most likely incapable of doing much good, because of inadequate scale or type of impact; and identification of key knowledge gaps that make model predictions suspect. In this context, the characterization of past to present conditions, current trends, and predictions of environmental sustainability for individual VECs provided by the ORMSS CEA study provides a close approximation to Walters' description of a dynamic model appropriate to an AM program.

In contrast to the ORMSS CEA study, many ecosystem and hydrological models applied to AM are numerical, and the elements and processes of a given system (e.g., river corridor) are quantitatively expressed within a computer output. However, field testing of such models is critical because model results should neither be equated with reality nor viewed in isolation from other integrating factors (NRC, 2004).

Three quantitative assessment tools with applications to AM are currently under development or evaluation for the Ohio River system. These tools, which conform to the above three aids suggested by Walters, include the following:

- NAVPAT -- Over the past 20 years, the Louisville District of the Corps has developed and refined the Navigation Predictive Analysis Technique (NAVPAT) model to assess potential incremental habitat effects of various navigation planning scenarios. The goal of NAVPAT is to provide quantitative results which can be used to assess positive or negative changes in available fish habitat quality for a specific area of a river cross-section or for an entire reach of river. In general, NAVPAT links barge tow movements to possible biological effects which result from habitat disruption. The NAVPAT model consists of four primary input components: river reach characteristics, economic scenarios, physical forces and biological species life-stage models. Similarly, the Corps is developing the Queuing Predictive Analysis Technique – QUEPAT- model to assess the environmental effects of barge tows stopping for periods of time (queuing) along nearshore areas while waiting to transit locks.

- ORFIn -- The Ohio River Fish Index (ORFIn), an index of biotic integrity developed by ORSANCO and other agencies during the past several years, is specifically tailored to the distinctive ecological characteristics of the Ohio River. The ORFIn measures 13 attributes of fish communities that either respond predictably to measures of human disturbance or reflect desirable features of the Ohio River. ORFIn is sensitive to a wide range of habitat and water quality conditions and is being used to develop numeric biological criteria for eventual incorporation into ORSANCO's Pollution Control Standards. Evaluation and refinement of ORFIn as a sustainability assessment tool will continue over the next several years.

- ORNIM -- The Ohio River Navigation Investment Model (ORNIM) is a tool specifically developed by the Corps to identify and evaluate the structural and nonstructural alternatives that yield the optimal combination of navigation capacity enhancement and nonstructural investments for the Ohio River system (Frechione and Walker, 2003). The Corps' Waterway Analysis Model (WAM), which is a lock simulation model, and ORNIM can be combined to estimate potential benefits of barge tow scheduling at Ohio River locks under ideal conditions.

<u>Monitoring Programs</u>

As mentioned earlier, for over 50 years, ORSANCO has conducted a broad range of water quality and biological monitoring activities that have documented conditions and illustrated trends. ORSANCO's current monitoring activities focus on bacterial monitoring near six major urban areas along the river, fish and macroinvertebrate monitoring, fish tissue sampling, metals sampling, detection of organics, and algae and nutrient sampling related to drinking water supplies and the development of criteria for nutrients.

Both ORSANCO and the University of Louisville are participating in the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) which includes the Ohio River. EMAP's goal is to develop the scientific understanding for translating environmental data from multiple spatial and temporal scales into assessments of current ecological conditions and forecasts of future risks to natural resources (http://www.epa.gov/emap). The development of indicators to monitor the condition of ecological resources is one of several AM concepts incorporated into EMAP. EMAP's study of the Great Rivers of the central U.S. (encompassing the Upper Mississippi, Ohio and Missouri rivers) began in July ,2004, and includes monitoring the Ohio River mainstem.

A long-term mussel monitoring protocol for the Ohio River has been developed and currently is under review by the U.S. Fish and Wildlife Service. The proposed protocol would focus on the acquisition of statistically valid and defensible data to assess the environmental sustainability of mussels over the long term. Specific monitoring objectives outlined in the protocol for multiple fixed monitoring stations for the entire Ohio River include: determine species richness of mussels; determine density of native mussels and zebra mussels; and determine recruitment of native mussels. The conceptual mussel sampling protocol is designed to yield needed trend information from sites sampled annually and to ensure data on at least a three year cycle for all other sites. Further, the proposed sampling is planned to occur within reasonable manpower and monetary constraints (USFWS 2005, unpublished).

Since the 1950's, regulated industries, including power companies, drinking water companies and industrial waste dischargers, also have conducted studies of mussels and other resources (e.g., fish, bacteria, temperature, and pH) near their facilities, often in collaboration with university researchers. Some of these studies were cited in the CEA study; further, representatives of this sector contributed to discussions on aquatic and riparian sustainability for the Ohio River. This sector will continue to perform impacts and compliance monitoring (e.g., studies related to §316(b) of the Clean Water Act) as required by their individual permits. However, the uncoordinated accrual of such data, collected to meet permit requirements, may have only marginal value to the system-wide focus of an AM program. Conversely, if organized and analyzed, such information could become a valuable data base for the AM program.

Actions Needed to Establish and Implement an AM Program

Developing and implementing an AM program for the Ohio River system could occur over time through the efforts of many stakeholders, but it would be unlikely to take place in a focused way unless several key initiating actions take place in a timely manner. These actions include:

- Authorization of an agency or organization to promulgate an AM program, provide continuity, and ultimately assume responsibility for the program's implementation

- Formation of a broadly representative stakeholder group, including members that would identify and conduct monitoring and other tasks and would be capable of recommending management adaptations in response to monitoring outcomes and other data, and

- Allocation of collaborative funding and personnel to institute and sustain the AM program over a test period of several years

Following the receipt of authorization and funding, and assuming that the lead agency or organization has formed a stakeholder group, efforts could be directed toward specific planning and implementation. Examples of these efforts include:

- Conduction of a comprehensive survey of existing databases and information related to selected VECs; e.g., aquatic and riparian habitats

- Establishment of a management board for the AM program, with the board comprised of responsible officials from several governmental agencies

- Development of the management objectives for the AM program, with such objectives reviewed by the management board and stakeholder group

- Establishment of an external peer review committee to examine the scientific and policy features of the AM program

- Delineation of specific questions to be addressed, and monitoring to be conducted, for the initial period (e.g., 2 to 5 years) of the AM program, with the questions and monitoring plans reviewed by the management board, stakeholder group, and external peer review committee

- Over the initial implementation period, conduct the monitoring, review and interpret the collected data in the context of historical information and management objectives, and adapt actions or policies as necessary. Dissemination of the findings should be accomplished via annual reports; and inputs relative to adaptive management should be sought from the external peer review committee, stakeholder group, and management board

Conclusions

Due to current NEPA-focused encouragements by CEQ, and the recommendations of a NRC study commissioned to evaluate AM as a prospective tool for water resources planning, it is timely for the Corps to seriously consider the establishment of an AM program for the Ohio River navigation system. Such a program would facilitate the continued, long-term operations of the navigation system in an environmentally sustainable manner. The environmental conditions and institutional arrangements associated with the Ohio River are particularly conducive to an AM program. For example, from an environmental perspective, the river system encompasses a large geographical area, contains numerous aquatic and riparian resources, and is subject to multiple stresses from both natural variabilities and societal projects. Institutional arrangements include multiple Federal and state agencies with overlapping and possibly competing interests, particularly with regard to uses of the river.

Potential key elements of an AM program for the Ohio River system include, but are not limited to, the assemblage of information on historical and current conditions, prediction of future conditions resulting from multiple projects and uses, involvement of a spectrum of stakeholder groups, use of quantitative or qualitative models, delineation of management objectives and a range of management options, development of a scientifically-designed monitoring program, and a decision-making framework that is responsive to the interpretation of data and inputs from various stakeholder groups and peer advisors. In addition, collaborative agreements will be needed along with adequate budgetary and personnel resources. Regarding these key elements, several foundations for them already exist. For example, several organizations and agencies already have formal and coordinating responsibilities related to Ohio River management; they include the Corps, the Interagency Working Group (including state resource agencies), the Fisheries Management Team, the Ohio River Valley Ecosystem Team, the Ohio River Valley Water Sanitation Commission (ORSANCO), and the Ohio River Basin Commission. Quantitative and qualitative models also are available, including the ORMSS CEA study, NAVPAT, QUEPAT, ORFIn, and ORNIM. Finally, extant or planned monitoring programs include the aquatic ecology program of ORSANCO, the USEPA's EMAP initiative, the USFWS's efforts to establish a mussel monitoring protocol at multiple locations, and permit-related monitoring by industries and municipalities.

Several initiating actions are needed to facilitate an AM program for the Ohio River system; they include authorization for a lead agency or organization, delineation of a stakeholder group, and allocation of collaborative funding and personnel. Follow-on implementation actions include the conduction of appropriate information and data surveys, establishment of a management board and external peer review committee, detailed planning for a focused monitoring program, and the establishment and annual usage of a decision-making framework related to adapting the management of natural resources and/or stressor actions. Finally, it is noted that integrating AM and monitoring into the everyday planning and operation of the Ohio River navigation system could provide a prospective tool that the Corps could use in meeting expanding public expectations regarding ecosystem and resource sustainability.

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