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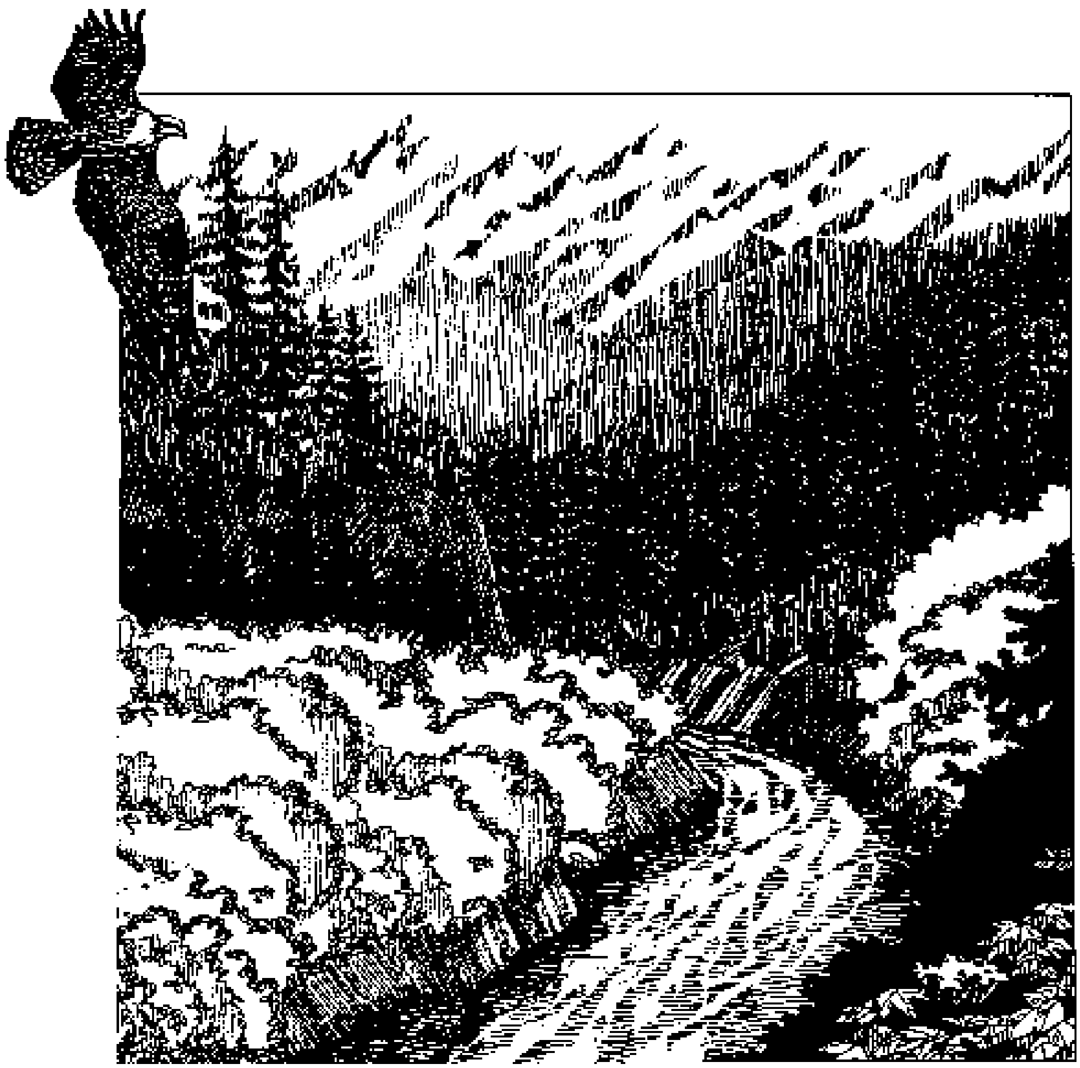
Risk Management Research Plan for Ecosystem Restoration in Watersheds



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Risk Management Research Plan for Ecosystem Restoration in Watersheds

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet these mandates, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Clinton W. Hall, Director
Subsurface Protection and Remediation Division
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EXECUTIVE SUMMARY

This document outlines the scope of the National Risk Management Research Laboratory's (NRMRL) risk management research in the area of ecosystem restoration. NRMRL is uniquely positioned to make substantial contributions to ecosystem science because of its in-house expertise relative to surface, subsurface, atmospheric, and hydrologic systems. These systems are the substrata for biotic interactions, particularly relative to higher plants and animals. Therefore, the data, expertise, and systems approaches currently available are necessary precursors to ecosystem restoration research. Also, subsurface, atmospheric, and hydrologic systems are frequently discounted within ecological studies. Thus, modest efforts to integrate ecological measurements with NRMRL's surface, subsurface, atmospheric, and hydrologic data promises to provide significant advances.

NRMRL's involvement in ecosystem research is keyed to water resources and land use because the Clean Water Act provides the goals of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. Therefore, effects on water quality and watershed land use that impact aquatic resources are of foremost concern. As a society we are confronted by a suite of environmental problems that are large-scale, persistent, and resistant to cost-effective remedy by current technologies. An excellent example is nonpoint pollution. Despite notable success at controlling pollution from point sources, substantial water-quality problems persist because of non-point source problems. Also, there is a strong tendency for research to be conducted within specialties, at local sites, on short time-lines. Despite detailed knowledge in many fields that bear upon ecosystems, our understanding of ecosystems as a whole is poor. This is because the discipline, site, and time-frame specific nature of our knowledge leads to spatial and temporal uncertainty. Ecosystems are complex, involving interacting biotic and abiotic elements over large spatial and temporal scales. Ecosystems can only be understood in the context of these interactions.

For the two foregoing reasons, a need for improved understanding of ecosystem processes is indicated. From this understanding, new and cost-effective approaches to ecosystem restoration and management can be developed. NRMRL's in-place competencies complement research already being conducted relative to ecosystem management that is primarily biological and ecological in nature. NRMRL activities in this developing research area can be best applied through interdisciplinary research, incorporating NRMRL's strengths in physical and chemical research with a developing ecological expertise.

Research conducted under this initiative will develop risk management based decision support systems and tools for ecosystem restoration. Systems and tools will be developed with quantified levels of spatial and temporal uncertainty. Finally, the systems and tools will be designed for use by local stakeholders for application in local restoration initiatives.

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RISK MANAGEMENT RESEARCH PLAN FOR ECOSYSTEM RESTORATION IN WATERSHEDS

Overview

Research planning for the Environmental Protection Agency's (EPA) Office of Research and Development (ORD) is divided into two groups: Human Health Protection and Ecosystem Protection. This plan is one component of the Ecosystem Protection group. It follows the risk paradigm described in the ORD Research Strategy (U.S. EPA, 1996a) that governs all ORD research. It is related to other research within the Ecosystem Protection group in wet weather flows (U.S. EPA, 1996b), contaminated sediment, and wetlands (U.S. EPA, 1992a). Other ORD laboratories specializing in effects, exposure and assessment conduct research related to ecosystem restoration.

This plan describes the scope of ecosystem restoration risk management research in watersheds to be conducted by the National Risk Management Research Laboratory (NRMRL). The research is intended to produce technically sound restoration and decision support tools for local communities and stakeholders. The plan's scope is limited to NRMRL activities.

NRMRL research in the area of ecosystem restoration is guided inpart by a need to meet performance measures specified in the Government Performance Results Act of 1993 (GPRA). This legislation specifies three objectives for Office of Research and Development (ORD) ecosystem restoration research:

- By 2002, provide cost-effective and reliable approaches for restoring riparian zones within watersheds.
- By 2004, provide diagnostic tools and models for assessing feasibility, priorities, and measures of success for watershed restoration projects and issue guidance on the application of the tools and models.
- By 2008, complete three pilot restoration projects for developed and partially developed watersheds with different endpoints of societal value.

The guidance for research conducted under this research plan should be interpreted in light of these objectives.

This plan places special emphasis on ecosystem problems in developing multi-use landscapes often associated with fringe-cities and coastal/estuarine sites. The plan's research focus will take advantage of NRMRL's competencies by concentrating on water resources and changing patterns of land use.

Research conducted under this plan will require substantial inter- and intra-agency collaboration. Agreement in concept has been reached that this program will be conducted in full partnership with other ORD laboratories and the EPA Office of Water (OW).

Opportunities for NRMRL Staff

Risk management in ecosystem restoration provides a new challenge to NRMRL research and technical staff, in addition to new opportunities. Some of these challenges are best addressed through re-training, both organized and informal. Others require a new outlook to uncover applications for existing expertise and experience, such as using ecosystem function or ecotoxicology as measures of ecosystem health instead of statutory human health based endpoints, or development of integrated media focused outputs. As recent efforts dedicated to defining alternative endpoints and in the area of groundwater/surface water interactions indicate, the ability to respond to this type of challenge is present at NRMRL. The NRMRL research group represents EPA's core of experts in areas such as subsurface processes, remediation technologies, process model development, and engineered risk reduction technologies. This grounding in basic processes is the foundation needed to develop valid and appropriate approaches to ecosystem management.

Ecosystem management, including ecosystem restoration activities, needs to be implemented through a system management approach. NRMRL's risk management expertise is well suited to this need. NRMRL's current and past role in risk management/risk reduction makes it the ideal choice as EPA's lead organization for developing risk management in ecosystem restoration as a research program. NRMRL's experience with systems engineering and systems approaches to problems will allow it to make significant contributions in the ecosystem management area, particularly in developing the tools needed by ecosystem managers and stakeholders to make risk based restoration decisions. These tools are decision support systems, restoration technologies and implementation protocols, watershed hydraulic models, ground water/surface water interaction models, and information databases. NRMRL is experienced in all of these areas.

NRMRL's skills, as noted above, are well suited (and needed) in the area of ecosystem restoration. For many, this new research area only requires a fresh outlook and commitment to recognize the opportunities it represents. Ecosystem management and ecosystem restoration are new, developing areas within EPA, ORD, and the environmental research community. The recent Stream Restoration Handbook (U.S. EPA, 1997a) provides important information that many NRMRL researchers will find useful in this research area.

Introduction to the Research Topic

Ecosystem management, restoration, and the concept of sustainability have moved to the forefront of both scientific and policy debates (i.e., Boyce and Haney, 1997). Many points remain unresolved, but it is clear that this attention represents a significant reexamination of land and natural resource management practices and policy. Further, uncertainty must be reduced if ecosystem management, and thus restoration is to be successful (Haney and Boyce, 1997).

The tasks outlined for the United States Environmental Protection Agency under ecosystem protection are to ensure public health and environmental protection for sustainable development. These tasks are frequently based on specific legislative mandates. Ecosystem protection is a national environmental goal (U.S. EPA, 1994). The Office of Research and Development established a strategic goal to "... develop and provide risk management alternatives to maintain and/or restore ecosystems ..." (U.S. EPA, 1996a). Risk management governs all ORD research (U.S. EPA, 1996a).

Systematic risk management research for ecosystems as described in this document has not been a focus of ORD planning. However, risk management is a concept that has antecedents within ORD. For instance, point source permitting under the Clean Water Act is based upon risk reduction. Also, Best Management Practices are directed towards improved water quality within watersheds. These antecedents are characterized by a focus on identification and control of point source emissions. Success has been focused upon reduced concentrations of chemical stressors (U.S. EPA, 1992b).

Increasingly, ecosystems are at risk from other types of stressors. Abiotic factors involving changing patterns of land use and hydrology interact with biotic factors involving interspecific competition, non-native species, and an expanding human population to produce impaired ecosystems (Hunter, Jr., 1996). Large-scale rapid-change is occurring at rates in excess of nature's adaptive ability (Woodwell, 1992).

Accordingly, research conducted under this plan (i.e., Risk Management Research Plan for Ecosystem Restoration in Watersheds [RMER]) by NRMRL will develop tools and practices for implementation by stakeholders and managers in local restoration initiatives. NRMRL's existing programs in pollution prevention, technology development, and water resources management address aspects of ecosystem management. Research conducted under RMER will build upon these competencies by taking a wider view, incorporating watersheds and their biota. To expand and complement NRMRL's historic focus on point source stressors, sustainability (Christensen et al., 1996) relative to water resources and changing patterns of land use will be the organizing principle.

Ecosystems are definition sensitive. Likens (1992) described an ecosystem as "... a spatially explicit unit of earth that includes all of the organisms, along with all components of the abiotic environment ...". Ecosystem function includes biota interacting with each other and abiotic conditions to produce a pattern of energy flow leading to characteristic trophic structures, biodiversity, and material cycles. Sustainability of ecosystems results from preservation of trophic structure, biodiversity, and material cycles (Christensen et al., 1996). Conversely, damage or impairment results from changes to trophic relationships, biodiversity, and material cycling (Cairns, 1982, 1988; Magnuson et al., 1980). Restoration/rehabilitation involves manipulation (broadly defined, including preservation) of the aforementioned to produce desirable outcomes. Risk management in this context seeks to quantify the level of certainty associated with manipulations toward producing desirable outcomes.

Definitions - Ecosystem Restoration

A rich vocabulary has developed within the science of ecosystem management. Variously, *restoration*, *remediation* and/or *rehabilitation* toward a *desirable future condition* are used to distinguish variations on the restoration theme. All assume that a restoration (action) will remedy an identified problem (Figure 1). Typically, all assume that restorative manipulations will be conducted and are beneficial. Restorations are frequently intended to restore initial conditions of structure and function (National Research Council, 1992). Relative to ecosystem restoration, the science of risk management is distinguished from restoration per se because risk management does not accept these assumptions. Rather, the science of risk management assesses the appropriateness of the assumptions and their application based on current knowledge and ongoing assessment of implemented restorative manipulations.

Broadly stated, a full suite of outcomes and actions are possible for any given site ranging from continued degradation (inaction), to unaided recovery (secondary succession), to restoration to a desirable condition (rehabilitation), or to restoration to initial conditions (restoration)

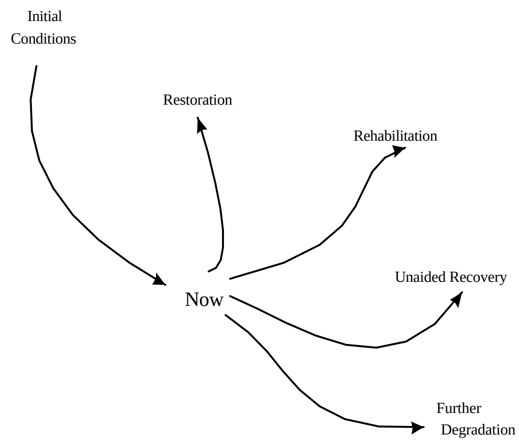

Figure 1. The science of ecosystem management has developed a rich vocabulary. This figure, modified from Magnuson et al., 1980 and Cairns, 1982, illustrates how *restoration*, *rehabilitation*, and *unaided recovery* have been used to distinguish variations on the restoration theme. All assume that a restoration (action) will remedy an identified problem. Restorations are frequently intended to restore initial conditions of structure and function.

(Figure 1). Rehabilitation and restoration involve application of planned restorative manipulations in an effort to direct recovery to a desired condition. A stakeholder defined *Desirable Future Condition* (DFC) could include any of these possibilities. The science of risk management can quantify the risk to biological, social, and economic systems posed by competing outcomes.

Restoration includes a widerange of potential activities including continued inaction, unaided recovery, or implementation of multiple restorative manipulations. In the best case, restorative manipulations are agreed to by stakeholders to produce a DFC. In reality, DFCs are only statements of intent. Ecosystems are dynamic and single sites are always strongly influenced by stochastic processes (Christensen et al., 1996).

Restoration is not a deterministic process. Multiple outcomes are possible and any potential outcome is a function of probability resulting from interacting initial conditions and restorative manipulations. At least in the near-term, restorations hold little promise of resembling native ecosystems (Kentula, 1994). The science of risk management can quantify levels of certainty relative to a full array of potential outcomes that could result from restorative manipulations.

Ecosystem restoration in a risk management context is the science of quantifying the risks, rewards, and levels of certainty associated with the full range of potential outcomes resultant from changes (both intended and unintended) to the landscape caused by land use and to functional connections between habitats, flora, and fauna within the ecosystem.

Research Orientation

Spatial and temporal-scales are critical aspects of ecosystem management. Boundaries defined for the study or management of one process are often inappropriate for the study of others (Wali, 1992; Christensen et al., 1996).

Although notable progress has been made in controlling many aspects of water quality and pollution prevention from point sources (U.S. EPA, 1995a), substantial water quality problems persist (U.S. EPA, 1984, 1995b; Smith et al., 1987; Baker, 1992). From an ecosystem perspective, this can be explained on the basis that surface and ground water receive inputs from entire landscapes including large areas that are not impacted by point source controls. In such circumstances, management of point sources may not enable further progress toward a realization of fishable and swimmable conditions in waters that are adversely impacted by nonpoint pollution.

Many current environmental problems are caused by a lack of concordance between the spatial-scale of resource demands (landscape-scale) (Franklin, 1997) and the spatial-scale of restoration and management efforts (local sites). Many current problems with water quality are the result of multiple land use changes; the net result has been that water is no longer buffered from upland regions (Loucks, 1992; Mitsch, 1992; van der Valk and Jolly, 1992). Therefore, at ecosystem spatial-scales we observe symptoms that are emergent properties of deeper causes. Notable examples include widespread eutrophication, red-tide, and the de-oxygenated zone in the Gulf of Mexico. Further, problems and symptoms are not confined to water: deforestation contributes to global warming (Woodwell, 1992), and deposition of atmospheric nitrogen contributes to forest decline through acid rain (Baker, 1992). Frequently, management has been focused on water per se, manifested in lakes, rivers, and wetlands with little regard to the surrounding ecological and hydrologic landscape context (National Research Council, 1992) that are source areas for much of the water in these ecosystems.

There is an overwhelming predisposition toward classification in all aspects of human affairs. In this regard, landscape units (e.g., parks, lakes, fields, wetlands) are viewed as stand-alone entities. Clearly, landscape units are not isolated (Risser, 1992; Loucks, 1992); rather, they are interactive. Scant regard has been placed on the connections between landscape units and the spatial and temporal-scales over which they operate.

To further cloud the issue, there are temporal elements to these problems. Sedimentation may not be a problem when it occurs as a result of an extreme precipitation event. This is a one time event that mimics conditions under which aquatic organisms evolved. Similarly, small amounts of sedimentation do not appear at first glance to be a problem. However, when sediment accumulates over decades in ecosystems that are not adapted to it, cumulative effects result. A failure to understand the importance of dynamics, particularly of disturbance, in ecosystems supports a tendency for object-oriented management objectives (e.g., single species, individual park) (Agee and Johnson, 1988) to the detriment of function and surrounding landscapes.

Ideally, ecosystem restoration research is conducted over large areas and long time-scales with connections to multiple ecosystem elements. In practice, these ideals are almost never met (Christensen et al., 1996) (Figure 2). By way of comparison, historically the focus of NRMRL research has been to collect detailed information at local sites over short to moderate time frames.

Clearly, there are frequently programmatic constraints that limit the length of time over which research can be conducted. In the case of RMER, projects can be funded for up to three years. This is not long-term in most ecosystem contexts. However, the program does provide latitude for the conduct of longer-term research than is typical for NRMRL.

The goal of RMER is to refocus a portion of NRMRL's research goals in three ways. First, include connections to multiple ecosystem components, including plants and animals. Second, incorporate larger spatial-scales through studies involving multiple sites and through integration of site characteristics with those of the surrounding landscape. Third, favor longer-term investigations when appropriate to hypotheses and studies with quantifiable temporal elements (Figure 2).

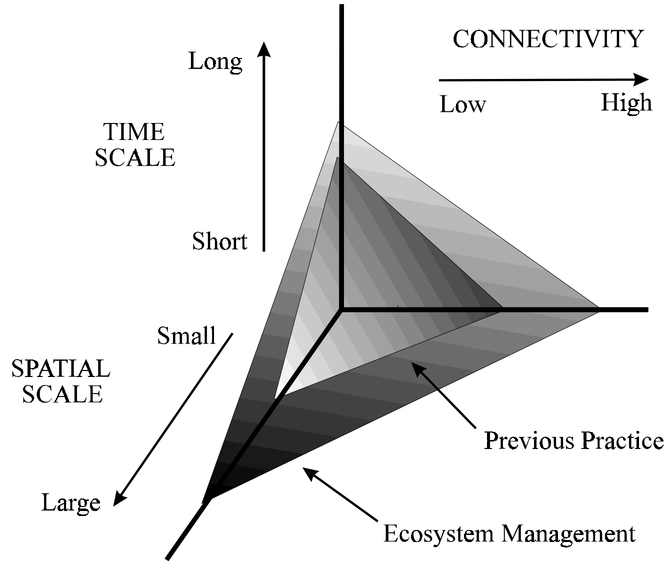

Figure 2. Previous NRMRL practice has been to conduct studies at single sites (small spatial-scale), focused on contaminants (low connectivity to other ecosystem elements), with minimal field time (short time-scale). Ecosystem management requires that attention be given to site connections to adjacent areas (larger spatial-scales), connections to plants and animals (connections to multiple ecosystem elements), over time frames sufficient to capture temporal variation (longer time-scales).

Expectations

There is a desire to restore degraded ecosystems. However, ecosystems are complex, resulting from a unique confluence of biotic, abiotic, historic, societal, and developmental conditions interacting to produce a current condition. Thus, it is expected that simultaneous, incremental improvements along these fronts will produce both short and long-term benefits. Further, the complexity of ecosystems dictates that in-place expertise can best be applied by integrating biotic and landscape-scale research objectives and data with the substantial in-house abiotic expertise found within NRMRL. Finally, it is expected that some failures will occur. Ultimately, these failures will aid development of strategies that can be implemented with known levels of uncertainty.

Areas of Priority Interest

NRMRL's interest in ecosystem restoration research is guided inpart by the need to meet GPRA performance measures. To reiterate, these measures include:

- By 2002, provide cost-effective and reliable approaches for restoring riparian zones within watersheds.
- By 2004, provide diagnostic tools and models for assessing feasibility, priorities, and measures of success for watershed restoration projects and issue guidance on the application of the tools and models.
- By 2008, complete three pilot restoration projects for developed and partially developed watersheds with different endpoints of societal value.

Five strategies address RMER research needs as dictated by GPRA: 1) identifying threatened ecosystems, 2) defining environmental goals and indicators, 3) developing and implementing science based plans, 4) measuring progress and adapting management to new information, 5) identifying tools and support that EPA can provide at the national level (U.S. EPA, 1994). Particularly as these strategies pertain to protection, maintenance, and restoration of lands and waters (U.S. EPA, 1994).

More specifically, ORD and NRMRL have identified the following areas of known interest.

1) Nonpoint source pollutants, including atmospheric deposition;
2) Ecosystem degradation by stressors associated with land use change;
3) Restoration of ecosystems impacted by contaminated sediment, soil, or water; and,
4) Restoration oriented research.

The performance measures specified by GPRA and concepts of ecosystem management and sustainability, when coupled to these areas of interest broadly define the scope of work to be conducted under RMER.

NRMRL's resources can best be applied to complement the efforts of other Federal and state agencies. Thus, lacking indications to the contrary, NRMRL chooses to focus research on multi-use landscapes most commonly associated with suburban fringe-cities associated with most developing metropolitan areas (e.g, Fairfax County, VA) and coastal/estuarine sites. Research into single-use forest or agricultural landscapes is not a priority under RMER, although it is acknowledged such landscapes are appropriate for some hypotheses, such as baseline data.

Regulatory and Policy Background

EPA's ecosystem protection role is based upon a need to meet performance measures specified under GPRA, including:

- By 2002, provide cost-effective and reliable approaches for restoring riparian zones within watersheds.
- By 2004, provide diagnostic tools and models for assessing feasibility, priorities, and measures of success for watershed restoration projects and issue guidance on the application of the tools and models.
- By 2008, complete three pilot restoration projects for developed and partially developed watersheds with different endpoints of societal value.

Further, EPA has a broad mandate to ensure public health and environmental protection for sustainable development. In 1994, EPA released a five-year strategic plan listing ecosystem protection as a national environmental goal (U.S. EPA, 1994). The strategies identified for pursuing this goal included 1) identifying stressed or threatened ecosystems, 2) defining environmental goals and indicators, 3) developing and implementing a plan based on sound science, 4) measuring progress and adapting management to new information, and 5) identifying tools and support that EPA can provide at the national level. Finally, EPA identified the overarching goal for ecosystem protection during the next five years as "... ability to protect, maintain, and restore the ecological integrity of the nation's lands and waters, including human health, urban areas, and plant and animal species ...". The Office of Research and Development (ORD) established a strategic goal (U.S. EPA, 1994) to "... develop and provide risk management alternatives to maintain and/or restore ecosystems ...".

The current set of EPA regulatory, oversight, and policy instruments include chemical-specific regulation via registration, control and classification of processes, as well as discharge and use permits that require compliance with ecological criteria (e.g., CWA); technology based requirements for specific pollutant sources and constituents as point and nonpoint sources (e.g., CWA); policy initiatives often in concert with other international, Federal, or state agencies; review and approval of environmental impact statements for federal projects (NEPA); and site remediation as part of mandated cleanup programs (RCRA & CERCLA). Under these programs, EPA has risk management, regulatory, and advocacy mandates to reduce or otherwise manage stressor levels, provide oversight and review to environmental impact and development activities, conduct remediation, and to adapt strategies in the face of new information.

Research Questions:

Water and Land Use as Focal Points for Ecosystems

As noted in the previous section, water resources and changing patterns of land use will be the organizing themes for research conducted under RMER. This does not merely mean impacts relative to chemical stressors.

Water is a quantifiable source and product of every ecosystem. Water impacts uplands as well as wetlands. Water has well-understood and quantifiable characteristics relative to transport and chemistry. Even the amount of water flowing is a characteristic of water resources. The interactions of many of these characteristics with biota are comparatively well understood. NRMRL recognizes that ecosystems are composed of more than biota and abiotic conditions interacting with water. Nonetheless, our knowledge of water provides a good starting point for NRMRL ecosystem restoration research.

Changing patterns of land use, especially habitat alteration, historically has been the leading cause of species and ecosystem decline. These patterns continue, even in the United States. Wildlife management has enjoyed great success with some species, returning them from near extinction. Given this precedent, it is reasonable to expect that management techniques can be developed that will benefit ecosystems and their component species in response to changing patterns of land use.

Research Questions

Importantly, RMER is not a vehicle for funding or otherwise underwriting restoration activities unless these activities are required for research purposes. Research activities conducted under RMER will be directed toward development of high quality tools for application by local stakeholders. Examples of appropriate tools under RMER include tools for biotic or abiotic manipulations of the landscape or tools as data-based decision support systems. Thus, the key research questions are:

1) How can we improve the known bounds of applicability for restorative manipulations?
2) How can we improve decision support systems for state and community planners to facilitate decisions, with known levels of certainty and cost, for evaluating probable outcomes of competing restoration alternatives on biota and abiotic conditions?

3) How can we improve protocols (with estimates of uncertainty) for measuring and predicting quantitative diagnoses of ecosystem structure and function as indicators of ecosystem restoration effectiveness and appropriateness?

Finally, tools developed under RMER should have applicability to GPRA performance measures.

Statement of Appropriate Subject Matter

Research projects should address performance measures specified in GPRA in the context of ecosystem management as designated in *The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management* (Christensen et al., 1996), *An SAB Report: Ecosystem Management; Imperative for a Dynamic World* (U.S. EPA, 1995b), or this research plan (RMER).

Research must demonstrate both connectivity between multiple ecosystem elements and an understanding of risk management. Connections between multiple ecosystem elements need to be more than superficial. For instance, is effort equally split between ecosystem elements, or does 90% of the activity go to one element while 10% goes to the other? Similarly, contaminants themselves are single features of ecosystems. A showing of contaminant reduction alone does not demonstrate connectivity. Moreover, a demonstration of contaminant reduction is but one part of risk management. Risk management is a larger subject matter.

Generally, field research is preferred. Ecosystem management involves key aspects of spatial and temporal uncertainty (Christensen et al., 1996). Reduction of these uncertainties is an important element of ecosystem research and, ultimately, restoration. Field studies with statistical control of spatial and temporal variation are the best means for improving our understanding of these uncertainties.

NRMRL's competencies are heavily weighted toward physical, abiotic, and microbiological functions. Although NRMRL acknowledges that ecosystems are complex and can be characterized by many metrics, NRMRL's competencies are focused. NRMRL's resources can best be applied in a directed research program focused on a few aspects of ecosystem health that are directly related to these competencies. Therefore, the focus of RMER will be water resources and changing patterns of land use. Multiple metrics impact these areas of focus, thus a wide breadth of research is enabled. However, all studies must have definable connections to water resources or changing patterns of land use.

Additionally, NRMRL's competencies tend to be site specific whereas ecosystem problems tend to be the result of widespread, landscape-scale activities. Therefore, ecosystem restoration research must account for landscape-scale. Research should focus on solutions to problems that are impacting ecosystems and not merely single sites, contaminants, or individual components of ecosystems.

Research Approach

Ecosystem restoration is a very large, integrative, and inclusive field. There are multiple projects that could be conducted under ecosystem restoration. Thus, to list or discuss specific hypothetical examples is pointless, for 100 examples go unmentioned for each one discussed. Therefore, we choose to develop the conceptual boundaries for RMER projects. However, project summaries from funded FY97 RMER projects are provided in Appendix A of this document. These summaries are provided as actual (non-hypothetical) examples and in no way should be construed to define the bounds of future research conducted under RMER.

Research activities conducted under RMER will be directed toward meeting GPRA performance criteria through development of high quality tools for application by local stakeholders. Examples of appropriate tools under RMER include tools for biotic or abiotic manipulations of the landscape or tools as data-based decision support systems. Thus, the key research areas are:

1) Improved restoration practices, with known bounds of applicability, for restorative manipulations.
2) Improved decision support systems for state and community planners to facilitate decisions with known levels of certainty and cost for evaluating probable outcomes of competing restoration alternatives on biota and abiotic conditions.
3) Improved protocols (with estimates of uncertainty) for quantitative diagnoses of ecosystem structure and function as indicators of ecosystem restoration effectiveness and appropriateness.

In all cases, the requirement for high quality demands that several aspects of uncertainty be addressed.

Ecosystems are definition sensitive. Therefore, proposed research needs to explicitly identify the spatial and temporal-scales under investigation. Further, upon project completion the limits (boundaries and effects) of tool applicability must be identified. Explicit identification of the population under investigation is crucial. For instance, data from a single constructed wetland cannot be extrapolated to other constructed wetlands, even similar ones nearby, with any known level of certainty: effects obtained from data from Chesapeake Bay cannot be extrapolated to the Red River with any known level of certainty. Nonetheless, experience gained in one ecosystem can provide deductive insights (Romesburg, 1981) into other ecosystems that are valuable to society. Further, ecosystem research does not mean that only large, landscape-scale research can be conducted. Research can be conducted at all-scales, however, explicit connections to other ecosystem elements should be identified (Christensen et al. 1996).

Cooperation

NRMRL, in cooperation with other ORD laboratories and OW, will focus on developing restoration techniques and data-based decision support systems to enable informed ecosystem management decisions by local stakeholders and managers. Anticipated clients are state and local stakeholders and managers. Partnerships with ongoing restorations initiated by stakeholders and on-site managers are encouraged. Research projects should be field-oriented and be designed with appropriate spatial replication.

The RMER program will benefit from cooperation with other relevant NRMRL programs, labs, and the Program Office. It is expected that improved cooperation will result from the recent reorganization. Further, the interdisciplinary nature of the research area will require collaborative activities.

Ecosystem restoration begins with identification of a problem that is associated with a current condition. Insights into the current condition, and future conditions, can be gained from many disciplines (Figure 3). RMER defines the problem as a host of concerns related to water resources and changing patterns of land use. The current condition is the product of interacting biotic and abiotic factors (Figure 3). For any given site, a number of future conditions are possible depending upon the result of biotic and abiotic interactions through succession (Figure 3) and the input of many disciplines is needed to provide a succesful outcome.

Within NRMRL, many opportunities for research and management are apparent.

1) What is the nature of the interactions in the current condition?
2) How many potential future conditions are possible, given the current condition? What conditions are not possible?
3) What are the natures of the biotic and abiotic interactions that lead to each potential future condition?
4) How can biotic and abiotic interactions be modified to produce a different future condition?
5) What costs relative to restorative manipulations are associated with management towards the future conditions?
6) What are the characteristics of the successional pathways leading toward each future condition?

Ecosystems are complex and involve the interaction of multiple biotic and abiotic processes. Thus, it is expected that a majority of successful projects will be comprised of teams of cooperating researchers each

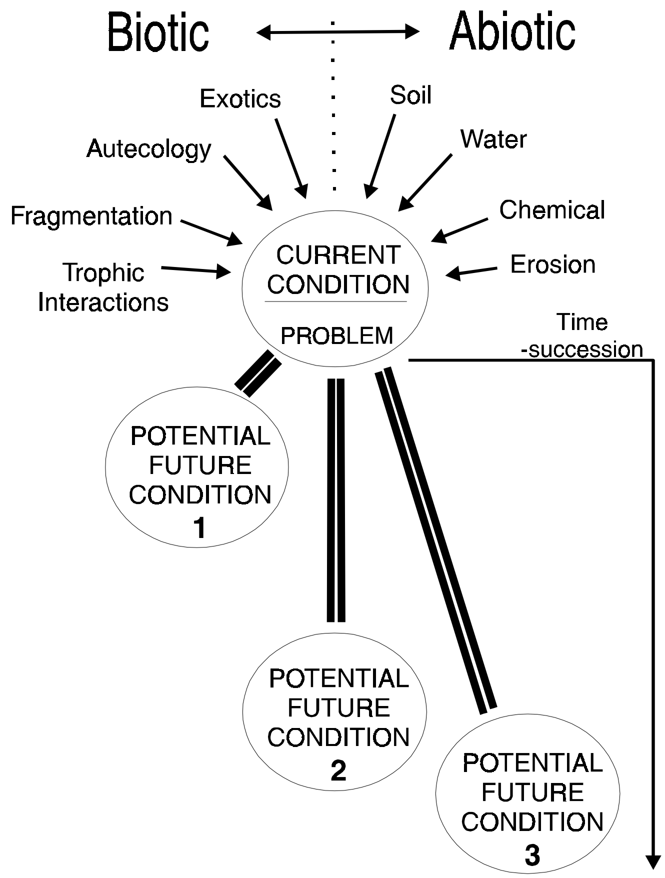

Figure 3. Ecosystem restoration focuses on identified problems. Biotic and abiotic factors have contributed to the current condition. Manipulation of biotic and abiotic factors through restoration leads to future conditions, interacting with succession. Future conditions are time-specific as succession is a continuous process.

contributing the insights of their specialty to the planning and outcome.

ORD labs can participate in RMER at a variety of levels. Areas include functional, structural, process, and systems-related interactions between biotic and abiotic ecosystem constituents relative to habitat, competition, chemistry, hydrology, geomorphology, spatial and temporal-scale. Potential cooperating ORD labs include National Exposure Research Laboratory (NERL), National Center for Exposure Assessment (NCEA), and National Health & Environmental Effects Research Laboratory (NHEERL).

Other federal and state agencies have expertise that NRMRL can apply to ecosystem restoration. It is recognized that a substantial amount of research is conducted by universities.

ORD Labs

As noted, RMER will benefit from interactions with other organizations performing effects, exposure, and assessment research related to ecological processes. Within EPA, this work is conducted by other ORD Laboratories in the context of ecosystem protection (U.S. EPA, 1997b). Research conducted under RMER will be related to activities of other ORD laboratories. Following is an abbreviated list of these activities.

National Exposure Research Laboratory (NERL)

Characterize ecosystem vulnerability at multiple spatial and temporal-scales via remote sensing, landscape composition analysis and pattern indicators, including the use of Geographic Information Systems.

1) Determine critical landscape patterns for watersheds to avoid significant decline in ecological processes that sustain desirable environmental conditions.
2) Relate spatial distribution of human and ecological resources in watersheds to valued environmental attributes.
3) Develop exposure indicators of ecological stress, including fish, macroinvertebrates, periphyton, and toxicity tests.

National Center for Exposure Assessment (NCEA)

1) Develop ecological risk assessment guidelines and methods to characterize risk to ecosystems and field sites.
2) Develop case studies for assessing risk to specific types of watersheds.
3) Conduct risk assessments for restoration options being considered by NRMRL.

National Health & Environmental Effects Research Laboratory (NHEERL)

1) Define reference conditions, including monitoring of approaches and indicators of effects.
2) Evaluate the effects of intervention, including performance criteria and siting guidelines.
3) Define ecological effects for contaminated sediments and wetlands.
4) Define ecological effects of exotic species.

Office of Water (OW)

RMER will be conducted in partnership with OW. Within OW, the Office of Wetlands, Oceans and Watersheds (OWOW) is particularly active with ecosystem protection and restoration activities, including work under the Clean Water Act (CWA) and Coastal Zone Act, Reauthorization and Amendments (CZARA). These Acts call for nonpoint source management measures for inland and coastal areas, respectively. OWOW programs, such as the National Estuary Program, focU.S. EPA resources on protecting and restoring coastal wetlands through state activities. OW also administers the Safe Drinking Water Act (SDWA), a portion of which is concerned with ecosystem protection and restoration in the context of source water protection for both ground water and surface water.

EPA Grants Programs

Substantial opportunities exist for collaborative relationships with EPA grantees receiving funds from programs administered by OW and ORD. Applicable OW grants include watershed planning assistance to local governments and states, and a $100 million-per-year nonpoint source program to states to facilitate planning for urban, agricultural and forestry needs. Many of these grants offer opportunities for research sites.

ORD grants are administered through a series of Research Focus Areas (RFAs). Applicable RFAs include:

- Ecological Assessment
- Environmental Fate and Treatment of Toxics and Hazardous Waste
- Risk-Based Decisions for Contaminated Sediments
- Bioremediation
- Water and Watersheds
- Decision Making and Valuation for Environmental Policy

Contacts with grantees will be made through OW for research sites and by individual researchers to ORD grantees to exchange information or to define other appropriate collaborative arrangements.

Other Federal Agencies

Numerous departments and agencies have programs that bear upon ecological restoration. These include, Regions within EPA, Department of Defense (DOD), U.S. Army Corps of Engineers (USACE), U.S. Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), U.S. Forest Service (USFS), Department of Interior (DOI), Department of Energy (DOE), National Park Service (NPS), U.S. Geological Survey (USGS), National Oceanographic and Atmospheric Administration (NOAA), and Bureau of Land Management (BLM). Many of these departments and agencies conduct on-going restoration projects, and have hands-on expertise. OW's watershed programs are closely coordinated with these agencies for field projects and technical transfer activities such as the "Watershed 96" conference and preparation of a stream corridor restoration handbook. Cooperation between NRMRL and these agencies will be used to achieve maximum research results.

Research Areas

The Research Areas outlined in Appendix B describe areas of interest to NRMRL. The appendix is intended to inform NRMRL's coordination and integration of RMER with EPA and the larger environmental research community. RMER is a NRMRL-developed vision of the role risk management research must have in ecosystem restoration research. NRMRL approaches its role in ecosystem management as previously described in this document to improve consensus and heighten coordination between the many agency, governmental, university, and private groups involved in ecosystem restoration. NRMRL intends to coordinate and cooperate with these groups whenever possible.

The RMER is intended to be, first and foremost, scientifically defensible and technically sound. Program and resource issues are not directly considered. It is the goal of RMER to raise the level of certainty for restoration of ecosystems. To that end, the program outlined by the following research areas is to guide program focus and project selection. It is intended that research proposed under RMER should fall within the research areas.

Research projects will be solicited. Proposals should address research needs and uncertainties as designated in *The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management* (Christensen et al., 1996), *An SAB Report: Ecosystem Management; Imperative for a Dynamic World* (U.S. EPA, 1995b), or this research plan.

It is important to recognize that the research areas are further limited and informed by the overall focus of the program, particularly water resources and land use as they relate to risk management for ecosystem restoration. Thus, for instance, although phytoremediation is a technology that has ecosystem restoration applications, from an ecosystem perspective it is not enough to demonstrate that phytoremediation by one or a few species can reduce contaminant concentration at a site while impacts to other species present are unquantified. As a further example, suppose a phytoremediation prescription called for planting of a monoculture of a particular species because it is efficient at reducing contaminants. Lacking supporting evidence, this action would have little benefit to the ecosystem. Monocultures are biotically impoverished and inherently unsustainable.

RMER will be implemented through annual calls for proposals that will be reviewed for technical merit and relevance. An outline of this process is presented in Appendix C.

Relevance Criteria

Proposals submitted for research under RMER must be relevant to the program. All successful proposals will undergo relevance review in addition to peer review for technical merit. This research plan broadly describes the bounds of relevance for the RMER program. Additionally, five specific guidance points are presented below for criteria that will be weighed during relevance review.

1) **Connections to Multiple Ecosystem Elements?**

   Does the proposed study investigate responses of several ecosystem elements (e.g., plants, insects, water chemistry, and contaminant concentration together) or does it focus on single characteristics? Also, is the effort equally divided between ecosystem elements, or are some elements included at a very cursory level of investigation?

2) **Risk Management or Contaminant Reduction?**

   Related to Point 1, and simply put, risk management is a larger subject than contaminant reduction. Reducing contaminants does not in and of itself reduce risk.

3) **Is There Appropriate Replication?**

   Ecosystem research requires that attention be paid to spatial-scale (i.e., landscapes, hierarchies, emergent properties); (Allen and Starr, 1982; Ahl and Allen, 1996; Brown, 1995). Therefore, studies must be conducted with appropriate spatial replication. For instance, constructed wetlands in general cannot be studied when research is conducted in a single constructed wetland.

4) **Field Orientation Preferred**

   Spatial and temporal uncertainty are given in ecosystem management. Reduction of these uncertainties is a key element of ecosystem restoration. Field studies with statistical control of spatial and temporal variation are the best method for improving our understanding of these uncertainties.

5) **General or Site Specific Results?**

   Site specific solutions are not a focus of ecosystem restoration. Research should be conducted on topics that are widely generalizable and have direct impact on products that can be used by turnkey clients (i.e., are not site-specific, but can be quickly incorporated into site-specific restoration programs).

Summary

This document describes the scope of ecosystem restoration risk management research to be conducted by NRMRL. Special emphasis is placed on developing multi-use landscapes, often associated with fringe-cities and coastal/estuarine sites. Research will take advantage of NRMRL's competencies in surface, subsurface, atmospheric, and hydrologic systems by concentrating ecosystem restoration risk management research on water resources and changing patterns of land use.

Water impacts uplands as well as wetlands. Water has well understood, and quantifiable characteristics, relative to transport and chemistry. The interactions of many of these characteristics with biota are comparatively well understood. Our knowledge of water provides a good starting point for NRMRL ecosystem restoration research.

Changing patterns of land use, especially habitat alteration, historically have been the leading cause of species and ecosystem decline. Wildlife management has enjoyed success in mitigating some impacts of land use change. Thus, it is reasonable to assume that management techniques can be developed that will benefit ecosystems and their component species in response to changing patterns of land use.

Contaminants alone are not stressed under this research plan. Contaminants alone are single features of ecosystems. A showing of contaminant reduction does not demonstrate connectivity. Moreover, demonstration of contaminant reduction does not address risk management. Risk management is a larger subject matter. Research must demonstrate both connectivity between multiple ecosystem elements and an understanding of risk management.

Ecosystems are complex, involving interacting biotic and abiotic elements over large spatial and temporal-scales. Previous NRMRL practice has been to conduct studies at single sites, focused on contaminants, with minimal field time. Ecosystem restoration requires that attention be given to site connections to adjacent areas, connections to plants and animals, over time frames sufficient to capture temporal variation. Ecosystems can only be understood in the context of these interactions. The interdisciplinary nature of ecosystem research suggests that substantial inter- and intra-agency collaboration will be required.

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ACRONYMS AND ABBREVIATIONS

BLM	Bureau of Land Management
BMP	Best Management Practice
CWA	Clean Water Act
CZARA	Coastal Zone Act, Reauthorization and Amendments
DFC	Desirable Future Condition
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
EPA	Environmental Protection Agency
GPRA	Government Performance Results Act of 1993
MSA	Metropolitan Statistical Area
NCEA	National Center for Environmental Assessment
NERL	National Exposure Research Laboratory
NEPA	National Environmental Policy Act
NHEERL	National Health and Environmental Effects Research Laboratory
NPS	National Park Service
NRMRL	National Risk Management Research Laboratory
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
ORD	Office of Research and Development
OW	Office of Water
OWOW	Office of Wetlands, Oceans and Watersheds
RCRA	Resource Conservation and Recovery Act
RMER	Risk Management Research Plan for Ecosystem Restoration in Watersheds
RFA	Research Focus Area
SDWA	Safe Drinking Water Act
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey

APPENDIX A:

SUMMARIES FROM SUCCESSFUL FY97 PROPOSALS

Project 1

TITLE: *Water, Soil, and Air Quality Impacts of Riparian Ecosystem Restoration*

Agricultural and forestry practices, point source pollution, and urban development have had considerable deleterious impacts on riparian habitat and water quality in the United States. Among these are stream bed sedimentation and bank erosion, nutrient loading and oxygen depletion, metal contamination, water temperature increases, and general decline in the quality of drinking water and wildlife habitat. To mitigate these impacts, efforts have been initiated to repair or restore riparian zones and stream beds using a variety of techniques, including revegetation, grazing restriction, and physical alteration of the stream bed itself. A particularly common strategy is to establish bottomland woody vegetation species in the riparian zone while eliminating grazing and other disturbances. Although this approach has been applied in several areas, very little data is available concerning its effectiveness in improving water quality and wildlife habitat. In particular, almost no information is available on long-term effectiveness or potential soil and air impacts. Since this vegetation is often established to buffer agricultural and forestry operations, it is important to understand how effective the plantings are in mediating soil and air transport of nutrients, pesticides, and sediment to the stream corridor. In addition, the vegetation planted is usually from the *Liquidambar*, *Platanus*, *Populus*, or *Salix* genera, all of which are highly productive early successional and shade intolerant species. They also emit significant quantities of isoprene and other organic compounds, which are significant sources of atmospheric organic acids and photochemical oxidants, which ultimately impact the riaprian zone as well. Our intent is to characterize some of the key air, soil, and water quality impacts of such riparian ecosystem restoration activities.

Our approach will be to use gas chromatography/mass spectrometry (GC/MS), soil enclosure chambers, and environmentally controlled leaf cuvette systems to characterize soil and plant trace gas exchange. Ambient air samples will also be analyzed for organic acids and VOC. Soils will be analyzed for litter quality and depth, nutrient content, porosity, and organic matter. Changes in sediment input from stream banks and sediment and nutrient fluxes in overland flow will be quantified. We will attempt to collect data prior to, during, and for at least two years after establishment of vegetation at a site in the mountains of Western North Carolina. The primary candidate sites are on the Little Tennessee River and its tributaries upstream of Fontana Reservoir. Here local stakeholder groups are currently engaged in restoration efforts aimed at improving water quality and fish and wildlife habitat. During the second or third years, we will also consider similar studies at a site in Eastern North Carolina on the Neuse River. Nutrient runoff into this system is suspected to trigger blooms of toxic dinoflagellates, which are thought to be responsible for large fish kills (in excess of millions of fish during each event) in the river and its estuary. Shellfish populations (and their marketability) have also been adversely affected with large resulting impacts on local economies. Work at this site will be coordinated with other groups, including North Carolina State University, who will be studying atmospheric deposition of nitrogen, nutrient runoff, hydrologic properties, and dinoflagellate populations in the Neuse River.

Data from these field studies will be used to examine the actual impacts of riparian ecosystem restoration on air, soil, and water quality. We will also obtain cost data from local stakeholder groups (some of which is already available) so that we may perform cost-benefit analyses based on results from these studies. Ultimately, we strive to develop a better mechanistic understanding of man's role in ecosystem degradation, and to develop, refine, and apply cost-effective restoration techniques.

Project 2

TITLE: *Phytoremediation Handbook for Site Managers*

Phytoremediation is the name given to a set of technologies that use vascular plants to contain, extract, or destroy contaminants. Research has been proceeding for many years to identify and optimize plants which can clean contaminants from ground water, or remediate or extract them from soil. Phytoremediation has received remarkable popular press in the last few years. Such diverse media as the *Wall Street Journal*, the *New York Times*, and National Public Radio have each had multiple stories of phytoremediation projects. The potential of phytoremediation is that there is some evidence that plants might be able to clean some sites faster than microbial bioremediation or natural attenuation, at much less expense than landfilling or physical and chemical technologies, and with less intrusion.

As a result of the partial information provided by the popular media, site managers and regulators need comprehensive and reliable information available on phytoremediation. The site owners and interested citizens groups will demand that the cleanest and cheapest technologies be employed in the remediation of a hazardous site. There are many sites where phytoremediation is clearly not applicable. This project would compile the research and field work that has been done to date into a form accessible to EPA RPMs, state regulators, and others who need to choose between alternate technologies using the resources of the internet to both gather and disseminate information, this handbook would be written in sections that could be regularly updated to keep it relevant as the technology changes.

Project 3

TITLE: *Investigation of Organic Pollutants in Surface Waters: Implications for Ecosystem Restoration*

The transport and dispersion of organic pollutants in surface waters to the sites of their ultimate deposition is often the result of their adsorption to particles suspended in the water. The size of the particles contributes to its diffusion and mechanical transport by surface water currents and to their sedimentation properties. Smaller particles typically sediment slower than larger particles, and thus may be transported further, allowing greater geographic dispersion throughout the watershed. The role of particle size and (associated) sedimentation capability is, therefore, an important issue in the transport of pollutants and, in turn, the assimilation of pollutants by the ecosystem. The heterogeneous nature of these particles causes experimental difficulties in characterizing their adsorptive behavior toward organic pollutants, resulting in a lack of available data about the ecological role of these substances.

In order to bridge this gap in knowledge, the proposed research will employ a technique called field flow fractionation, which can efficiently separate suspended particulate matter into discrete fractions based on particle size/sedimentation capability. In the past decade, this technique has been increasingly applied to environmental problems, and has generated unique and significant data.

Although additional ecologically significant research should be performed in field flow fractionation technology, the objective of this proposed three-year research plan is to relate the particle size/sedimentation properties of suspended water particulates to their ability to adsorb organic pollutants. The proposed research will identify specific properties of water systems which influence the ability of suspended particles in the water system (i.e., a river) to sediment, and, in turn, which water systems are particulary susceptible to pollution release. By relating water system properties to sedimentation ability, the results of this study may provide watershed risk managers experimental data with which to make ecologically, scientifically, and financially sound decisions about the release of pollutants into surface waters. The data generated by the proposed research will also be of interest to other ecology studies, such as computer modeling and bioavailability. In the process, an important scientific tool, field flow fractionation, for ecological studies will be further developed.

Project 4

TITLE: *Geohydrologic Foundations for Ecosystem Restoration: Modeling of Baseflow Loadings of Nutrients in Mid-Atlantic Coastal Plain Watersheds*

The Chesapeake Bay and other estuaries of the mid-Atlantic coastal plain are threatened by the abundance of nitrogen from anthropogenic sources. Up to 80% of stream flow in the region is supported by ground water, with its associated load of nitrate-nitrogen. The combination of geographic setting and ground-water flow pathway controls the delivery and form of nitrogen to the discharge reaches along the streams and the bays. The effectiveness of ecosystem restoration approaches, such as source control and use of riparian buffer strips, depends upon the site specific geohydrological function of the groundwatershed. The proposed research will synthesize understanding of the role of the subsurface in transporting nitrogen from the land to the surface water drainage systems. A computer modeling approach is proposed that will be conditioned by field observations at select watersheds within the study region. Hydrogeologic mapping and geologic modeling will provide the foundation for evaluating nitrate yields from geomorphic regions and nitrate residence times within groundwatersheds. Conjunctive ground-water/surface water modeling will be explored in the Chester River and the Patuxent River watersheds to document process-level understanding of nitrate baseflow loadings. Insights will be extrapolated to the Delmarva Peninsula coastal bays and the northern necks region of the Virginia western shore. The research will be conducted in close collaboration with U.S. Geological Survey, exploring the extensive data sets and field capabilities of the District Offices in Towson, MD, Richmond, VA, and Dover, DE. Baseflow modeling of nitrate will be linked to the hydro/ecological/economic modeling in the Patuxent River watershed that is being done through the NSF/EPA grant to the University of Maryland. This will provide an opportunity to explore state-of-the-art in ecosystem restoration decision support systems. Empowerment of community-based approaches to ecosystem restoration will be supported in this project through the development of scientific visualizations, models, maps, and reports, made available over the Internet.

Project 5

TITLE: *Development of Isotope Hydrologic Techniques for Resolution of Recharge-Discharge Processes in Natural and Constructive Wetlands: Application to the Grand Kankakee*

Marsh Within the Calumet Lacustrine Plain Ecosystem

Recharge-discharge dynamics in a wetland water budget influence the hydrology of an ecosystem. There exists disagreement over the role of wetlands in recharge. Often attempts are made to support wetland protection on the basis that wetlands are recharge areas. However, many studies indicate that wetlands are primarily discharge areas. Constructed wetlands are used to enhance or restore some ecosystems generally without deciphering beforehand the expected recharge-discharge dynamics. Some constructive wetlands evolve into sinks for contaminants while other wetlands become infiltration galleries to local water supplies.

This proposed research primarily investigates how environmental isotopes can better define hydrologic processes occurring in the grand Kankakee Marsh, 32 km south of Gary, Indiana, currently being constructed in the Kankakee outwash and lacustrine areas of the Calumet plain ecosystem in northern Indiana. The focus of this research is how well environmental isotopes describe flow components, flow paths, residence times, and source regions impacting the recharge-discharge dynamics of a wetland. Isotope hydrologic techniques are direct tracers of fluid properties of the water cycle plus storage regions; and when combined with traditional indirect hydrometric techniques should result in improved indicators of recharge-discharge dynamics in wetlands. Also the isotope data will be used to (1) extrapolate the isotope point data to the entire flow system; (2) visualize the hydrologic processes indicated by the isotope data to be occurring; (3) calculate surface- and ground-water flow rates; (4) determine the hydrologic effects and consequences of different wetland restoration approaches; and (5) estimate the effects of wetland restoration on nearby agricultural land.

Development of analytical protocols will include stable and unstable isotopes for waters and solutes. Water isotopes appear favorable tracers for surface water-ground water interaction studies. For example, the strong isotope fractionation effects of ^{18}O and ^{2}H from evaporation may result in subtle contributions between wetland surface waters and subsurface flows to be quantified. Further, since the water molecule contains ^{3}H, a distributed model of the exchange process can be measured in time and space. Other stable solute isotopes (e.g., ^{13}C, ^{15}N, ^{34}S) and certain radionuclides (e.g., ^{87}Sr, ^{210}Pb, ^{32}Si, ^{14}C, ^{85}Kr, ^{39}Ar, ^{36}Cl) may trace solute/gas processes and estimate flow path residence times and recharge-discharge rates. Thus forecasting restoration trends before measurable water quality parameters improve is viable for wetlands.

The anticipated products include (1) a report describing wetland recharge-discharge processes of wetlands in the Grand Kankakee Marsh currently being reconstructed in the Kankakee outwash and lacustrine areas of the Calumet plain ecosystem; (2) a ground-water model that simulates and displays hydrologic processes and assists in wetland management decisions; (3) a preliminary assessment of hydrologic functions on vegetation composition; (4) a performance assessment of measured isotope tracers for wetland hydrology; and (5) analytical protocols transferable to constructive wetland planning and development.

APPENDIX B:
RESEARCH AREAS

I. ECOSYSTEM MEASUREMENTS

A. Ecosystems Evaluation

1. Stressor Management

Stressor attenuation, broadly defined as including chemical, biotic, and abiotic limiting factors, is the operational focus of RMER. As such, proper evaluation of stressors is a key project area.

a. Stressor Identification

b. Stressor Interaction

Multiple stressors affect ecosystems. Proper evaluation of the interactions is critical to ecosystem evaluation.

2. Sustainability

Sustainability is the long-term goal of ecosystem management. However, our ability to define and predict ecosystem sustainability is limited.

a. Productivity Prediction

Develop capability to predict the ability of reconstructed, remediated, and current ecosystems to produce desirable biological, social, and economic outputs over the long-term.

b. Diversity/Complexity Determinations

Diversity is associated with sustainability. However, the performance of metrics for diversity under different conditions is poorly understood.

c. Uncertainty Evaluations

Evaluate uncertainties and key knowledge gaps in evaluation of sustainability.

3. Ecosystem Function

Our understanding of ecosystem function is still developing.

a. Media Interfaces

Interfaces between water, land, and air are thought to be active areas of chemical stressor attenuation. Research is needed to evaluate the significance of these interfacial areas to attenuation processes.

b. Uncharacterized Ecosystems Systems

Many ecosystems are poorly understood. Additional research into such basic processes as energy cycling and biotic/abiotic interactions is needed to assess restoration potential.

c. Material Cycles

Ecosystems maintain function by cycling material (e.g., nutrients, trace components, energy). Maintenance and restoration of these cycles is critical to restoration of ecosystem structure.

d. Boundary/Fringe Effects

In practice, ecosystems are artificially defined according to societal constraints. The impact of these constraints on measurements of ecosystem parameters and function, and thus predictions of sustainability are not known.

B. Ecosystem Measurements for Evaluation

1. Decision Support Systems for Ecosystem Restoration

a. Goals Definition Protocols for Ecosystems Management

Provide protocols, information, and tools for stakeholders and decision makers to select appropriate and achievable goals and endpoints for ecosystem restoration actions.

b. Links to Human Health /Environmental Effects Database

Develop informational linkages to databases on human health.

c. Value Added Determinations

Protocols for evaluating the expected benefits of ecosystem restoration in the context of expected costs and uncertainties.

2. Protocols for Hydroecological Assessment

a. Hydraulic Models

Regional, watershed, and local hydraulic models for surface and ground-water characterization.

b. Ecosystem Models

Wildlife, landscape, and trophic models for evaluating and predicting ecosystem function and response.

c. Boundary Definitions

Protocols for selection and evaluation of boundary conditions on ecosystem models.

3. Restoration Technologies Selection

a. Restoration Technologies Identification

Database development, access protocol, and linkages for disseminating restoration technologies.

b. Appropriate Use Protocols and Guidelines

Performance evaluation of restoration technologies for specific goals and endpoints under various ecological constraints and uncertainties.

c. Restoration Approach Selection Protocols

Evaluation protocols and criteria for the selection of appropriate ecosystem management/ restoration approach.

4. Protocols for Restoration Assessment

a. System Effects Evaluation Protocols

Protocols for evaluating ecosystem function and identifying key indicators during restoration.

b. Cost Prediction and Monitoring Protocols

Protocols for predicting, monitoring, and evaluating costs of restoration.

c. Goals Attainment Protocols

Protocols for evaluating incremental improvement in ecosystem function and sustainability.

II. RESTORATIVE MANIPULATIONS

A. Restoration Technology

1. Engineered Restorations

a. Constructed Wetlands

Methods for providing enhanced assimilative capacity in conjunction with utility to plants and animals.

b. Streams – Riparian Zone

i) Urban

Methods for enhancing ecosystem function of urban streams.

ii) Suburban – Developing Fringe

Methods for maintaining ecosystem function of streams in developing areas.

2. Remediation Technologies

Developing sustainability through improved function by maintaining nutrient retention, reducing erosion, fostering connections to adjacent areas, and controlling anthropogenic stressors.

a. Sediments

b. Soil

c. Ground Water

d. Aquatic Systems

3. Predicted Assimilative Capacity

a. Chemical Pollutants

Ecosystems receive pollutants of various types, through intentional discharge or as result of natural cycling. Sustainability of ecosystems can be affected. Therefore, it is important from management, preservation, and restoration perspectives that we develop a thorough understanding of assimilative capacity.

i) Effects on native ecosystems

ii) Effects on restored ecosystems

b. Land Use

How does land use in and around restored ecosystems affect assimilative capacity of component habitats and ecosystems?

c. Cycling – Transport

Material transport and cycling through the ecosystem plays a critical role in determining the limits of restoration. Further, many ecosystem problems are the result of phenomena that involve material transport. Eutrophication is one example.

i) Water

ii) Nitrogen, Phosphorus

iii) Carbon

iv) Trace Elements

v) Contaminants

vi) Heat Transport

4. Predicted Effects of Activity Restriction

a. Land Use

To what extent can simple access and activity restrictions affect ecosystems? What conditions indicate application of access and activity restrictions?

i) ORV's

ii) Grazing

iii) Hiking

iv) Water Sports

b. Engineered Controls

What are the limits in terms of restored or preserved ecological structure and function that are inherent in engineered systems.

i) Water Level

ii) Barriers

iii) Buffer Zones

B. Restoration Assessment

1. Restoration Evaluation

Development of methods for evaluating intended and unintended effects of restorative manipulations.

a. Systems Function

b. Sensitive Species

c. Utility

d. Adaptive Management

2. Stressor Attenuation

APPENDIX C:
SOLICITATION PROCEDURE

Development of methods for evaluating stressor attenuation and effects thereof on restorative manipulation.

Research projects under RMER will be solicited annually through FY2001. The following timeline represents the annual cycle that will be followed. Participants are reminded that this is a developing process that will undergo modifications in the face of experience and new program needs. This timeline represents NRMRL's intended outcome at this time.

DATE	ACTIVITY
OCTOBER – JULY 1	Proposal Preparation
MAY 1	Call for Next Fiscal Year's Proposals
JULY 1	Proposals Due, Process Closed Until Next Call
JULY 2 – JULY 31	Internal NRMRL Relevancy Review
AUGUST 1 – SEPTEMBER 30	Outside Peer Review
OCTOBER 7	Announcement of Successful Projects