ILLINOIS RIVER BASIN RESTORATION
COMPREHENSIVE PLAN
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDIX H

MONITORING PLAN

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EXECUTIVE SUMMARY

Rivers and streams are a valuable and integral part of every major ecotone and alteration of these systems has a long and varied history throughout the world. Many of these changes are a direct result of various management practices designed to meet human needs including flood control, power generation, navigation, irrigation, and recreation. Dominant management practices used to meet these needs have typically involved altering flow and habitat availability through impoundment, channelization, leveeing, and water diversion. All of these practices have far ranging temporal and spatial impacts on the physical and biological processes that define a given ecosystem. However, new initiatives to repair aspects of ecosystem structure and function are beginning to emerge. The Illinois River Ecosystem Restoration (IRER) project is one such initiative that is focusing on restoring not only mainstem areas of the Illinois River, but also much of the contributing watershed.

The IRER is a multi-disciplinary, collaborative initiative between several federal agencies (U.S. Army Corps of Engineers, U.S. Environmental Protections Agency, U.S. Fish and Wildlife Service, U.S. Geological Survey, Natural Resources Conservation Service), the state of Illinois (Department of Natural Resources, Environmental Protection Agency, Department of Agriculture), local and/or regional government agencies, and several non-government organization (e.g., The Nature Conservancy). The overall goals of the IRER are to: 1) maintain and restore biodiversity 2) reduce sediment delivery from tributaries, 3) restore backwater and side channel habitats, 4) restore floodplain and riparian habitats, 5) reconnect the river to its floodplain, 6) naturalize hydrology, and 7) improve sediment and water quality with the intent to improve the structure and function of the Illinois River Basin. To achieve these goals, most of the restoration practices implemented through IRER will focus on projects that establish physical reductions in sediment loads; restore or protect side channel, backwater, and floodplain habitats; and naturalize water level fluctuations throughout the basin. One very important aspect of this restoration effort is documenting the physical and biological responses throughout the process to provide information into an iterative feedback loop. These responses can primarily be measured through long term monitoring at several spatial scales. Our objectives were to develop a conceptual and structural framework for watershed assessment and long term monitoring as part of the IRER program.

This report contains two chapters. The first chapter deals specifically with developing a long-term monitoring framework. This monitoring protocol highlights an inter-disciplinary effort attempting to monitor all major characteristics of the river (e.g., water quality, geomorphology, biota). The bulk of this chapter focuses on identifying appropriate biotic and abiotic response variables that can be used to identify ecosystem change as a result of restoration practices. Within the Illinois River Basin, there are many potential measures that may be useful in assessing goal-specific accomplishments. The response measures identified throughout the proposed plan should provide information that is ecologically meaningful, relevant to the spatial and temporal scales being measured, responsive to implemented restoration practices, provide benchmarks of progress in accomplishing the stated goals, and be easily understood.

The proposed monitoring framework is defined at three distinct, hierarchical spatial scales to facilitate ecosystem response to the restoration goals and will also provide information that 1) characterizes the current status of the ecosystem (status), 2) tracks changes in the ecosystem through time at multiple spatial scales (trends), and 3) rigorously evaluates project specific management practices (evaluation). Within each spatial scale, the typical sampling design, sampling approach, and likely variables (or metrics) that should be measured are discussed. Response variables will be discussed at two levels: 1) those that are critical and must be measured and 2) those additional variables that are desirable and would provide a significant amount of information, but may not be as immediately critical as those listed above. We recognize that several ongoing data collection efforts and programs (e.g., Environmental Management Program's Long Term Resource Monitoring Program, Illinois River long term fish population study, USGS and ISWS hydrology monitoring, water quality monitoring, etc.) within the basin will likely be beneficial and complimentary to the proposed monitoring program presented here. Therefore, the intent of the proposed monitoring framework is to complement the already existing programs to create a more comprehensive monitoring effort.

Because river restoration is a newly emerging field, there are likely considerable knowledge gaps that may need to be investigated to provide a better understanding of ecosystem responses to restoration practices. In this situation, short term (i.e., 3-5 year) studies may be appropriate to identify the underlying processes that will aid in understanding the ecosystem. Accordingly, we have provided a summary of potential focused research topics.

In the second chapter of this report, we present a general summary of watershed assessment approaches. Watershed assessments are a crucial first step in identifying environmental degradation and also in identifying the action needed to fix problems. However, we present only the basic paradigms to appropriate watershed assessments because information beyond biotic and abiotic conditions (e.g., public opinion, economics, etc.) should be included and are beyond the scope of this document.

Chapter I
LONG TERM MONITORING

INTRODUCTION

River Restoration Background

Rivers and streams are a valuable and integral part of every major ecotone and alteration of these systems has a long and varied history throughout the world. Many of these changes are a direct result of various management practices designed to meet human needs including flood control, power generation, navigation, irrigation, and recreation. Dominant management practices used to meet these needs have typically involved altering flow and habitat availability through impoundment, channelization, leveeing, and water diversion. All of these practices have far ranging temporal and spatial impacts on the physical and biological processes that define a given ecosystem. For example, about 14% of the world's total annual runoff is held in reservoirs that has ultimately resulted in changes to both the biotic and abiotic characteristics of these systems because the aquatic environment has been converted to a lentic system (Downes et al. 2002). Biotic changes can range from local changes in community composition and/or structure to broader extirpations of species or entire communities and changes in fundamental processes (e.g., nutrient cycling; bioenergetics, etc.). Abiotic shifts are similarly affected with relatively localized issues like point-source pollution to systemic issues like sedimentation and shifts in geomorphology of the stream bed and its floodplain.

The effects of these modifications are beginning to be ameliorated in some systems. The science of restoring riverine systems is relatively young, but attempts to repair damaged systems due to human impacts are emerging in several places around the world. Common techniques used to address major problems within a river system include improving water quality, removing dams, reconnecting channels with their floodplains, flow remediation, and increasing stream meander. Many ongoing river restoration projects are spatially limited by focusing on restoring small rivers and streams or fairly localized reaches of larger rivers (e.g., Cook et al. 1992; Biggs et al. 1998; Cals et al. 1998; Lake 2001; Erskine 2001). However, there are now a handful of restoration projects materializing that are taking a more holistic approach to large river restoration including much, if not all, of the entire basin. For example, the Kissimmee River restoration effort has been the impetus of restoration activities since the early 1970's where the focus has been aimed at restoring the river basin's flow regime, water quality, and habitat diversity (Toth et al. 1997). Other major river systems that have existing or emerging restoration programs include the Murray-Darling Basin (Australia), the Rhine River Basin (Europe) and the Volga River (Russia). While the spatial and temporal scales and the specific objectives that exist among these projects may vary slightly, the overriding goal of these efforts remains the same - to restore the ecosystem.

Ecosystem restoration is defined as an applied approach to re-establish the structure and function of an ecosystem (Cairns 1988; Downes et al. 2002). Conceptually, structure pertains to biotic and abiotic diversity; whereas, function typically refers to the processes that drive the ecosystem (e.g., productivity, sedimentation, nutrient transport, nutrient loading). Therefore, the primary goal of any restoration effort should be to redirect the structure and function trajectory of a degraded ecosystem to something that more closely approximates historic conditions (i.e., pre-impoundment, pre-channelization, pre-European settlement, etc.). It is crucial that both structure and function be considered and incorporated into restoration planning processes to ensure a holistic approach to restoration activities. This means that the restoration process should be a thorough, relatively long term and comprehensive commitment that also incorporates an iterative process to capitalize on new information as it becomes available (Williams et al. 1997).

There are a myriad of established restoration techniques and/or programs that can be readily implemented in the riparian areas and smaller watersheds of the Illinois River (Table 1). Likewise, a smaller list of generally accepted management practices are available for restoration in larger tributaries and river systems (e.g., dredging and water control structures). The challenge will be to assess their efficacy and impacts at both local and smaller spatial scales along the river basin. Therefore, a key element to this process is establishing an ability to identify or detect changes to the ecosystem in response to restoration practices used to accomplish the restoration goals. Consequently, it is critical to establish, *a priori*, a scientifically rigorous and explicit monitoring design to ensure that the most efficient use of time and money are implemented with the greatest information return.

The thrust of evaluating restoration successes or failures involves an ability to extricate the complex interactions between natural variability, human activity, and responses to restoration efforts in a given system (Bryce and Hughes 2003). These issues are magnified in large river systems, like the Illinois River, because they typically traverse a longitudinal gradient that can encompass many landscapes. Further complications arise in larger rivers because they are relatively unique and provide little opportunity for replicated study at the broadest spatial scales. Similarly, responses can also occur at varying time scales that are dependent upon processes driving the system and the extent of the restoration effort. This creates several unique challenges to restoring large rivers, especially in the assessment and monitoring stages (Pegg and McClelland in press). Issues like appropriate scales of measure (e.g., mainstem, local, other), logistical limitations, and financial constraints all pose significant obstructions to appropriately evaluate ecosystem responses. Recent advances in technology, like remote sensing, have helped overcome some of these obstructions providing an opportunity to develop a sound restoration monitoring program. However, novel approaches will be required to adequately assess ecosystem changes through time and at multiple spatial scales.

Illinois River Ecosystem Restoration (IRER)

This Illinois River Ecosystem Restoration effort is a multi-disciplinary, collaborative initiative between several federal agencies (U.S. Army Corps of Engineers, U.S. Environmental Protections Agency, U.S. Fish and Wildlife Service, U.S. Geological Survey, Natural Resources Conservation Service) the state of Illinois (Department of Natural Resources, Environmental Protection Agency, Department of Agriculture), local and/or regional government agencies, and several non-government organizations (e.g., The Nature Conservancy) with the intent to improve structure and function of the Illinois River Basin (Figure 1). The over-riding philosophy behind this restoration effort centers on the fact that there are several specific factors, or stressors, currently degrading the structure and function (or integrity) of the Illinois River Ecosystem. Those factors have been identified as excessive sedimentation rates, loss of floodplain and side channel connectivity and highly variable water levels that ultimately translate into environmental extremes and/or loss of habitat for biotic organisms. Specifically, the goals of the IRER are to:

- Restore and maintain ecological integrity, including habitats, communities, and populations of native species, and the processes that sustain them,
- Reduce sediment delivery to the Illinois River from upland areas and tributary channels with the aim of eliminating excessive sediment load,
- Restore aquatic habitat diversity of side channels and backwaters, including Peoria Lakes, to provide adequate volume and depth for sustaining native fish and wildlife communities,
- Improve floodplain, riparian, and aquatic habitats and functions,
- Restore and maintain longitudinal connectivity on the Illinois River and its tributaries, where appropriate, to restore or maintain healthy populations of native Species,
- Restore Illinois River and tributary hydrologic regimes to reduce the incidence of water level conditions that degrade aquatic and riparian habitat, and
- Improve water and sediment quality in the Illinois River and its watershed.

Under these objectives, most of the restoration practices implemented through the IRER will focus on projects that establish physical reductions in sediment loads; restoring or protecting side channel, backwater, and floodplain habitats; and naturalizing water level fluctuations throughout the basin.

As the number of site-specific projects increases, we ultimately expect cumulative ecosystem improvements that should be detected at not only the localized project sites, but also at broader spatial scales including major tributaries and the mainstem Illinois River (see Comprehensive Plan for more detail). Therefore, it is critical that ecosystem responses to the restoration practices be appropriately assessed to ensure the restoration goals are effectively measured at all spatial scales. Accordingly, our objective was to develop a framework for long term monitoring and watershed assessment that would provide valuable insight into the restoration efforts, through an iterative process, as part of the IRER program. Because river restoration is a newly emerging field, there are likely considerable knowledge gaps that may need to be investigated to provide a better understanding of ecosystem responses to restoration practices. In this situation, short term (i.e., 3-5 year) studies may be appropriate to identify the underlying processes that will aid in understanding the ecosystem. Accordingly, we have also provided a summary of potential focused research topics.

Conceptually, as ecosystem limiting factors are sufficiently addressed throughout the Illinois River Basin, ecosystem structure and function will improve. The issue at hand is determining how to measure both the amelioration of the limiting factors (stressors) and improvements to the ecosystem in a scientifically rigorous, yet cost effective approach. There are three main approaches to gathering information relevant to this type of assessment: 1) use existing or newly developed indicators of ecosystem health, 2) develop conceptual and/or quantitative models that predict ecosystem change, and 3) collect data over long time periods to determine the overriding processes. Each approach has associated positive and negative biases and uncertainties that should be considered. Arguably, these three approaches can and should be linked and coordinated to ensure data needs for each are met. Simply stated, proper planning and implementation to capitalize on all three approaches will provide the best evaluation of the status of the IRER program in terms of meeting the established restoration goals.

Indicators of Ecosystem Health

Summary indices have been used in the past to provide a general view of ecosystem condition. Their popularity stems from the fact that a relatively small amount of information need be collected to hopefully show overall condition because collecting information on every aspect of an ecosystem is not feasible from both a logistics and cost stand point. Many of the indices typically use an aggregation of several measured variables, or metrics, used to mark overall system health. This approach began initially by using specific chemical indicators of point source contamination for assessment and monitoring of aquatic systems (Karr 1991). However, there has been a growing body of evidence over the past two decades that shows one or a select few biotic and abiotic variables can provide much more meaningful ecological indicators that can aid in evaluating the full range of ecosystem condition and responses to restoration or disturbances in aquatic and terrestrial ecosystems (Karr 1991; Pajak 2000; Yoder and DeShon 2003). For example, monitoring programs like the U.S. Environmental Protection Agencies' (EPA) Environmental Monitoring and Assessment Program (EMAP) now include a variety of biotic indicators in addition to physical measures to estimate the condition of aquatic ecosystems (Hughes et al. 2000). These indicators take into account the physical condition of the environment, but also focus on various levels of the ecological hierarchy, including indicators of individual organism health or condition, population level metrics, and complex, multimetric indices that aggregate measures from multiple assemblages of organisms and their environment that reflect overall ecosystem health.

Good indicators, including complex and multimetric indicators, are useful for assessing and tracking shifts in resource condition because they offer easy comparability across regions. However, even though multimetric indicators such as Index of Biotic Integrity (IBI) have proven to be responsive to ecosystem change (Gammon and Simon 2000; Karr and Chu 2000; Bryce and Hughes 2003), the complexity of both the indicators themselves and their interaction with various stressors can present challenges to accurately and effectively communicating information to decision makers and the public (Schiller et al. 2001). Much of the controversy stems from the ambiguity and inherent variability associated with some of the measures used in the aggregation of measurements into an index. The exact process of the aggregation can be controversial and mathematically complex, and is usually conducted by specialized research scientists (Barber 1994; Schiller et al. 2001).

While such indicators provide valuable information, there are several uncertainties associated with solely using this approach. First, the spatial extent of this system is considerably larger than the ecosystems in which many of the biotic indicators were developed. This means that the transferability of IBIs and similar indices among catchments and at varying scales of inference (e.g., spatial scales) without careful consideration and evaluation may be limited (Angermeier and Karr 1986) and should be a strong emphasis for additional focused research. Another uncertainty with using indicators is that a reference condition is typically needed to establish responses. Most of the Illinois River Basin has been subjected to anthropogenic impacts (Sparks 1995). Locating pristine reference sites will therefore be unlikely and will have to rely on using historical data, conceptual and quantitative models, and the best professional judgement of the resource managers to establish restoration targets that reflect a reference type condition or restoration goal. Because this is not entirely an objective process, a considerable amount of variability can be introduced into an index at this stage. Given these uncertainties, indicators still remain a preferred method of assessing ecosystem responses because the philosophy is conceptually simple and they are also easy to relay to decision makers. An added benefit to using a suite of indicators is that the information used to calculate each metric can be easily used within an adaptive management plan. Much of the information collected can be readily used in newly developed metrics as knowledge of the system increases. Inherently the main focus of the monitoring framework should be to collect data that are appropriate to an iterative process whereby the indicators are evaluated for their effectiveness to measure ecosystem responses to the restoration goals. Therefore, the infrastructure of using indicators should include an ability to identify, evaluate, and implement existing and new indicators through focused research and evaluation. Conceptually, the linkages between the components of this process are shown in Figure 2.

Within the Illinois River Basin, there are many potential measures that may be useful in assessing goal-specific accomplishments in subject areas like geomorphology, hydrology, and biology (Tables 2-5). The list of variables in Tables 2 -5 is by no means comprehensive and provides only general categories from which information may be gathered throughout the basin. Much of the long term monitoring framework discussed below is aimed at identifying important information that can be gathered from these general categories. In many cases, the information can be broken into sub-categories or other measures of change like population metrics (e.g., Karr 1991) that may summarize information about the entire ecosystem. However, it is important to note that within these categories, useful variables calculated from this list should provide information that is ecologically meaningful, relevant to the spatial and temporal scales being measured, responsive to implemented restoration practices, provide benchmarks of progress in accomplishing the stated goals, and easily understood.

Conceptual and Quantitative Models

The second approach to assessing restoration activities is the use of both conceptual and quantitative models. This approach is important because it can provide valuable information into the iterative restoration process. Conceptual models can be useful tools in presenting a clear idea of how the ecosystem generally works and also may provide information about how resource managers perceive the effects of various changes.

Quantitative models capitalize on existing and new data as they are collected and are an integral part of the restoration equation. These models are useful to provide a more mechanistic understanding of how the ecosystem has responded to change (Bahr et al. 2003). The largest asset to modeling is that it goes well beyond simple data collection and can provide a more holistic view of the ecosystem. DeAngelis et al. (2003) further highlighted three main reasons for using models within a monitoring framework. First, models may be needed to evaluate restoration targets for indicators or measures that can be directly measured. Second, models formalize hypothesized causal relations that link restoration efforts to ecological outcomes. Finally, models provide a means of forecasting to evaluate outcomes of various restoration practices. Examples that may prove useful to the IRER program include models that evaluate sedimentation rates, changes in hydrology, and changes in biotic trophic interactions (bioenergetics). The drawback is that in some instances proper models are not well developed or information is often limited in either spatial or temporal extent thereby limiting the inferences and applicability of such models. Fortunately, the information put into the models will continually improve through additional data provided by the long term data collection efforts. This aspect highlights the fact that there should be an adequate balance between modeling and data collection so that both approaches can be simultaneously advanced.

Long Term Data Collection

Ultimately, the empirical data that are used for the indicator and modeling approaches will be collected through coordinated data collection efforts that will maintain a long term data string. While long term data collection is the foundation for both the indicator and modeling approaches, it also provides unique characteristics in that it can provide information about the underlying processes of ecosystem structure and function - both present and future. Additional information that is gained over time will also be invaluable to the indicator and modeling aspects of the monitoring program by making them substantially more robust.

Long term data collections can also provide a great deal of information about the statistical abilities of the monitoring framework to detect change. For example, Lubinski et al. 2001 evaluated the ability of the Long Term Resource Monitoring Program (LTRMP) on the Upper Mississippi River Basin to detect change at several spatial scales for several biotic and abiotic components. Lubinski et al. (2001) used existing data from the LTRMP to conduct a power analysis of several factors and found that the LTRMP sampling design, while having widely variable results, was relatively adequate to detect changes in water quality, aquatic vegetation, and fish data, but needed additional sampling for macroinvertebrates. Existing Illinois River data will provide some insight on how effective the data collection may or may not be, but similar types of evaluations should also be conducted on the IRER monitoring data set at appropriate intervals to document the efficacy of the program and also to identify areas that need improvement.

As the cumulative number of restoration projects increase throughout the basin, ecosystem responses are expected at many spatial and temporal scales. However, there are likely lags in any detectable changes in the ecosystem because it will take some time for the ecosystem to "stabilize" after construction or to reach some additive level where the ecosystem shows change. For example, as water quality improves at a restoration site, noticeable responses in biotic communities may take one or several years to allow the communities to respond to the new conditions through completion of life cycles and immigration. In this context, there is evidence suggesting the fish communities along the Illinois River improved at a lag of about 10 years in response to improved water quality (Pegg and McClelland in press). Unfortunately, very little published information is available to provide guidelines for identifying appropriate temporal and spatial inferences. The crux of this issue therefore is determining what constitutes the appropriate temporal and spatial scales for measuring change among each variable measured. The paucity of information in this realm then mandates that long term data be collected to not only provide insight into response times for the IRER program, but will also provide guidance for other restoration projects within the region and nation.

Report Structure

This report contains two chapters. The first chapter deals specifically with developing a long term monitoring framework. This monitoring protocol highlights an inter-disciplinary effort attempting to monitor all major characteristics of the river (e.g., water quality, geomorphology, biota). The bulk of this chapter focuses on identifying appropriate biotic and abiotic response variables that can be used to identify ecosystem change as a result of restoration practices.

This monitoring framework is defined at three distinct, hierarchical spatial scales to facilitate ecosystem response to the restoration goals and will also provide information that 1) characterizes the current status of the ecosystem (status), 2) tracks changes in the ecosystem through time at multiple spatial scales (trends), and 3) rigorously evaluates project specific management practices (evaluation). The broadest scale is the mainstem scale and will likely represent the cumulative or system-level improvements. Second, the sub-basin scale will be monitored to measure responses within a somewhat smaller spatial context than the mainstem effort. Because each discipline will be required to deal with this spatial scale in slightly different fashions to measure ecosystem responses, monitoring efforts highlighted at this level will be discussed in detail within each discipline. However, the spatial scales will generally be sampled at the Hydrologic Unit Code (HUC) 8 or HUC 12 levels (Figure 3). Finally, project-specific monitoring will be conducted to evaluate the implemented restoration practices. Project-specific monitoring should also provide a more rapid assessment (in relative terms) of biotic and abiotic improvements. This framework is designed to show ecosystem responses at all spatial scales to provide an easy assessment of the restoration targets identified in the IRER goals and objectives.

Within each spatial scale, the typical sampling design, sampling approach, and likely variables (or metrics) that should be measured will be discussed . Response variables will be discusses at two levels: 1) those that are critical and must be measured and 2) those additional variables that are desirable and would provide a significant amount of information, but may not be as immediately critical as those listed above. The cost estimates provided (Table 6) should be cost-indexed for future inflation. The data collected from this effort will be electronically stored and available via computer using technology already in place (e.g., Illinois River Decision Support System).

In the second chapter, we present a general summary of watershed assessment approaches. Watershed assessments are a crucial first step in identifying environmental degradation and also in identifying the action needed to fix problems. However, we present only the basic paradigms to appropriate watershed assessments because information beyond biotic and abiotic conditions (e.g., public opinion, economics, etc.) should be included and are beyond the scope of this document.

Coordination with Ongoing Sampling Efforts

There are several ongoing data collection efforts and programs (e.g., long term fish population study, hydrology monitoring, water quality monitoring, Long Term Resource Monitoring Program, etc.) within the basin that will likely be beneficial and complimentary to the proposed monitoring program presented here. These data are beneficial because they provide the only existing information about the current condition of the ecosystem. Although existing information is valuable, the existing programs are by no means comprehensive and leave many critical information gaps throughout the basin. However, a concerted effort to dovetail existing work with the proposed monitoring framework discussed here can provide much more valuable information than any one data collection effort could ever achieve on its own. In other words, the sum of all these programs can equal more than a simple summation of the respective parts. The composite set of information can then lead to more accurate data for detecting ecosystem improvements and will ultimately lead to more informed ecosystem management decisions. Therefore, the intent of the following monitoring framework is to complement the already existing programs to create a more comprehensive monitoring effort. Built into the framework is the assumption that existing data collection efforts are required to meet other objectives, in addition to the restoration monitoring. Therefore, they shall continue as such without direct financial support from the IRER. Coordinating additional monitoring with existing programs will provide gains in knowledge of ecosystem responses rather than compete. With this in mind, several important monitoring efforts are specifically discussed in the monitoring framework section as they may be integrated into the IRER monitoring program. Many other data sets exist that can also contribute significantly to the monitoring and assessment of the Illinois River Basin but may not provide as clear a link or be as readily assimilated into this framework. Therefore, a more comprehensive summary of these data sets may prove most useful in the watershed assessment phase and are summarized there.

Our intent is to recommend a wholly integrated monitoring framework across disciplines and spatial scales. However, in presenting the monitoring framework, we feel it important to specifically identify the types of data that each discipline/spatial scale requires to make appropriate restoration goal oriented assessments. This is merely a presentation issue within this report and in no way implies redundant data collection efforts are necessary. Rather, we envision data collection of variables common among disciplines (e.g., land cover, physical habitat measures, etc.) to be collected by the discipline that has the best expertise to collect the data. These data will then be provided among disciplines to create a fully integrated database.

Study Design – Statistical Approaches

Designing a framework that provides the ability to test hypotheses in a rigorous, statistical fashion is crucial to the success of not only the monitoring plan, but also the restoration activities being evaluated. Further, the value of such a program without this characteristic is severely reduced. There are several options that can be used to perform these analyses including trend analysis, regional references, Before-After Control-Impact (BACI) design, and iterative modeling as new information is gathered (as discussed in the project-specific sediment monitoring section). Each approach is useful, but exhibits desirable characteristics within certain disciplines that facilitate restoration evaluations. Therefore, we recommend a monitoring design that provides an opportunity to quantitatively measure ecosystem change in the following ways.

Trend Analysis

Many larger ecosystems pose unique problems that prevent experimental assessment using traditional approaches. The main problem is that in most cases, un-impacted systems of similar size, structure, and function are not available, thereby making either paired or replicated analyses impossible. In this instance, monitoring aspects of the system over long periods can provide the most robust approach in measuring system changes. The value of this approach is that the power in detecting overall changes increases with time because temporal variability can eventually be accounted for with a long enough time series of data. Therefore, we recommend a consistent and recurring monitoring effort at the broader spatial scales presented here.

Regional References for Sub-Basin Comparison

Regional reference sites are least disturbed areas within the same region as the treated sub-basin. Abiotic and biotic indicators of stream quality at the regional reference sites are used as benchmarks to assess changes in treated sub-basins once restoration practices are implemented. There are two basic approaches to establishing the regional reference condition (Wiley et al. 2002). The simplest is to use sites that have not been impacted or have a relatively low level of anthropogenic impacts for comparison among the impacted sites. Alternatively, when clearly identifiable reference sites are not available, Simon (2002) recommends regional normalization for the variables or metrics being measured. Regional reference condition normalization is an approach that uses statistical modeling techniques to estimate reference conditions. The mechanics behind this normalization are relatively detailed, but conceptually simple. The basic premise is that standardized comparisons are made against sites that have the least amount of impact in the region or target measures that are then used to gauge ecosystem responses to restoration or other management practices. A limitation to this approach is that the normalization will be required for each sub-basin or other spatial scales to which this technique might be applied to ensure applicability. However, given the paucity of un-impacted sites within the sub-basins of the Illinois River, this method can be very useful.

BACI Design

It is widely recognized that implementation of restoration/remediation practices in watersheds is our best hope of minimizing the impacts of nonpoint source pollution on surface waters. Accomplishing this in a cost-effective manner requires a much greater understanding of the large-scale effects of restoration practices on both physical and biotic attributes of aquatic systems. Such understanding is best obtained through carefully designed and controlled long-term experiments carried out at several spatial scales. The overall objective of this long-term monitoring framework is to develop and implement a scientifically sound monitoring program that will effectively detect physical and biologically meaningful changes in stream integrity in response to watershed management practices. Our study design was developed based on the experiences of other watershed remediation programs in the United States (Spooner and Line 1993; Wolf 1995; Wang et al. 1996) as well as our own experiences in the Pilot Watershed Program (Dodd et al. 2003).

A sound experimental design is essential to document a strong relationship between implementation of restoration practices and changes in overall stream quality as well as specific indicators of stream quality (i.e., macroinvertebrate and fish communities). The basic design advocated by Spooner and Line (1993) and Wang et al. (1996) involves the use of paired watersheds, in which only one of the two watersheds receives restoration practices. The paired watersheds should be as similar as possible in characteristics such as climate, geology, drainage area, aquatic thermal regimes, land use, and stream gradient. The experimental design used to assess the impacts of unreplicated perturbations is referred to as the Before-After-Control-Impact-Pairs (BACIP) design (Stewart-Oaten et al. 1986; Stewart-Oaten et al. 1992). In this design, paired samples are taken simultaneously (as nearly as possible) at the Impact site (i.e., where a restoration practice has been applied) and a nearby "Control" site. Replication is achieved by collecting such paired samples on a number of dates both Before and After the treatment has been applied in the Impact site. Each observed difference (e.g., in smallmouth bass density, sediment load) between the Impact and Control sites in the Before period is considered to be an estimate of the mean difference that would have existed in the After period had the restoration practice not been implemented. A time series of observed differences between the Impacted and Control sites is developed, and a change in the mean difference between the Before and After periods indicate that the system at the Impacted site has undergone a change relative to the Control site. Assumptions of the statistical model for this design are discussed in detail by Stewart-Oaten et al. (1992). The design can be augmented to allow increased ability to detect treatment effects by incorporating more than one Control site (Underwood 1991; Underwood 1994).

The ability of the BACIP design to detect effects of a treatment depends strongly on the number of sampling dates Before and After the treatment is initiated, the effect size of the treatment (defined as the difference between the average Before and After differences between the Impacted and Control sites), and the variability in the differences between the Impacted and Control sites in each period (Osenberg et al. 1994). Obtaining an adequate number of Before samples is crucial, because additional Before samples cannot be obtained after the treatment is initiated. Osenberg et al. (1994) showed that parameters that are measured (e.g., water chemistry, invertebrate/fish communities) can vary markedly in their ability to detect significant treatment effects. In addition to using larger scale data such as water quality or fish community characteristics at the watershed scale, Osenberg et al. (1994) suggests that parameters based on properties of individual organisms (e.g., growth rate) may be useful in detecting treatment effects, especially when the number of sampling dates is relatively small.

There are several spatial scales at which the BACIP design can be applied in watershed studies. For example, if we are interested in the local effect of a restoration practice (e.g., installation of a 1 km vegetated buffer strip), a Control site could be selected immediately upstream of the buffer strip, and measurements for the Impact site could be made within the treated segment. Assessment of sub-watershed and watershed-wide effects of restoration practices requires the use of a paired watershed to serve as the Control as well as incorporation of several sites throughout the Impacted and Control watersheds. In general, our approach will be to use the BACIP design to assess local, sub-watershed, and watershed-wide effects of restoration practices on the hydrology, geomorphology, and biological communities.

Long Term Monitoring Design

Bisbal (2001) identified five universal themes that are common among most monitoring programs. Those features include characteristics that:

1. All programs should measure attributes of environmental conditions and biotic inventory at relevant temporal spatial scales,
2. Research should be conducted to improve ecosystem understanding in both disturbed and undisturbed ecosystems,
3. Provide integration, coordination, and collaboration of efforts across organizations and geographic scales,
4. Ensure management decisions are based on the best and current information available, and
5. Predict future conditions and suggest hypotheses for future evaluation.

In this context, the long term monitoring framework we present here is designed to highlight the most critical data that need collection (i.e., minimum funding level) and additional information that would facilitate tracking or testing for ecosystem structure and function (i.e., ideal funding level) as they meet the goals and objectives of the IRER.

Responses can be measured at many temporal and spatial scales. The best means to track change is to ensure that the monitoring is conducted at the same scale as that applied to the restoration efforts. Therefore, we suggest a monitoring framework that encompasses three spatial scales to ensure responses are detected both in a timely and systemic manner. The first level of monitoring will deal specifically with responses in the mainstem Illinois River and its floodplain. This monitoring will likely give the best indication of changes in the overall system. The second level of monitoring will move away from the mainstem and focus on sub-basins or tributaries to the Illinois River. This scale of monitoring will likely provide information on the regional responses of the ecosystem to restoration or other factors that can facilitate change. Finally, we will monitor and rigorously evaluate restoration practices at the project specific level. This scale will provide the best ability to test the effectiveness of practices implemented on the project site using standard statistical designs (e.g., BACI).

Monitoring Plan
MAINSTEM

GEOMORPHIC MONITORING PLAN

Changes in the geomorphology of the uplands and river systems are complexly linked to the seven ecosystem restoration goals identified for the Illinois River basin. Basin geomorphology, including stream channel morphology and processes, landscape (uplands beyond the 100 yr floodplain) morphology and processes, and underlying geology, has direct implications for five of these goals:

- Reduce sediment delivery to the Illinois River from upland areas and tributary channels with the aim of eliminating excessive sediment load.
- Restore aquatic habitat diversity of side channels and backwaters, including Peoria Lakes, to provide adequate volume and depth for sustaining native fish and wildlife communities.
- Improve floodplain, riparian, and aquatic habitats and functions.
- Naturalize Illinois River and tributary hydrologic regimes to reduce the incidence of water level conditions that degrade aquatic and riparian habitat.
- Improve water and sediment quality in the Illinois River and its watershed.

In the Geomorphology Monitoring Plan (GMP) developed here, tools are suggested for measuring progress towards these goals. Geomorphology as a field encompasses a wide range of aspects of the physical and chemical environment. This plan focuses on providing an historical and spatial geomorphic context for the hydrology, sediment and habitat monitoring activities described in this document. At small scales, the GMP is mainly concerned with evaluating factors that affect sediment yield from the upland landscape, whereas at large scales the GMP is mainly concerned with the geomorphic response of stream channels to specific restoration projects. Sediment quality, water quality, and wetlands issues are also addressed.

Monitoring Goals and Objectives

The goals of the GMP vary with scale. Because monitoring is most successful when addressed towards particular research questions, monitoring at the project scale will seek to identify specific large scale responses of stream channels to particular restoration practices. At the mainstem and sub-basin scales, it is difficult to pose specific process-response questions, and to link large-scale projects to systemic changes (Rae 1995; Reid 1995; Lisle 1999; Watershed Professionals Network 1999). Therefore the goal of the GMP at small scales is to periodically assess indicators for trends in system "health" and to gauge progress of the IRER in reaching its goals. The goals of the GMP will be met by achieving the following objectives:

Provide baseline characterization of watershed geology and morphology.

Essential in the assessment phase is a comprehensive picture of the three-dimensional geology, materials properties, and configuration of the watershed. Assessment will cull from wide variety of existing and some new data to establish the current condition of the watershed and infer future response to change. This description of the physical setting is integral to all other monitoring and assessment activities.

Characterize anthropogenic and intrinsic changes in the watershed that affect water and sediment runoff (stream power and sediment yield).

Features such as precipitation, Impervious Factor, and BMP area have potentially strong influence on water and sediment runoff that are put into ISWS sediment budget model. Measurements could eventually become inputs to an upland sediment yield computer model that would be linked to the ISWS sediment budget for assessment of landscape sensitivity and prediction of sediment yield changes with changes in the watershed.

Determine intrinsic dynamical behavior of stream channels within each target watershed.

Rates of change of stream channels that are part of "natural" meandering behavior can be used to evaluate channel response to restoration measures. The objective is accomplished through analysis of historical air-photo data, and periodic surveys of channel pattern and morphology, and analysis of floodplain geology.

Evaluate impact of site-specific restoration projects, BMP implementation in floodplain and uplands, land use changes, and climatic variability.

Pre-project assessment and post-project monitoring of stream geomorphology is essential for evaluating success of each project. In addition, project effects must be compared to the long term effects of agricultural BMPs and other land use practices. These effects are not often reported, although they are expected to be marked and widespread. Changes in channel cross-section, bed and bank material, channel slope, and channel pattern are critical data for many ecosystem monitoring and assessment activities. Periodic surveys at ISWS streamflow monitoring sites and additional locations determined during baseline watershed assessments will provide the basic data.

Determine long term changes in sediment and water quality along the Illinois River and major tributaries.

In the Comprehensive Plan, it is assumed that objectives for meeting sediment and water quality goals will be achieved through progress in meeting the other goals. This assumption will be tested by periodic (~ 10 yr) review of reports from federal (USGS, USEPA) and state (IEPA) agencies, and a new IDNR sampling program to provide temporal and spatial control.

Provide measurements of change in channel and watershed geomorphology.

Continued observation of channel and floodplain adjustments to projects and watershed changes are critical to monitoring work of collaborating disciplines. A set of indicators appropriate for measuring progress towards restoration goals can be established from a broad suite presented here.

Review of Conceptual Models of Fluvial Geomorphology

Generally, models of stream dynamics and watershed processes can be divided into three groups, theoretical, empirical, and conceptual. Predictive capability of each of these model types varies. Theoretical models are based on mathematical and physical principles and can predict phenomenon very accurately under ideal conditions. Theoretical models serve as the basis for empirical and conceptual models. Empirical models are developed by collecting and analyzing data. Much of our understanding of fluvial systems has been acquired through the use of empirical models. Empirical models estimate the relationships between variables (e.g. drainage area and discharge) and therefore can characterize a geomorphologic process in a specific stream for the duration that data was collected. After empirical relationships have been established, scientists may attempt to extrapolate these relationships and make predictions. Conceptual models are developed from relationships derived from empirical and theoretical models, and help mangers and scientists to simplify difficult concepts by breaking them down into general categories. While conceptual models may aid our understanding of stream systems and facilitate communication among peers, the use of conceptual models for prediction of geomorphologic process for designing restoration projects is unwarranted. A model that is both applicable and useful to the Illinois River Basin should first characterize the geomorphologic relationships to determine rates and directions of change of processes in Illinois streams. Through characterizing geomorphologic processes, locations of sediment sources and sinks may be determined. Four of the dominant models in current fluvial geomorphologic thought are described below.

A Classification of Natural Rivers (Rosgen 1994)

Model description – The Rosgen method is a conceptual model, but is more accurately described as a classification scheme. The Rosgen-method "integrates", or rather indexes, variables through stratifying data from a wide range of physiographic and climatic settings into "stream types".

The expressed objectives of the Rosgen method are:

1. "Predict a river's behavior from its appearance."
2. "Develop specific hydraulic and sediment relations for a given morphological channel type and state."
3. "Provide a mechanism to extrapolate site-specific data collected on a given stream reach to those of a similar character."
4. "Provide a consistent and reproducible frame of reference of communication for those working with river systems in a variety of different professional disciplines."

Data needs – Table 7 lists information required for each level of stream inventory and the objectives of each level.

Model Assessment – The Rosgen method has received wide recognition and is potentially applicable to Illinois streams. However, the data on which the Rosgen method is based was largely collected from the western North America and New Zeeland. Therefore geologic, climatologic, and ecologic factors distinctive of the Midwest may not be well accounted for. More important, the reliability of the model for predicting of channel change is tenuous at best and has yet to be verified (Miller and Ritter 1996; Ashmore 1999). It may instead be limited to conceptualization of stream dynamics and communication frame of reference for resource managers (Juracek and Fitzpatrick 2003).

Miller and Ritter (1996) and Ashmore (1999) questioned several of the assumptions in the method presented in Rosgen (1994) as well as some of the variables (or metrics) used. Ashmore (1999) argued "that grain size and slope are the primary variables for channel design and that stream type is irrelevant." He pointed out that empirically derived relationships do not require the classification of streams and that Rosgen classification ignores the accepted understanding of fluvial processes. Miller and Ritter (1996) gave a pointed discussion as to why the Rosgen classification cannot be used to formulate management outlined by Rosgen (1994). Perhaps the most problematic is that Rosgen classification does not consider climatic or hydrologic regime. As Rosgen (1994, p. 187) stated "Stream types can imply much more than what is initially described in it's alphanumeric title."

The Rosgen method is based on data from natural rivers. By contrast, most channels and their watersheds in the Illinois River Basin are modified. Drainage (tiling, ditching, channelization) and pumping have greatly changed the hydrography and hydrology over the past two centuries (Thompson 2002, Prince 1997). In many cases it is likely that streams and their watersheds are still responding to settlement era modifications, not to mention more recent disturbance. Because restoration efforts will be focused on the disturbed and not natural systems, geomorphologic models based on disturbed system are likely more applicable and more useful for designing and monitoring restoration projects.

Channel Evolution Model for Incised Channels (Schumm et al. 1984)

Model description – Schumm et al. (1984) present a model for channel evolution based on data from several creeks in northern Mississippi. This model uses space for time substitution to represent change through time (e.g. evolution). The first step in developing the model is classifying stream reaches based on the dominant processes at work in each reach. Identifying locations of nickpoints by field inspection was central to classifying reach types. For example, uppermost reaches (upstream of the primary nickpoint in Oaklimiter Creek) were considered Types I, II, and III and were characterized as degradational with little sediment in the bed of the channel and erosion and sediment transport as the dominant processes. Lowest reaches were classified as Types IV and V and were characterized by sediment accumulation, meandering planform and stable alternate bars. In the Schumm et al. (1984) model for channel evolution it was determined that width to depth ratios discriminated between reaches that were in disequilibrium (unstable) and quasi-equilibrium (stable).

Data needs – Data for this channel evolution model were generated from Soil Conservation Service surveys. Morphometric data were either generated from cross-sectional and longitudinal surveys (i.e., width, depth, width-to-depth ratio, slope) or measured directly in the field (depth of sediment in the channel). Stage of channel evolution is determined based on these morphometric variables (Table 8).

Model Assessment – The model was developed for watersheds ranging from 50 to 400 mi^2. Schumm et al. (1984) stated that the predictive power of their channel evolution model is limited by the range of conditions on which it was based and size. Therefore this particular channel evolution model would only be applicable to Illinois streams if they are found to be in the same range of conditions including but not limited to size. Data similar to those collected for northern Mississippi streams would have to be collected to verify that Illinois streams fall within the appropriate range. The conceptual channel evolution model would not be directly useful for monitoring purposes, however procedures used to develop the channel evolution model could be used to measure change over time.

Channel Evolution Model for Disturbed Channels (Simon 1989; Simon 1994)

Model Description – Simon (1989, 1994) presents an empirical model of bed elevation adjustment in response to channel modification. The data collected on West Tennessee streams that were cleared of vegetation and modified by channelization. Simon observed that degradation occurred for 10-15 years upstream of an area of maximum disturbance (AMD) and aggradation occurred downstream of the AMD. Sites that were initially degrading after disturbance experienced a secondary phase of aggradation in response to excessive incision. From the results of this model, conceptual models of bank-slope development and modified channel evolution were produced. The key to applying these models is knowing when and where a channel disturbance or modification has occurred.

Data needs – To model bed level adjustment, aggradation/degradation rates were calculated using periodic bed level elevations at USGS and Corps gauging stations. Bed level adjustment can only be estimated for streams that have multiple gauging stations and where regular measurements of bed level are collected at several points along the stream. Elevation and discharge data needs to be collected over a sufficient duration as to encompass the channel disturbances (development or restoration). The conceptual models were based on observations of bank slope, bank material, ages of vegetation, bed-level adjustment among other factors.

Model Assessment – This model was developed from data collected in streams with watersheds ranging from 10 to 2445 mi^2. The techniques used in the model could be applied in Illinois streams of similar size where data is collected at multiple gauging stations (water, sediment, and bed level) or where data at a gauging station is supplemented by regular measurement of bed level at several locations along a stream of interest. If the density of bed elevation data points in space and time are sufficient this model could be applied to streams prior to restoration to characterize response to disturbance and therefore more efficiently apply restoration measures. Nevertheless, pervasive stream behavior as specified in the model has not been demonstrated for the Illinois River basin. The potential for using the bed elevation adjustment model for long term monitoring of restoration is high if monitoring networks are in place prior to restoration.

Relative Bed Stability index (Olsen et al. 1997)

Model Description – This assessment method works under the assumption that an increase in peak flows over time leads to increased channel instability. The authors propose a quantitative method called the relative bed stability index (RBS) to assess channel stability on the stream reach level. They generate RBS values for critical shear stress and critical unit discharge empirically for stream reaches in western Montana.

Data needs – This technique requires slope, discharge, and grain size data (D-50, D-84). After RBS's are calculated for several stream reaches, their percentage distributions give indications of how many unstable stream reaches exist. Field measurements include channel cross section, water surface slope, streambed particle size distribution, and field identification of bankfull stage.

Model Assessment – This method could be applied at the reach scale (project level) to assess channel stability. The RBS index could provide estimates of relative stability at the reach scale if baseline data were collected prior to project construction. The data used to develop this assessment technique were exclusive of many features inherent to natural streams (reaches with bends, pools, bars) and thus cannot account for horizontal instability (channel migration). This technique may be useful in assessing situations where excessive channel incision is occurring but may not be diagnostic for determining restoration measures.

Summary

Four geomorphologic models are assessed in this report. This is a very small sample of the potential pool of geomorphologic models, but it is representative of the range techniques available for geomorphologic monitoring of streams in the Illinois River Basin. Conceptual models are presented by Schumm et al. (1984), Rosgen (1994), and Simon (1989). While Rosgen's model may be useful as a communication tool, the Schumm et al. (1984) and the Simon (1989) models aid in communicating the nature of site-specific phenomenon by linking process to response (c.f., Juracek and Fitzpatrick 2003). The procedures used by Schumm et al. and Simon in developing their respective models could prove useful in monitoring change through time in stream channels in Illinois, and thus could also be used evaluate the success of restoration practices on a watershed, subwatershed or project scale. Olsen et al.'s (1997) method to assess relative bed stability is reach-specific and could be useful at project sites. Nevertheless, other more comprehensive procedures should be investigated.

Review of Existing Monitoring Study Designs

There is no comprehensive geomorphic monitoring presently done in Illinois, although there are a few monitoring programs that could be drawn upon. The existing stream monitoring network is a critical component and its features and shortcomings are described elsewhere in this document. Upland erosion estimates by county Soil and Water Conservation Districts have been ongoing since 1994, but the data are not statistically valid at any scale (Illinois Department of Agriculture 2002) and have to be carefully examined for usefulness in determining sediment yield or indicating landscape change. As annotated in Appendix A, datasets such as landcover, aerial photography, and Conservation Reserve Enhancement Program (CREP) records are potentially rich with geomorphic information, but considerable work must be done to extract and that information and to develop suitable analytical metrics. Water and sediment quality data are currently monitored at both the Federal and State levels, but methods vary significantly so that robust conclusions cannot be easily drawn.

We have reviewed geomorphic monitoring programs and research efforts directed at evaluating monitoring tools. The scales and scopes of these programs, which come from across several continents, vary considerably (Table 9). The best plans consider not only processes and products in stream systems, but link these to evolution of the surrounding landscape (e.g., Collins and Knox 2003; Harvey 2001; Simon 1989). Further, they are targeted with clear goals with defined endpoints (Rae 1995; Reid 1995; Lisle 1999; Trush 1995). The plans are tuned to regional or local requirements.

General guidance for developing a set of indicators for geomorphic change at small scales is provided by Osterkamp and Schumm (1996), Welch (2003), and USNPS (2000b). Osterkamp and Schumm (1996) suggested that monitoring the combination of flow and sediment yield would be likely to show long term, basin wide environmental change. Sediment yield could be assessed by monitoring slope soil profiles, using coring to determine sediment storage in floodplains, and other techniques. Welch (2003) developed a ranked set of indicators for monitoring in Canadian parks. The ranking considered relevance of the indicator to monitoring goals and environmental setting, degree of connection of an indicator with other indicators, and practicality of measurement. Although the exact list is not necessarily appropriate to Illinois, the conceptual model could be useful.

Many of the monitoring programs reviewed rely solely on observations of in-channel processes. In fact, geomorphic components are often restricted to flow gaging, sometimes including suspended sediment monitoring. By contrast, others (Rae 1995; Spittler 1995; Owens and Walling 2002; Rhoads and Miller 1999; Lisle 1999) found that ignoring beyond-channel or "watershed" processes severely limited the value of the monitoring, especially the ability to discriminate cause-effect relationships. Harvey (2001) is an excellent example of developing critical linkages between watershed and channel processes.

By way of summary, Table 2 lists 12 geoindicators after Berger and Iams (1996) that could be used to monitor geomorphic change in the Illinois River basin. Geoindicators are "measures of geological processes and phenomena occurring at or near the Earth's surface and subject to changes that are significant in understanding environmental change over periods of 100 years or less" (Berger 1996). Thus they have been selected because measurement methods with statistical discriminating ability have been demonstrated. Although the specific measures are not new, the geoindicators program has made a significant contribution by casting an extensive list of geological processes and products into a monitoring framework. The geoindicators framework has been used by the U.S. and Canadian national parks in resource management planning (USNPS 2000a; USNPS 2000b; McCarthy 2001).

Table 2 is comprehensive in the sense that some indicators overlap with other disciplines, while other indicators may have only local significance. Indicators selected from this list and exact methods used to measure them must address particular research questions at specific scales. At this stage of planning it is not easy to determine what will be the most useful indicators, although several are suggested below. Karst activity, for example, is relevant to only small portions of the basin and thus may not be immediately important. Several of the water and sediment quality parameters are already monitored to some degree by agencies such as USGS and IEPA, although we recommend additional sampling and small scale analysis here. Similarly, flow and suspended sediment protocols are being developed by ISWS.

Proposed Monitoring Plan

The Hydrologic and Sediment Monitoring Plan described elsewhere in this document is targeted at changes in sediment transport and delivery by streams. The Geomorphic Monitoring Plan complements that effort by focusing on changes in watershed or upland conditions affecting sediment yield (sediment derived from the watershed; the difference between yield and delivery is storage) as well as stream morphology. These analyses both feed on data acquired in other monitoring programs (e.g., flow and suspended sediment load) as well as feed back information on the physical setting for analyses within those programs.

Small scale monitoring, which is addressed at ecosystem restoration in the Illinois River mainstem and sub-basins, would most likely comprise periodic and general assessments of watershed condition. That is, investigation would be limited mainly to trend analysis, at least until ecosystem management covers a significant portion of an individual sub-basin. Monitoring at these scales should focus on factors that affect sediment yield, including climate, landcover, and soil erodibility (Table 2). Changes in these parameters indicate potential changes in sediment yield, which in turn can be compared to changes in stream carrying capacity of suspended and bedload sediment, and to sediment delivery as measured at stream gauging stations as determined in the Sediment and Hydrology Monitoring Plan. Predictions of sediment storage or removal from alluvial valleys can then be made. Wetlands are expected to be important features of restoration in the Illinois River Basin, but their use as a either a tool or a target of monitoring is complex. Wetlands in this context are discussed generally below. Improvements in water and sediment quality are expected to occur as secondary benefits of restoration projects. To determine progress towards these goals, a geochemical monitoring plan is suggested.

Critical Response Measures:

Stream Power and Sediment Yield – One objective in basin-wide geomorphic monitoring should to determine trends in parameters that affect stream power and sediment yield from the uplands. Stream power, a function of flow, channel slope, and channel morphology is an estimate of a stream's ability to erode and transport sediment, and thus is fundamental to stream channel dynamics (Rhoads 1995). A significant portion of the sediment currently transported by tributary streams is thought to be remobilized from pulses of sediment delivered from uplands and stored in floodplains during agricultural clearance of the watershed (Bhowmik and Demissie 2001). Sediment yielded from the uplands either is fed directly to streams or replenishes the supply of stored sediment. Thus monitoring watershed factors that influence the combination of stream power and sediment yield provides critical context to flow and sediment load monitoring proposed elsewhere in this document. Further, the combination of slope, landcover/landuse, soil erodibility, and hydrology can feed a robust model for upland sediment yield. Changes in the landscape that affect stream power and are likely to be sensible over 5-100 years include climate, landcover, and landuse (including land practices and channel modifications). Slope and soil erodibility are unlikely to change at small scales of analysis over this span of time. A basinwide analysis of these data should be conducted every 10 years.

People are perhaps the dominant geomorphic agent worldwide (Hooke 2000). Their activities are captured in landcover and landuse maps, although the potential effects are complex. The dominant activities in the IRB are urban and suburban development, agriculture, and transportation. Also important but smaller in areal extent is resource extraction (water, earth materials, etc.). Landuses are patchy across the landscape, each type may affect rates, volumes, or flow patterns of water and sediment runoff differently for specific types of precipitation events (Riggs and Ames 2000). Thus the scale of influence of any specific landuse or collection of landuses may be restricted (Niehoff et al. 2002).

Impervious factor (also ‘imperviousness’, ‘impervious cover’), extracted from landcover maps or other data sources, has been used as an indicator of landuse in several of the monitoring plans we reviewed. It is the sum of societal hard surfaces that prevent infiltration of precipitation, and thus affect overland runoff, typically by increasing the onset and peakedness of flood discharges on hydrographs. The increased overland runoff may also affect sediment yields. Although landuse affects on ecosystems are complex and thus detailed analysis requires complex models, impervious factor is a good initial indicator of the effects of the built environment on system hydrology (Randhir 2003). Although commonly applied in urban regions (e.g., Zielinsky 2002), it has also been used in monitoring programs in non-urban settings (e.g., Water Resources Section 2002). Impervious factor is typically conceptualized as the proportion of a watershed that has been built upon; the effective impervious area (EIA) only includes built areas that are directly connected to the watershed drainage system. Effective impervious area thus includes street surfaces and adjacent sidewalks, driveways connected to streets, rooftops directly connected to a curb or stormwater system, and parking lots (Randhir 2003). Further, there are several ways of estimating impervious factor, and results may differ significantly (Endreny et al. 2003). It is important to note that mitigation areas are not typically included in determinations of impervious factor. A refined EIA metric could include credits for mitigation if a suitable data source could be found.

Climate changes that could occur over a period of decades and affect basin hydrology include storm intensity, storm frequency, temperature, and seasonality. Climate monitoring and research has a long history at the ISWS. These data need to be reviewed for implications of long-term trends on stream power.

Data Needs -- Landcover data are a rich dataset that attracts much attention because it is relatively easy to obtain and provides statewide coverage at moderate resolution. Further, the Illinois Department of Agriculture is expected to update the landcover dataset at 1 to 3 yr intervals (IDNR et al. 2003), providing the potential for a consistent and current dataset for long term monitoring. The existing dataset is adequate for regional (1:100,000 and smaller) studies. Research must be done, however, to assure that the landcover data provide sufficient accuracy in impervious factor estimates at sub-basin and project sub-basin scales, as well. Endreny et al. (2003) demonstrated that the source scale of impervious factor estimates has a strong affect on modeled watershed hydrography when scaling a calibrated BASINS model from a catchment (0.2 mi^2) to a sub-basin (400 mi^2). We recommend a pilot research effort to determine impervious factor from DOQQs using digital methods analogous to Endreny et al. (2003; see also ESRI 2003). This may increase the scalar usefulness of impervious factor as an indicator by an order of magnitude.

Regional climate data are obtained by the ISWS and reported from eight stations within the Illinois River basin subannually. These data should be sufficient to allow identification of long-term regional climatic trends that affect flow. If larger scale analyses are needed, however, it must be determined whether or not estimations of precipitation within a target watershed are sufficiently accurate from these data.

Slope can be determined from DEMs that exist at resolutions varying from 10m to 30m at 1:24,000. Higher resolution LIDAR data has also been captured for the DesPlaines valley. Although spatial coverage over the Illinois River basin is good, the accuracy of slope estimated from variably-scaled data must be assessed. Further, portions of this dataset are out of date and the dataset is mainly static unless new initiatives are begun. A static dataset could be a problem for project or catchment investigations because large scale slope changes can be significant over 50 years. For example, significant differences in slope from decades-old maps have been observed during ongoing mapping at ISGS. Nevertheless, regional slope evolution operates at much longer time scales, so current slope data may be sufficient for regional studies. A focused research project is suggested to address these issues.

Soil erodibility data obtained from USDA soil surveys are presently available basinwide as small scale (1:250,000) STATSGO data. Within a few years, all counties are expected to have large scale (1:15,000) SSURGO data that would be suitable for several scales of analysis.

Estimated cost: $75,000 for each decadal analysis assuming use of existing data.

Desirable Response Measures:

Agricultural and Planning BMPs-- Agriculture plays a dominant role in shaping the landscape of Illinois through cropping practices and drainage. Agricultural practices are influenced through several state and federal programs, but since participation is voluntary and the programs have independent and potentially conflicting goals, combined effects are not well documented. Presumably the general result is one of reduced soil loss (sediment yield) from uplands and increased direct runoff from drainage. Although the affects are complex, it would be useful to gauge progress in land management by comprehensively mapping areal coverage of BMPs. Possible indicators are percent area of watershed in BMP and percent area of contiguous BMP. Sub-basin wide data would have to be compiled from USDA-Farm Service Agency and Soil and Water Conservation District records. The format of records varies from paper to GIS-ready, depending upon the county. Agricultural BMP mapping provide an interesting comparison to impervious factor because their areal extents have a presumed inverse relationship.

BMP data could be extended to include runoff mitigation sites in developed areas. These would help refine impervious factor analysis. There is no known database of mitigation sites, although some may be maintained by county planners or approximations may be developed from developing areas where zoning requires runoff mitigation planning. Data mining and feasibility studies for database creations would be an essential preliminary step.

Estimated cost: $35,000 - $75,000 per survey.

Wetland Function – Wetlands play multiple roles in the management plan: as goals of the plan, as management tools, and as geoindicators. The existence of wetlands alone contributes to the goal of achieving biodiversity and habitat. In addition, wetlands are a management practice; increasing wetland acreage will increase the functions of wetlands and achieve other goals. For example, water quality improvements can be made by increasing wetland area, which will increase floodwater storage and remove more suspended sediment. Finally, wetlands and their functions are geoindicators that can be used to determine the state of watershed health, need for management, and success of management strategies.

Wetlands perform a number of known functions, including providing habitat for flora and fauna;

providing hydrologic functions such as flood control, stabilizing channels and banks, and sustaining low flows; providing water-quality improvements such as denitrification, removing sediments and adsorbed metals, and others. However, the quantity of each wetland function likely depends on the type of wetland and its setting.

Scope of current wetland research and monitoring

The vast majority of current wetland research and monitoring in the Illinois River Watershed is done on a project-specific basis. Different governmental agencies, non-governmental organizations (NGOs), and private companies and individuals are performing or funding wetland restoration and creation, and they require widely varying levels of monitoring. Significant wetland restoration and creation projects are either funded or regulated by federal and state agencies under various governmental programs, including the U.S. Army Corps of Engineers (Section 404), Illinois Environmental Protection Agency (319 Program), the Natural Resources Conservation Service (WRP, CREP), and others. Unfortunately, the data are not being collected in a systematic or uniform manner due to the differing guiding regulations. No known systematic wetland research or inventory is underway throughout the Illinois River watershed other than the National Wetlands Inventory from the 1980s, which is now out of date.

Establishing Goals and Monitoring

If wetlands are to be studied as a measure of the Illinois River watershed, it is first necessary to determine what wetland parameters need to be monitored. This can only be done in the context of the goals of the Illinois River management plan, because each function of a wetland will impact the goals of the management plan differently.

Unfortunately, the location of Illinois wetlands, the magnitude of their functions, and their impact on the management goals is not fully known and is not being determined by the project-specific monitoring that is currently underway in the watershed. Therefore, it is necessary to establish a research program that identifies and quantifies the functions of the various types of wetlands throughout the watershed and determines how each function helps fulfill the goals of the management plan. With that information, the steps that should be taken to maximize the benefits of wetlands toward fulfilling the goals of the management plan can be determined.

In the interim, it may be possible to use indicators or data collected at reference sites as a partial substitute for basin-wide data. Indicators may include such as total wetland acreage, duration and frequency of flooding, sedimentation rate, water quality, and others. Some goals, such as increased habitat and flood storage, are directly related to total wetland area, although the magnitude of the function provided by each type of wetland will differ widely. Other goals may not be described well by indicators, and it may be preferable to use studies of reference sites to infer the health, function, and status of Illinois wetlands before and after the management goals are being implemented. The few wetland studies in Illinois that identify or quantify wetlands functions may act as a guide to the indicators that can be used.

Estimated cost: None can be specified at this time.

Sediment and Water Quality - Goal 7 of the Comprehensive Plan calls for improvements in sediment and water quality. Progress towards this goal is expected to be the passive result of restoration projects not directed at sediment and water quality, however. Nonetheless, monitoring must be conducted in order to determine whether or not there is progress towards these goals.

Various federal and state agencies have monitoring plans for water quality and sediment quality (e.g., LTRMP 1999; IEPA 2002). They employ a wide range of biological, chemical and physical indicators to develop indices of the "quality" of the waters in Illinois. Results from these investigations are difficult to integrate, however. The level of spatial coverage and frequency of sampling vary from agency to agency. More importantly, results from different monitoring activities are not be readily comparable due to differences in sampling and analytical protocols. Stream sediments are often collected with various surface grab samplers with no further treatment (Rhoads and Cahill 1999). Other protocols specify variously subsampling sediment by wet or dry sieving at various size fractions ranging from 63 micron to 2 mm (Adolphson et al. 2002; LTRMP 1999; IEPA 2002).

To resolve these issues and to gauge systemic responses of sediment and water quality to restoration activities, a program should be established at IDNR to collect water and sediment quality data in key watersheds of the Illinois River. The program would obtain water and bulk sediment samples to be analyzed for a suite of nutrients, inorganic contaminants, and organic contaminants following methods of Rhoads and Cahill (1999). Monumented sites on high to small order streams would be reoccupied cyclically complete a basin-wide assessment every ten years. Robust statistical techniques have been developed for evaluating temporal and spatial trends in geochemical data, although they may require tuning to the specific needs of this project (Singh 1993; Singh and Nocerino 1995; Singh et al. 1994). A manual for standard methods of collection and analysis would be developed to ensure long-term data reliability. Elements of both a critical and desired program are outlined below. These programs are in addition to those suggested in the Aquatics plan, because the Aquatics protocols are specifically directed to habitat and fish-toxicity issues.

The decadal analysis of the dataset would include a survey of results from other geochemical monitoring programs.

Phase I (Critical and Desirable Programs)

1) Identify the lead agency and PI for project. 2) Prioritize stream sampling locations. 3) Develop sampling, analytical and data storage procedures. 4) Hire a fulltime field/database technician (s).

Estimated cost: $35,000 to $70,000.

Phase II (Critical Program)

Stream water and sediment samples will be collected annually from major tributaries to the Illinois River and 10% of the watersheds or surface area. Annual sampling will be cycled so that all watersheds are sampled at least once sampled in ten years. Five key sites will be sampled annually. Approximately 250 water and 125 surface sediment samples should be obtained. Water samples will be analyzed for nutrients, inorganics and standard water quality parameters ($14,000). All sediment samples will be analyzed for nutrient and inorganic contaminants, and a subset of 50 will be analyzed for organic contaminants ($28,000).

Estimated cost: $95,000/year, including supplies, overhead, and 1 FTE.

Phase II (Desirable Program)

Stream water and sediment samples will be collected from major tributaries to the Illinois River and 20% of the watersheds or surface area. Annual sampling will be cycled so that all watersheds are sampled at least once sampled in five years. Ten key sites will be sampled annually. Approximately 500 water and 250 surface sediment samples should be obtained. Water samples will be analyzed for nutrients, inorganics and standard water quality parameters ($28,000). All sediment samples will be analyzed for nutrient and inorganic contaminants, and a subset of 100 will be analyzed for organic contaminants ($56,000).

Estimated cost: $185,000/year, including supplies, overhead, and 2 FTEs.

ECOLOGICAL MONITORING PLAN - AQUATIC

The mainstem Illinois River is comprised of six impounded reaches of varying lengths and habitat characteristics. The upper river is generally characterized as a narrow valley, with a more swift current due to a higher gradient. The lower river has a lower gradient and is characterized as an alluvial floodplain (Starrett 1971). These physical differences translate into distinct differences in geomorphology as well as habitat structure and complexity and may, in part, contribute to divergences in biotic and abiotic variables between the upper and lower river (Baker et al. 1991; Lamouroux et al. 1999). For example, recent studies of fish populations in the Illinois River have suggested two distinct fish communities that are consistent with geomorphic differences (Pegg and McClelland in press). The first community is generally comprised of the lower three pools; whereas, the second community is made of fishes found in the upper three pools. This and other similar information provides useful insight into how monitoring data should be collected along the mainstem Illinois River. Further, any data collected at this level should provide information at resolutions covering impounded, upper/lower division, and entire river to assess ecosystem responses in the context of the restoration goals is recommended. Therefore, a sampling design that ensures complete coverage of all pertinent hierarchical scales.

Sampling for aquatic biota will be structured in a stratified random block design with dominant habitat types being the lowest sample unit. This is a common experimental design and one that is currently used through the Environmental Management Plan's (EMP) Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River Basin. While the variables that should be measured along the Illinois River may differ slightly from that of the LTRMP, the proposed sampling framework will philosophically follow the LTRMP's design in most respects (e.g., Gutrueter et al. 1995). The premise of this design is that the sample sizes are structured such that they are weighted by the size of a given study reach and the available habitats found within that reach.

Measurable changes in biotic communities to restoration practices will likely occur through both relatively simple, direct responses as well as through more complex secondary or higher order interactions. The organisms that can provide information on these responses are varied and complex in themselves ranging from microscopic fungi to larger fish and water birds (Table 3). All of these taxa can provide valuable information, but some are better suited for monitoring due to sampling logistics and public/scientific perceptions of value. Therefore, it is critical to enure that any taxa measured will provide meaningful information towards detecting systemic transformations. The following provides a general overview of the critical and desirable response measures (with their associated justifications) for monitoring on the mainstem Illinois River.

An important aspect to note is that the sample sizes recommended for each measure do not indicate exclusive sampling efforts for each measure. In most cases, data needed for each measure will be collected simultaneously at each site to improve cost efficiency.

Biotic indicators used to assess ecosystem health and responses to restoration are not well developed for larger rivers like the Illinois River, but there are a few regionally developed indices that may provide some broad initial guidance on community responses until an Illinois River specific index can be developed (e.g., Wisconsin River and Ohio River indices) through focused research. Developing ecological indicators for large rivers presents several challenges relative to non-wadeable streams. Reference sites are absent, since nearly all large rivers in temperate latitudes have been significantly altered (Benke 1990; Dynesius and Nilsson 1994). Natural variation in life-history, adaptations to environmental conditions across a biological hierarchy, and within indicator metrics (e.g., richness, growth, proportion of large river species) is much greater within the geologic, climatic, latitudinal, and longitudinal landscape of rivers than for wadeable streams where many of the existing indices were developed. For example, tolerance to turbidity in native riverine fishes is an important variable used in many indices. However, the actual measured metric can have highly different meaning in the context of where the fish evolved. Much of the mainstem Missouri River has historically been very turbid and the fish are therefore well adapted to high turbidity, whereas natives fishes in the upper Mississippi and Illinois rivers are less well evolved to cope with high turbidity conditions. The interpretation of a high score in the turbidity tolerance metric could then have very different meaning depending on which system is being assessed. However, the need to communicate environmental information to decision makers in an understandable fashion is essential if ecological assessments are to affect public policy and benefit the resource. The challenge for developing ecological indicators in any focused research will be to disentangle the complex interactions between natural environmental variation and effects of human activity on the landscape (Bryce and Hughes 2003), and effectively communicate this information to the public (Schiller et al. 2001). However, we expect that some elements of this mainstem data set will likely show ecosystem responses in terms of the restoration goals. Many of these elements will likely be included in any indicator developed for the Illinois River and will therefore still provide valuable and meaningful information on their own. These measures may include items like shifts in community composition, improved abundances of native species, and many of the same metrics calculated in the sub-basin and project specific evaluation scales (Table 4) as structure and function are systemically improved. The thrust of the proposed monitoring effort therefore is focused on judicious data collection that will provide insight into individual biotic responses and also feed information into a myriad of potential comprehensive biotic metrics that can be used to measure ecosystem responses to the IRER goals.

Critical Response Measures:

Fish - Fish have been used widely in the past to document changes to various ecosystems (e.g., Karr 1991). This group of organisms are valuable because they are found throughout the mainstem Illinois River and provide a cumulative reflection of many trophic levels to environmental changes including many of the expected changes that will occur through the IRER efforts. Additionally, a large amount of information can be gathered on this group with a relatively small amount of effort including species distributions, changes in species richness, changes in community structure and function, population dynamics data, growth rates, and many other categories that have all been used to classify the 'health' of fish communities (e.g., Karr 1991). These responses can also be measured at multiple scales (i.e., mainstem, sub-basin, local) and through time that increases our ability to integrate our findings across multiple spatio-temporal scales. Finally, this group is an ideal selection for monitoring because the general public has at least a basic understanding of what changes in fish communities mean to an ecosystem.

The fish data collected through this monitoring effort will supplement three major on-going monitoring efforts in the basin 1) Long term fish population monitoring (F-101-R), 2) annual sampling by the IDNR through F-67-R, and 3) the LTRMP. All three data sets provide valuable information on the existing and historic conditions of the Illinois River in some capacity. However, each is limited in either spatial and/or temporal coverage of the mainstem. For example, the LTRMP samples fish populations throughout the La Grange Reach using a multiple gear approach, but provides no information on the remainder of the river. The other two projects are similarly hindered in that they sample at sites located throughout the mainstem river, but are conducted in only certain habitats and over a very limited time frame each year (late summer/early fall) and use only electrofishing gears that is biased toward sampling only shoreline habitats. Therefore, the proposed monitoring framework presented here should attempt to fill in the spatial and temporal data gaps to provide the best information possible on the fish community responses to the restoration goals. Ongoing research is attempting to evaluate the compatibility of these three data sets for future analyses but the results are not expected for some time. However, the LTRMP efforts use a multiple gear approach to characterize the fish community within a broad range of habitats (i.e., mainstem, side channel, backwater) compared to the other two projects. This aspect of the LTRMP is highly desirable and makes it a favorable approach the proposed framework should build upon to provide easy comparability.

Fish sampling protocols on the mainstem will typically follow the LTRMP with respect to gear selection, site selection, and data gathering (Gutrueter et al. 1995). Information from other reaches collected for IRER monitoring will therefore easily dovetail into existing data and monitoring efforts that should strengthen the overall capabilities of this monitoring program. However, a significant variation to the LTRMP sample design is that we recommend collecting seasonal fish data as weather conditions allow to provide data on seasonal habitat use and distributional patterns. Specifically, winter sampling will not breach the compatibility of the LTRMP and IRER data sets. Rather this adds an additional temporal dimension that is lacking in the LTRMP effort.

Linking existing with new data collection efforts can be relatively easily accomplished by simply expanding the level of effort used in the LTRMP to include the remaining reaches of the Illinois River that are not currently being sampled. The main assumption here is that the power to detect changes in the fish community will be similar to Lubinski's et al. (2001) findings for the Upper Mississippi River Basin. For example, annual LTRMP fish sampling in the La Grange reach typically collects about 450 samples per year from the dominant habitats available during the summer and fall. If this level of effort is scaled up to the entire length of the mainstem, then a proportionate number of samples that should be collected from the rest of the river would total about 1,100 over the same time frame. An additional river-wide effort of about 520 samples collected during the winter months should also be incorporated into the monitoring framework to ensure over-winter habitat use issues can be addressed. This level of effort is assuming all dominant habitats (main channel, side channel, connected backwater, unconnected backwater) sampled in the La Grange Reach are available in the same proportion throughout the river. Because the upper half of the river does not have an extensive floodplain like that of the lower river, it is reasonable to expect the actual number of sample sites to be scaled down appropriately as habitat availability is quantified throughout the basin. Therefore, the suggested sample sizes here should represent the maximum number of samples to be collected.

Aquatic Vegetation - Aquatic vegetation is an important component of riverine ecosystems because it provides nutrient remediation characteristics, stabilization of sediments and also provides habitat and food for many aquatic organisms. Therefore, aquatic vegetation is highly sought after and establishing or maintaining stands of aquatic vegetation have been the crux of many habitat remediation efforts along the river. Vegetation may also provide local and regional response information to restoration practices. In the lower half of the Illinois River, vegetation responses could be a very effective measure of the status of naturalized water levels (Goal 6) because it is currently thought that rapid and extreme water level fluctuations that presently occur are limiting factors for vegetation in the main channel border, side channel, and connected backwater habitat areas. Furthermore, because all dominant habitats will be sampled, aquatic vegetation data can be used to compare management strategies (i.e., connected vs. unconnected backwaters).

Submersed and emergent aquatic vegetation will be monitored using standard LTRMP sampling techniques (e.g., rake, quadrat, transects; Yin et al. 2000) at the same location fish sampling occurs. Where feasible and/or available, remote sensing technologies will also be used to measure stands of vegetation at all spatial scales. Remote sensing may considerably reduce field costs for this data collection effort in the future. Unfortunately, the costs are currently inhibitive and will require the vegetation monitoring to establish and maintain a large field component at present.

Macroinvertebrates - One of the more important taxa that can quickly identify localized changes in mainstem habitats are macroinvertebrates (excluding freshwater mussels). These taxa are important not only because of their rapid response to environmental change, but they also play a significant role in food web dynamics by breaking down organic matter into useable nutrients for themselves and other lower trophic organisms and also by providing a food source for higher trophic organisms like fish, birds, reptiles, and amphibians.

A limitation to using macroinvertebrates is their lack of mobility. Therefore, presence or absence of a species or group of species will likely provide localized to regional information on responses to the IRER efforts. However, their importance to the ecosystem warrants continual assessment at all spatial scales possible. Sampling methodology will should generally the ponar grab sample method used by LTRMP. This effort samples macroinvertebrates in all the dominant riverine habitats, but is limited in both temporal sampling and the level of analyses. The LTRMP effort currently only samples macroinvertebrates during one season (spring) at about 120 random sites (stratified by available habitat) within the La Grange Reach. These efforts should be expanded to include the entire basin and at least seasonal (4 times/year) sampling, if not a more frequent level of effort. Therefore, the level of additional work would be considerable (about 1,550 samples annually), but will likely provide more immediate response indicators than fish or aquatic vegetation that have longer life-cycles. Within this context, the macroinvertebrates should also be identified to the lowest taxonomic level possible rather than grouped into a few large categories as is the current standard protocol for the LTRMP (Thiel and Sauer 1999). Taking this approach will not preclude these data from integration with the LTRMP data, but will provide considerably more information on communities and their responses to the restoration goals beyond the very general information that is currently provided.

Water Quality - Water quality, while not a direct measure of biotic responses, can be extremely useful in measuring biotic associations and reactions to newly created environmental conditions. We propose to measure physical attributes of water quality like turbidity, conductivity, and flow rates as well as variables that can give information on nutrient availability like total nitrogen, total phosphorus, chlorophyll-a, etc. Data will also be collected to assess general habitat characteristics (e.g., substrate type, amount of structure, etc) of sample sites where biotic data collection occurs.

Standardized water quality sampling has been well established by the EPA, USGS, and other organizations. Many of those aspects have been included in the LTRMP protocols and we therefore recommend following the LTRMP water quality sampling protocols (www.umesc.usgs.gov/ltrmp.html). However, the location for sample selection and timing though should be slightly modified and will be at two levels. Ideally, a full suite of water quality and physical habitat data should be collected where any biotic sampling occurs. These data will be used to identify causal relations between physical and chemical improvements in the system. However, completing a full suite of water quality parameters for each site is not feasible. Therefore, physical water quality and habitat information (temperature, conductivity, dissolved oxygen, etc.) will be measured at each site, but other water quality information (nutrients, anions, cations) will only be collected at about 10 percent of the biotic sample sites from each habitat and reach combination.

Secondly, water quality monitoring should be at regular intervals (e.g., bi-weekly) throughout the year at a select few sites within each reach. The exact total number of sites should generally total less than 10 per impounded reach. Key sites would typically include headwater and tailwater, main channel, major side channel, tributary confluences of major tributaries, and other important sites as determined by the U.S. Army Corps of Engineers and State of Illinois.

The water quality monitoring effort described above does not include monitoring efforts that measure toxic chemicals (e.g., PCBs, atrazene, etc.) and heavy metals (e.g., mercury). These parameters are being adequately measured by existing water quality monitoring efforts through the USGS (National Water Quality Assessment program), USEPA, and the Illinois Environmental Protection Agency. Therefore, there is no need to expand the sampling effort in this area of water quality monitoring. An added benefit to using these data is that in many instances these contaminants are also measured in fish tissue providing another link between biotic and abiotic responses to ecosystem improvements.

Zooplankton - One potentially valuable indicator of system productivity that is not currently measured through any existing monitoring program is zooplankton. These organisms are at the lower end of the food-web and may be valuable indicators of system productivity. In this context, zooplankton may show the most rapid systemic response to IRER restoration goals due to their position in the trophic level. Very little information is available on zooplankton communities throughout the river other than a few short-term studies that have largely focused on ancillary issues to monitoring such communities (Kofoid 1899; Emge et al.1974; Goodrich 1999). Therefore, it will be important to collect zooplankton community structure and abundance data throughout the river. Sample collection is relatively simple and should follow methods highlighted in Lemke et al. (2003) or similar sampling protocols at sites where other biotic information are being collected.

One drawback to this approach is that identification can be time consuming and require a relatively high level of training in the laboratory. However, their ecological significance makes them a desirable taxa to monitor. A simple means to determine the scale of information needed will be to evaluate zooplankton community and structure data through focused research at the beginning of the monitoring effort. This evaluation will primarily use saturation curves to refine the exact number of samples required to make sound assessments of this diverse group of organisms without losing significant information.

Estimated cost: $525,000 for the first year and $475,000 for subsequent years.

***Desirable Response Measures*:**

Mussels - Freshwater mussels are likely one of the more sensitive groups of organisms to environmental change in lotic systems. They are certainly one of the most threatened groups of organisms in North America and as a result warrant attention (Cummings 1991). Multiple gear approaches have been used in the past to characterize mussel communities suggesting a multi-gear approach as most the effective sampling approach to gather information. Typically these gears include using divers, braille rails, and dredges. Using these collection techniques can also be somewhat cost inhibitive. This is especially the case if divers are required as this type of diving necessitates better than entry level expertise and experience. The typical life-cycle of these organisms is such that measurable responses to ecosystem improvement may take may years. However, freshwater mussels are extremely sensitive to negative changes in environmental conditions. This makes mussels a valuable data source because they may be good measures to an unexpected biotic response from management practices or restoration efforts. There are some limited data collection efforts in the Illinois River that are conducted by the IDNR during commercial harvest periods. However, these data are usually limited to a specific area that is marked for harvest each year and not comprehensive. Data collection for this taxa would likely be somewhat different than that identified for the other biotic components. Community measures would largely focus on sampling known mussel beds to monitor shifts in communities at representative locations throughout the river.

Estimated cost: Additional $75,000 per year.

ECOLOGICAL MONITORING PLAN - TERRESTRIAL

In its pristine condition the Illinois River watershed was a very diverse system. Communities associated with the riparian zone alone included upland forest, mesic prairie, wet meadow, shallow marsh, deep marsh, shrub wetland, floodplain forest, deep water, channel, shallow water, and hill prairie (U.S. Fish and Wildlife Service). Diverse plant communities along the river supported incredible wildlife abundance and diversity with may species highly adapted to specific habitat conditions. The river and its wetlands were once considered one of the most productive fishing and waterfowl hunting areas in the United States (Bell 1981).

Many wildlife species still spend part of the year along the Illinois River and the streams in its watershed, from year round residents to species found there only during migration, and entirely terrestrial species to those found on land for brief but critical stages of their life. Wildlife use the Illinois River, its tributaries, and the lands found along them as a continuum and the boundaries of legally defined floodplains, riparian zones, and wetlands mean little to animals. In addition, the aquatic-terrestrial interface is dynamic, at one time changing gradually on a seasonal cycle, now it changes rapidly and on a much shorter cycle. Rapid changes in water depth and position of the interface force major changes in wildlife distribution and use of habitat. Many wildlife species found in the watershed have declined significantly. For some species, such as waterfowl, declines are well documented, but relatively little is known of the current and former status of many others.

Monitoring of wildlife abundance and quantification of their habitats is very intensive. Even species that use similar habitats require different sampling methodologies. Therefore, indicators have drawn interest for monitoring of environmental conditions and methods have been tested using birds and amphibians. Wildlife are particularly attractive as potential indicators because they integrate the cumulative effects of environmental stresses. Across species groups there may be redundancy in their responses. However, due to differences in the ecology of different species and species groups, and because some species are subject to stressors outside the Illinois River system none can be used as a single indicator for all the others. Many species have become so rare that they warrant monitoring their status alone.

Maintenance and restoration of community and species level biodiversity is an over arching goal of the Illinois River restoration program. Biodiversity within the Illinois River basin is an important component of biodiversity within the state of Illinois. Many wildlife species by themselves integrate factors at multiple spatial scales and specific relationships are difficult to quantify, but wildlife components taken together provide an excellent biodiversity and system integrity indicator for the Illinois River watershed as a whole.

Wildlife monitoring is intended to build on current monitoring programs. However, because most programs are not designed to assess conditions strictly along the Illinois River and its tributaries, do not collect data at enough points for a statistically useful sample at the sub-basin or watershed scale, or are not designed to evaluate responses from restoration efforts, they do not adequately provide for the needs of this program. The objectives of the wildlife/terrestrial monitoring component are to use wildlife and terrestrial vegetation measures to quantify habitat conditions and indicate watershed protection, to suggest protocols that can be used to assess wildlife and vegetation response to restoration, and provide measures that are scientifically sound and interpretable by the general public. Wildlife and vegetation monitoring should compliment other aspects of the overall monitoring program. Development of this monitoring protocol is ongoing and must remain adaptive after monitoring begins.

Some data will only be collected along the mainstem, some only in sub-watersheds, and some will be collected in both areas. Monitoring of critical response measures includes 10 programs with 14 components (Table 5). Some components rely entirely on analysis of data collected under existing programs or require adding additional sampling points to existing programs. Other components use existing programs as a framework to build a program designed specifically for the Illinois River watershed.

Sampling Considerations & Data Analysis

Caution should be exercised in evaluating the results of restoration practices. Many projects, for example riparian forest establishment, will take time to develop and anticipated species response could take many years. Intensive monitoring of birds, plants, and amphibians should detect subtle changes and document restoration trajectory.

Data at specific monitoring points, project areas, within sub-basins and mainstem, and for the entire watershed should be evaluated over time. Data should be summarized and reported at each spatial level to indicate status and success of restoration activities for each scale. Statistical comparisons between sampling units should be avoided but qualitative comparisons can be made.

Sauer et al. (2003) provides an excellent treatment of considerations and analyses for estimating population change for different types of monitoring data. For monitoring components surveyed annually, an assessment should be made after 5 years, incorporating observed variation, to determine if sample sizes are suitable for detection of response and whether strong relationships exist between variables.

Critical Response Measures:

B. Wetland habitat communities in floodplain - Landscape assessment using remote sensing is a powerful tool for quantifying small scale patterns and major habitat deficiencies. However, wildlife utilize habitat at much larger scales and remote sensing is inadequate for accurately distinguishing different community types. Aerial/photographic survey of floodplain habitat or spatial assessment with intensive ground-truthing provides a more accurate and detailed assessment of the amount of each wetland community type within the floodplain. This is particularly important because a change in wetland community by degradation may remain undetected using only remote sensing and many wildlife species, while sensitive to landscapes, make use of habitat at smaller scales. In addition, several important wetland community types (i.e., submergent, floating leaved, emergent, and moist soil) have become rare along the Illinois River as a result of major hydrologic fluctuations.

The USGS Upper Midwest Environmental Sciences Center provides a community level coverage along the Illinois River mainstem for the Long Term Resource Monitoring Program (LTRMP) once every 5-10 years. A sub-community level classification is produced for the entire mainstem using a combination of aerial photography and expert interpretation. The LTRMP community level data should be used to monitor changes in community composition over time for the entire mainstem, river segments, and for project areas. Community level assessment of sub-basin riparian areas is not recommended because of lower overall diversity of communities in sub-basins and cost to complete classifications for all riparian area throughout the watershed.

Community level assessment relates to Illinois River restoration goals similar to landscape level assessment but at a higher spatial resolution. Vegetative communities along the Illinois River mainstem have been affected primarily by altered hydrology and sedimentation. Vegetative response in some mainstem wetlands has been rapid when hydrologic conditions have been temporarily restored during drawdowns or drought (USGS 2003). Therefore successful hydrologic restoration is the key, and combined with measurable reduction in sediment could result in rapid increases in target plant communities.

Estimated cost: $1,000.

D. *Waterfowl* - Historically the Illinois River was a nationally significant waterfowl area with wetlands along the river providing important feeding and resting habitat for waterfowl during migration (Bell 1981, Havera 1999). The Illinois River still provides important waterfowl habitat, however, years of surveys have documented dramatic declines in waterfowl along the river. While many waterfowl species have declined in numbers resulting from loss of habitat in their nesting areas, the decline in use of the Illinois River can also be attributed to habitat loss and degradation and a resulting shift in migratory stopover patterns. For example, diving ducks were once found in large numbers along the Illinois River but shifted their use to the Mississippi River and other areas following the loss of their preferred food sources (Havera 1999). Differences in habitat preference among waterfowl species make their numbers a potential indicator for many habitat types.

The proposed waterfowl monitoring program will supplement existing fall and winter surveys conducted by the Illinois Natural History Survey (INHS) and the Illinois Department of Natural Resources (IDNR) by reinstituting spring migration surveys. The spring surveys will be used to determine waterfowl response to spring habitat conditions. Spring surveys should be conducted weekly from mid-February through April. Selection of monitoring sites for both spring and fall/winter surveys should be based on the experience and expertise of INHS & IDNR biologists. However, monitoring sites should not be limited to areas that already support high numbers of waterfowl resulting from higher quality habitat. Monitoring of potential or historically important waterfowl habitat areas may be a means to track restoration progress. In addition, the list of potential monitoring sites should be updated periodically to include new areas that develop following restoration efforts.

Waterfowl species that still make use of the basin are expected to respond quickly to changes in habitat conditions. Some annual change in waterfowl numbers reflects habitat quality on nesting grounds. Differences in migration use-days between Illinois River habitat areas probably better reflects relative habitat quality between sites. Species with reduced use of the Illinois River basin may take longer to respond depending on the level of change and the annual variation of habitat conditions for different areas.

Monitoring of waterfowl relates strongly to restoration goal one of restoring and maintaining a diverse waterfowl population and sustainable populations of all species. Waterfowl should also respond to improved aquatic habitat diversity and efforts to improve riparian habitat and function.

Estimated cost: $38,000.

E. Wading birds and cormorants - This group includes relatively common species such as the great blue heron and several rare species listed as endangered or threatened. Optimal habitat for wading birds depends on very specific hydrologic conditions. Ideal conditions allow backwaters to fill from the adjacent river during flood stage allowing fish to enter, followed by a slow draw-down which creates foraging opportunities for these birds as fish are stranded in small pools (Gawlik et al. 2003). These conditions are most critical for medium and small wading birds because they tolerate a narrower range of water depths. Hydrologic conditions along much of the Illinois River prevent adequate fish use of wetland areas or appropriate foraging conditions for most species.

Colonial nesting waterbirds are also sensitive to disturbance and rookeries are typically found some distance from high levels of human activity. Most species prefer mature trees for placement of nests. High mortality of floodplain forest trees has resulted in fewer potential nest sites in some areas.

Monitoring will include an aerial survey conducted annually to document rookery locations, followed by intensive ground monitoring of all known rookeries to document the number of active nests. Monitoring will be confined to rookeries found along the Illinois River mainstem. If monitoring of all mainstem rookeries becomes cost prohibitive, a random sample can be selected for monitoring. However, all nest areas that contain cormorants, rare herons or egrets should be monitored. Data should be used to document and map all rookeries, and summarized by number of active nests by rookery and by species.

Herons, egrets, and cormorants are good indicators of hydrologic conditions, fish populations, and riparian forest structure. A response in rookery distribution and numbers will be most rapid following hydrologic restoration, provided nest trees are present in an area. Anticipated response time is 5-10 years. Species diversity and abundance of colonial nesting waterbirds is expected to increase at the mainstem level over a longer time period following restoration progress, including forest maturation.

Estimated cost: $25,000.

G. Shorebirds - Many species migrate through Illinois in large numbers but few species breed here. Most shorebirds require protected beaches or predator-free islands for nesting, and show high fidelity to nest sites. The altered hydrology and flows on the Illinois River have eliminated stable islands. Suitable foraging habitat is found in shallow water areas and mudflats, but major water level fluctuations results in this habitat being present for short periods.

Shorebirds make use of a range of areas during migrations. Some species use ephemeral wetlands in agricultural fields as stopover habitat during wet springs. Similar to other riparian associated species, route based surveys have limited utility for most shorebirds (de Szalay et al. 2000). Monitoring should be targeted to unique habitats within riparian areas, areas utilized every year, and breeding species. Fall water levels currently provide the most suitable habitat for shorebirds within the Illinois River basin, therefore abundance during spring migration should be emphasized as an indicator.

Some monitoring is being conducted opportunistically within the Illinois River basin (Horath et al. 2002) but the program should be greatly expanded. Sampling should include all or a random sample of known and potential habitat areas along the mainstem and tributaries. The International Shorebird Survey (ISS) protocol (Manomet Center for Conservation Sciences 2004) will be used at selected sites. The ISS spring surveys are conducted April 1 through June 10 and fall surveys July 11 through October 31. Complete surveys are difficult to achieve for large and diverse sites, therefore an estimate must be made of the habitat type and area observed. Sampling can be done from selected vantage points within a habitat area. Summary analysis for habitat areas and for the entire mainstem should include migration use-days for all shorebirds and by species. Potential Illinois River basin breeding species are a target indicator because their use may reflect basin factors over a longer time scale.

Estimated cost: $50,000.

H. Bald eagles and ospreys- Bald eagles and ospreys utilize similar habitat. Both species build their nests in large, usually dead trees near open water and forage primarily on fish. The habitat requirements of both species are similar to herons, although they usually forage in deeper water than wading birds. Eagles may exclude ospreys from breeding territories but osprey nests have been documented in heron rookeries. Both species are recovering from population lows in the 1950's and 60's, and they are both considered rare in Illinois (Havera and Kruse 1988). The number of eagle nests is increasing along the Illinois River but no osprey nests have been documented in recent years. Restored habitat along the Illinois River, including management for mature riparian forests or construction of nest platforms near suitable foraging sites but away from human disturbance may result in further increases in nesting activity by both species. Foraging conditions will benefit from improved water quality and generally lower water conditions in backwater lakes and side-channel areas.

Monitoring will build on existing programs and emphasize numbers of nesting eagles. Breeding activity and success should be monitored by maintaining a database of nests, mapping known nest sites, and soliciting reports of new nests from biologists and the public. All nests or a subset of nests should be checked 3 times during the nesting season to determine the proportion of nests occupied and number of young fledged (IDNR protocol – Glen Kruse, personal communication). In addition, winter habitat conditions for eagles should be assessed using the IDNR mid-winter eagle survey. Similar to many other Illinois River wildlife species, eagles and ospreys respond directly to habitat conditions over relatively small areas but integrate the indirect cumulative effects of hydrology, sedimentation, and pollutants over large spatial scales.

Estimated cost: $2,000.

N. Aquatic reptiles - Aquatic reptiles are a relatively unstudied component of large river systems. In part, this results from difficulty in monitoring them at large scales. Many species are thought to be rare or declining. Moreover, this group provides excellent indicators of both aquatic and terrestrial components of riparian systems because they forage in water, reproduce on land, have unique habitat requirements, and some are extremely sensitive to water quality. Amphibians and fish are an important forage component for many aquatic reptiles. Both snakes and turtles require basking sites during spring and early summer when morning temperatures are cool. Water snakes (genus Nerodia), and probably aquatic turtles, require shallow wetlands with gentle slopes at the land-water interface (Laurent and Kingsbury 2003).

Monitoring should be conducted along the mainstem in 30 randomly selected side channels and backwater areas. Monitoring at each site will include basking transects to record numbers of snakes, turtles, and basking sites, location observed, and basking substrate. Run transects by kayak adjacent to the shore line. Because some aquatic turtles are sensitive to water quality, turtle trapping should also be done at each site to determine aquatic turtle community composition and species richness. Monitoring should be conducted from April through early June when basking behavior is most common and before vegetation becomes too dense (Laurent and Kingsbury 2003).

Estimated cost: $27,000.

Other measures - Several proposed wildlife/terrestrial habitat response measures are sampled by HUC 8 units, including both mainstem and tributary HUCs (Table 10). The response measures that include both mainstem and tributary HUCs include: landscape habitat composition, site-specific habitat/vegetation, bottomland/riparian forest and grassland birds, marsh birds, amphibians, and terrestrial mammals. The sampling protocol for these measures are explained the Sub-basin - Ecological/Terrestrial Section. Estimated cost for the mainstem component of these measures follows.

Estimated cost: Landscape habitat composition and metrics (A) - $3,000; CTAP based intensive monitoring of site-specific habitat/vegetation ©), bottomland/riparian forest and grassland birds (K & L), marsh birds (F), and amphibians (M) - $252,000; Terrestrial mammals (I) - $6,000.

Desirable Response Measures:

O. Avian reproduction - Abundance of breeding birds does not necessarily indicate functional habitat quality. Reproductive success may be low even where adult abundance is high (i.e., sink habitat). High quality habitat patches may suffer from landscape or patch fragmentation effects due to high rates of nest predation and parasitism. Therefore, avian reproductive success integrates many factors and provides a good indication of functional habitat quality at the patch and landscape levels.

To evaluate nest success, five sites per habitat (i.e., forest, grassland, wetland) in each sub-basin should be monitored from roughly April to July. Similar to bird monitoring, each sub-basin will be monitored once every 5 years. Nests should be monitored once every 3 days during the active nest cycle and analyzed using the Mayfield method (Mayfield 1975). Nest success should be analyzed by species, reproductive guild, and community, and can be summarized within watershed units.

Avian reproductive success integrates large spatial scales but is expected to respond slowly to restoration efforts. Wetland or grassland breeding avian species will respond more quickly than forest breeding species because herbaceous communities develop more quickly following restoration than forests. A detectable response in reproductive success will probably only be seen following significant increases in habitat patch size and a long period of time for habitat development. Detectable changes in forest bird reproductive success may not be observed for at least 30 years.

Estimated cost: $41,000.

P. Amphibian reproduction - Amphibian embryos are extremely sensitive to environmental conditions. Successful reproduction by amphibians depends on hydrology, water chemistry, and specific habitat requirements (U.S. EPA 2002b). Amphibians require fishless wetlands for successful reproduction and different species prefer different microhabitats for egg deposition. Counts of egg masses provide an indication of breeding effort and the proportion of viable egg masses indicates wetland health (U.S. EPA 2002b). Amphibian adults and embryos are sensitive to many of the same factors with embryos more sensitive than adults. Amphibian egg masses can be used to detect non-vocal species, including salamanders, not detected using call-based surveys.

To monitor amphibian reproduction, a random sub-sample of 15 of the selected amphibian monitoring sites in each sub-basin should be selected. Potential sample sites can be from any of the three habitat types (i.e., forest, grassland, wetland) where calling amphibians were detected. Data collected should include egg mass counts by species and proportion of viable eggs per egg mass. Two visits should be made to each site to detect all breeding species at a site.

Similar to frog and toad call counts, amphibian reproductive effort is expected to respond quickly to improving habitat conditions, particularly hydrology and water quality. Diversity of breeding amphibians provides an additional indicator of habitat complexity. Viability of amphibian eggs generally provides and indication of environmental conditions, potentially at a scale beyond the Illinois River basin.

Estimated cost: $6,000.

HYDROLOGIC AND SEDIMENT MONITORING PLAN

The Integrated Management Plan for the Illinois River watershed had identified sedimentation and un-natural water level fluctuations as the two major causes for ecological degradation in the Illinois River. After extensive discussions and investigations, the Illinois River Basin Restoration project team has identified seven ecosystem restoration goals for the basin. Even though all of the seven goals are related to the hydrology and sediment transport and deposition characteristics of the rivers and streams in the basin, five of the goals address sediment and hydrology directly. These goals are:

- Reduce sediment delivery to the Illinois River from upland areas and tributary channels with the aim of eliminating excessive sediment load.
- Restore aquatic habitat diversity of side channels and backwaters, including Peoria Lakes, to provide adequate volume and depth for sustaining native fish and wildlife communities.
- Improve floodplain, riparian, and aquatic habitats and functions.
- Naturalize Illinois River and tributary hydrologic regimes to reduce the incidence of water level conditions that degrade aquatic and riparian habitat.
- Improve water and sediment quality in the Illinois River and its watershed.

To achieve these goals, a much better understanding of the hydrology and sediment transport and deposition characteristics of the Illinois River and its tributary streams is needed. An effective hydrologic and sediment monitoring network will be vital to a successful restoration program for the Illinois River. This proposed monitoring network will not only provide data that can be used to measure progress towards meeting the goals of the program but will provide the information that is needed now to effectively and efficiently begin implementation of the Illinois River Basin Restoration Project. The hydrologic and sediment monitoring plan presented here is developed to address these needs.

Monitoring Goals & Objectives

It is proposed that a long-term network of streamflow and suspended sediment monitoring sites be established within the Illinois River Basin (IRB), building upon the existing stream and sediment monitoring stations operated by the United States Geological Survey (USGS) the United States Army Corps. of Engineers (USACOE), and the Illinois State Water Survey (ISWS). This monitoring network would have three goals: 1) assess the current hydrologic regimes and suspended sediment transport rates occurring within the IRB; 2) monitor and quantify any changes in hydrologic regimes and suspended sediment transport rates that occur in the future; and 3) evaluate the impacts of restoration projects on stream hydrology, sediment transport and sedimentation. The proposed network will accomplish these goals by providing crucial data needed to help meet the following objectives:

Establish a more detailed and improved sediment budget for the Illinois River: As sedimentation is a major problem in the Illinois River, an accurate and frequently updated sediment budget describing sediment transport rates in the Illinois River and its 11 major tributaries is of primary importance for future river management decisions. The present sediment budget for the Illinois River Basin is our best estimate based on limited available data. The proposed monitoring plan will enable us to develop a much improved sediment budget for the Illinois River basin. With an improved sediment budget resource managers will be better able to establish current or baseline conditions, target restoration efforts, determine basin wide trends over time in sediment loads and delivery and improve our understanding of the codependency of factors influencing the ecological status of the Illinois River and its tributaries.

Identify drainage areas with the highest sediment yields: A detailed sediment budget describing the sediment transport rates of different tributaries, physiographic regions, and stream sizes will determine which types of streams/watersheds have the highest sediment yields within the IRB. In turn this data will provide for an efficient allocation of restoration efforts by allowing managers to prioritize efforts within those areas where the greatest return can be expected.

Evaluate the impact of site specific projects, watershed BMPs, changes in land-use, and climate variability: Monitoring the hydrology and sediment transport rates occurring before and after specific projects/BMPs have been implemented within a stream and/or watershed will provide much needed information regarding the effectiveness of implemented work. Similarly, monitoring the hydrologic and sediment regimes of a watershed before and after land-use changes occur will provide information on how land use affects hydrologic regimes and suspended sediment transport rates. Long-term hydrologic records within a variety of watersheds are also essential for evaluating and accounting for the effects of climatic variability when determining any long-term hydrologic trends within the IRB.

Provide flow and sediment data on small to medium size streams: Many of the important hydrologic, hydraulic, and sediment processes crucial to determining the Illinois River's overall flow regime, sediment transport rates, and ecological health depend on the processes occurring within the small- and medium-sized streams within the basin. Long-term flow and sediment data collected on small- and medium-sized streams are necessary for evaluating the effects that tributaries have on the ecology of the Illinois River through such mechanisms as sediment deposition and their effects on river stages.

Provide calibration, validation, and boundary condition data for the many numerical models likely to be used in studying and developing Illinois River management plans: Many of today's water resource questions are being answered through the use of numerical models that simulate hydrologic, hydraulic, and sediment transport rates. These models allow resource managers to interpret how proposed restoration projects affect not only the project location but how specific projects may influence other components of the system at different spatial scales. To calibrate, validate, and run these models, long-term flow and sediment data are needed. The proposed network will significantly increase the availability of such information in the IRB.

Quantify basic hydrologic parameters for use at ungaged locations within the IRB: The hydrologic and sediment transport properties of many ungaged watersheds will need to be estimated using hydrologic and sediment data collected from watersheds that have similar characteristics. Implementation of the proposed network will provide the required data for watershed models and regional statistical analysis techniques that can be used to estimate hydrologic and sediment transport rates at ungaged locations within the IRB. This in turn will facilitate the planning, development, and evaluation of future IRB restoration projects and best management practices.

Monitor changes in channel morphology: Channel slope and cross-sectional shape are routinely used to compute many hydraulic and geomorphic relationships. The grain size distributions of a stream's bed material, bank material, and suspended sediment are crucial pieces of information used in computer models, sediment transport equations, effective discharge computations, and habitat assessments. The periodic collection of this data at monitoring sites throughout the IRB will provide basic information to hydraulic engineers, geomorphologists, and biologists on current conditions and how channel conditions are changing within streams over time.

Existing Monitoring Network

Streamflow Records - In Illinois there are currently 97 active continuous discharge gages in the Illinois River Basin (IRB) of which 89 are operated by the USGS and 8 are operated by the ISWS. The names and locations of these active gaging stations are presented in Table 11. Also identified in Table 11 are the 80 discontinued gaging stations in the IRB, the number of years over which data have been collected at each station, and whether these data are a full 12-month record (F) or partial (P) record.

The locations of active and inactive gaging stations in Illinois are given in Figure 4. Figures 5 and 6 show the active and inactive gaging stations on streams that have watershed areas less than 400 and 100 square miles, respectively. A review of these figures shows:

• Fifty-two (54%) of the 97 active stations are in the Chicago metropolitan area, specifically in the Fox, Des Plaines, and Chicago-Calumet watersheds. Most of these are in small urban (or urbanizing) watersheds (<100 square miles).

• In the remaining portion of the IRB, most of the gages are on larger watersheds, with drainage areas greater than 400 square miles. There are 19 stations in watersheds less than 400 square miles, 11 of which are located in the Sangamon River watershed (Figures 5 and 6).

• Outside of the Chicago area, there are 10 active gages on small watersheds (<100 square miles). Three of these watersheds are located either in urban areas or immediately downstream of reservoirs (Figure 7a). Of the remaining seven gages, only one has a continuous discharge record longer than 5 years. The other six gages, operated by the ISWS, have relatively short discharge records and are supported by short-term CREP and Lake Decatur research projects (Demissie et al. 2001; Keefer and Demissie 1996).

Suspended Sediment Records - In Illinois there are 21 active monitoring sites collecting suspended sediment data in the IRB. Figure 4 shows the locations of these sites. The USGS is currently collecting sediment data at six locations in the Illinois River Basin. The USACOE is currently collecting suspended sediment data at two locations within the IRB, while the ISWS is currently collecting suspended sediment data at the remaining 13 locations. Between 1972 and 2003 suspended sediment data have been collected at a total of 58 monitoring sites in the IRB. The names and locations of both active and inactive suspended sediment monitoring sites along with details regarding the amount of sediment data available at each of these gaging stations is described in Table 12. The drainage areas being monitored by the 21 active sites are shown in Figure 7b. The locations of these sites are given in Figure 8. Figures 9 and 10 show the locations of sub-basins where suspended sediment monitoring sites monitor basins with drainage areas of less than 400 square miles and less than 100 square miles, respectively. From the information in Figures 7-10 one can make the following six observations:

- Three of the 21 active sites are on the Illinois River while 13 sites are on major Illinois River tributaries with watershed areas greater than 400 square miles. Eight of the 13 suspended sediment sites on major tributaries are part of the Illinois State Water Survey's WARM network, which collect instantaneous suspended sediment samples once a week at various sites throughout Illinois (Allgire and Demissie 1995). Most of the WARM sites provide periods of record in excess of 20 years. Two of the monitoring sites on major Illinois River tributaries are monitored by the USACOE. Data has been collected at both sites since 1997. The remaining three sites, recently reactivated by the USGS, are located on the Fox, Des Plaines and Spoon Rivers.

- The 5 sites monitoring drainage areas less than 400 square miles are all within the Spoon and Sangamon River watersheds (Figure 9). Monitoring at these sites is supported by the short-term CREP research project.

- There are only two suspended sediment monitoring sites in the Chicago metropolitan area.

- None of the bluff streams that are within the mainstem Illinois River Sub-basin and drain less than 400 square miles are currently being monitored for sediment.

- If long term-support is not obtained to continue the sediment monitoring at the ISWS's CREP monitoring sites, no sediment monitoring will occur on streams draining less than 400 square miles.

- If funding is not available to maintain the ISWS 5 CREP monitoring sites and four USGS sites that began collecting sediment data this year (2003), the overall sediment monitoring network will be reduced from 21 sites to 12 sites in the next few years (Figure 7b).

The number of active sediment and discharge monitoring locations within the various major Illinois River sub-basins is shown in Table 13. From this table and Figures 8-10 it can be seen:

- That no sediment monitoring is occurring within three of the 11 major sub-basins of the Illinois River. These sub-basins are the Chicago/Calumet, Iroquois, and Macoupin sub-basins.

- Six Illinois River sub-basins have sediment monitoring sites only on the sub-basin's major river. These six sub-basins are the Des Plaines, Fox, Kankakee, La Moine, Mackinaw, and Vermillion sub-basins.

• The sediment loads representative of streams draining less than 100 square miles and flowing into nine of the Illinois River's major tributaries are not currently being monitored (Figure 10).

• None of the many bluff streams with drainage areas smaller than 400 square miles that flow directly into the Illinois River (found in the Illinois River sub-basin) are currently being monitored for discharge or sediment.

Shortcomings of the Existing Network

The current flow and sediment monitoring network in the Illinois River Basin is insufficient for addressing the many scientific and management questions which need to be answered in order to develop a sound river management program for the Illinois River Basin. The following paragraphs identify four major areas in which the current monitoring network fails to meet current monitoring needs.

Insufficient data to establish a detailed sediment budget for the Illinois River. Only about 70 percent of the major tributaries to the Illinois River are being monitored for suspended sediment. Moreover, as most of the monitoring records at these stations are based on weekly instantaneous suspended sediment samples, load values (particularly peak loads) transported during storm events may be poorly estimated (Allgire and Demissie 1995). Consequently, current sediment budgets for the Illinois River must be currently computed using limited and derived data (Demissie et al. 1992). To obtain a more accurate sediment budget for the IRB, suspended sediment sampling frequency needs to be increased at existing suspended sediment monitoring locations and additional suspended sediment sampling needs to be performed near the confluences of all the Illinois River's major tributaries. Without such basic monitoring our ability to understand and manage the numerous sediment problems within the Illinois River is severely hindered.

Insufficient long-term monitoring of small- and medium-sized streams. Outside the Chicago-metropolitan area virtually no long-term monitoring of flow and sediment is being conducted on small- (< 100 square miles) to medium- (< 400 square miles) sized streams. This lack of long-term monitoring on small- to medium-sized streams is problematic for several reasons. First, one cannot effectively monitor the impacts that watershed BMPs have on downstream conditions. Second, the sediment loads of small- and medium-sized streams cannot be easily estimated and incorporated into overall sediment budgets for the IRB (Demissie et al. 1992). Third, the data needed to perform geomorphic studies involving effective discharge, bankfull discharge, and stream restoration design for small streams is not available (Crowder and Knapp 2002). Similarly, a paucity of long-term flow monitoring on smaller streams prevents one from quantifying the effects that climate variability, and changes in land use have on the IRB's smaller streams (Knapp and Markus 2003).

No monitoring of sediment grain size distributions, bed load transport rates, and basic instream channel properties. Currently, streamflow and suspended sediment monitoring sites are not monitoring erosion/deposition rates, changes in cross-sectional shape, and channel slope. Nor are the grain size distributions of the channel's bed material, bank material, and suspended sediment being periodically measured. Such fundamental information is needed to run hydraulic/ hydrologic models and to use existing sediment transport equations. Additionally, such information can be used to provide a more detailed assessment of the existing hydraulic, ecological, and geomorphic conditions within the IRB.

No sedimentation monitoring program exists for the backwater lakes along the Illinois River. Current bathymetric and sediment characterization information does not exist for most of the backwater and floodplain lakes of the Illinois River. It is crucial to perform periodic bathymetric surveys for these lakes. Updated bathymetry and sediment characteristic data when combined with historical mapping products such as the Woermann maps will provide information on the processes that are occurring within these backwater lakes as well as insight into how sedimentation differs between lakes with respect to orientation, channel geometry, degree of connectivity to the mainstem, and/or inputs from local tributaries. This information will also be necessary for the development of site-specific plans for restoration efforts. Sediment volumes, existing or planned minimum depths, and areal extents of various habitat types and potential beneficial uses of sediment can all be determined for current conditions or calculated for different management alternatives.

The proposed monitoring plan consists of three components: mainstem monitoring, basin-wide monitoring, and project specific monitoring. The mainstem and basin-wide components focus on providing a network of monitoring sites and periodic bathymetric surveys to address long-term and systemic issues within the IRB. Based on the current monitoring network's shortcomings, it is recommended that the existing monitoring network be significantly enhanced by placing additional sediment and discharge monitoring sites throughout the Illinois River Basin. The proposed increases in sampling frequency and number of sites are intended in part to address two issues in understanding sediment yields and transport in the Illinois River basin: 1) what is the temporal variation in sediment delivery at selected sites, including changes over time resulting from best management practices (BMPs), and 2) what is the spatial variation in sediment across the basin? These data are needed before we can effectively predict which sub-watersheds are the major sources of sediment in streams so that we can more effectively address how and where to target restoration efforts. In both the temporal and spatial context we are currently trying to use a limited amount of sediment data to analyze a highly variable process.

Recent analysis of sediment records in Illinois by the ISWS for use in estimating effective discharges (Crowder and Knapp 2002) highlighted the problems with determining sediment-discharge relationships with limited data. For those stations on large streams where suspended sediments were sampled every one or two weeks, many years of data were needed to define a stable sediment rating, such that it is difficult to identify meaningful temporal trends within these long sampling periods. One major obstacle is that there is considerable variability (scatter) in the sediment load for a given discharge class, and for higher discharge classes there are relatively few samples from which to estimate the mean sediment load. The use of standard power function (log linear) curves to estimate average sediment loads in lieu of adequate data proved to be inaccurate. Whereas increased sampling on larger tributaries for low and medium flow events (for which there is normally plenty of data) may not significantly improve sediment-discharge relationships, increased sampling of higher flow events is needed for establishing and identifying temporal changes in such relationships. For smaller streams, sediment sampling during storms becomes particularly crucial because most high flow events will be totally missed by standard periodic sampling.

From the current sediment network we have been successful in identifying broad-scale sediment budgets and spatial differences in sediment delivery across the Illinois River basin. However, we have data from very few small watersheds, such that it is difficult to determine whether our small watershed data are representative of other ungaged watersheds across the Illinois River basin. Both modeling efforts and data at additional sites will be needed before we can determine the amount of spatial variability, uncertainties, and relatives difference that could be related to management practices.

A final factor that needs to be addressed is the influence of climatic variability on analyzing trends in stream sediment. The amount of flow and sediment in a stream are highly responsive to the variable sequence of climatic events. In analyzing the influence of climate variability on streamflow quantity, ISWS studies have concluded that streamflow variability associated with climate fluctuations may often be sufficient to mask the impacts of other factors (such as changes related to moderate levels of land-use change or BMPs). We need to keep in mind that we are trying to estimate changes in average stream sediment of 10-20% over time, and that interdecadal changes in total flow volume associated with climate variability are commonly in excess of 20 percent. This is why long-term records are needed for identification of trends in hydrology, sediment yield, and related processes.

Within this plan the placement of new monitoring sites focuses on characterizing the physical processes occurring within different types of morphological and physiographic settings along with identifying the influence land use and climate variability may have on hydrologic and sediment transport processes. Within the Till Plains Section of the Central Lowland Province, there are four major physiographic units making up the IRB (outside the Chicago area): the Galesburg Plain, the Springfield Plain, The Bloomington Ridged Plain, and the Kankakee Plain (Leighton 1948). Table 12 also shows the major physiographic region(s) each sub-basin lies within. Additional monitoring sites are being added so that small- and medium- streams are monitored within each of the sub-basins and the four major physiographic regions making up the IRB.

With a large network of streamflow gages already operating in the Fox, Des Plaines, and Chicago/Calumet sub-basins, additional streamflow and sediment monitoring within these sub-basins is not proposed.

The Illinois River sub-basin is identified as being in particular need of additional monitoring. The bluff streams found in this sub-basin are unique and the apparent high sediment delivery rates of the streams may play a crucial role in the Illinois River's sediment transport processes. To date there has been little hydrologic and suspended sediment monitoring conducted on these bluff streams. Consequently several new monitoring sites are proposed for this sub-basin.

Overall, this proposed monitoring plan efficiently allocates monitoring efforts between the mainstem Illinois, major tributaries of the Illinois River and small- and medium-sized streams throughout the IRB. The resulting network of hydrologic and sediment monitoring stations is a holistic monitoring approach that will better reflects the stream processes occurring within the large variety of watersheds found in the IRB.

Critical Response Measures:

Streamflow and Suspended Sediment - Standardized sampling equipment and procedures will be implemented at all sites within the monitoring network. The equipment and sampling regiment used at a particular location will reflect the stream's size, and storm hydrograph duration. Methods at each gaging site will also follow commonly accepted streamflow and sediment sampling procedures as described by Edwards and Glysson (1999), Rantz (1982a), Rantz (1982b), and FISP (1952).

In general, the monitoring network will collect continuous stream gage data, record hourly or sub-hourly discharge estimates, and collect daily suspended sediment samples. When needed, storm sampling will also be provided at each monitoring site.

Morphologic and Sediment Grain Size Data - At each site, channel slope, cross-sectional shape, suspended sediment grain size distribution, and bed and bank-material compositions will be periodically sampled and/or measured for a reach extending about ten times the width of the stream at the gaging site.

Bathymetric/Sedimentation Survey of Backwater Lakes - The backwater and associated floodplain lakes of the Illinois River are known to be vital to the processes that determine the overall ecology of the Illinois River. To better quantify the sediment characteristics and sedimentation processes that are occurring within these lakes, periodic bathymetric surveys and sediment sampling will be performed at locations where sedimentation has been identified as an ecologic or economic concern.

Ecologically important backwater lakes, side channels, and wetland areas will be identified and periodically surveyed using standard bathymetric surveying practices (USCOE 2002), so that sedimentation patterns and rates can be determined for different reaches of the Illinois River. Sedimentation rates will be determined through sediment dating techniques using Pb^{210}analysis of collected core samples. The use of radiometric dating techniques provides data on sedimentation rates for specific periods and how these rates have changed over time as opposed to the average rate of sedimentation that can be inferred from bathymetry alone. Priority will be given to performing bathymetric surveys that describe sedimentation rates over the entire length of the Illinois mainstem. However, if justified, locations on Illinois Tributaries may also be surveyed.

Locations for bathymetric and sediment characteristic surveys will be identified with input from the agencies conducting ecological monitoring and implementing specific projects (e.g., dredging, water retention, and habitat restoration).

Proposed Basin-Wide Hydrologic and Sediment Monitoring Sites

With the present monitoring network our ability to detect basin wide changes in sediment transport and delivery is negligible, other than at those few stations monitoring small watersheds such as the CREP monitoring network. With the proposed basin wide monitoring network our ability to detect system wide trends and changes in sediment loads and delivery rates would significantly improve. Assuming this network will be operated throughout the Illinois River Basin 519 Restoration Project (10+ years) the accuracy of our sediment yield estimates will improve by more than 50 percent when compared to current capabilities. This improved estimate should allow researchers to determine if progress is being made towards the stated objectives of the IRB 519 Project.

A list of monitoring sites that compose the proposed network that would provide data to achieve the objectives listed in the "Goals and Objectives" section is provided below. Following the name/location of each proposed discharge and sediment monitoring site are comments describing which actions need to be implemented at that location. At locations where discharge and sediment are currently being monitored a recommendation is made to "increase sampling frequency." For stations that currently have active streamflow gages, but need sediment monitoring, a recommendation to "monitor sediment" is made. At sites where neither discharge nor sediment is currently being monitored a recommendation is made to "activate" or "reactivate" discharge and sediment monitoring. To "activate" a station implies no prior data has been collected at that site, whereas to "reactivate" a station means previous discharge and/or sediment data was collected at that site. The locations of all of the proposed monitoring sites within the Illinois River Basin are shown in Figure 11.

Mainstem Locations:

<u>Sites on the Illinois River</u>.

A01 Illinois River at Henry (monitor sediment)

A02 Illinois River at Kingston Mines (monitor sediment)

A03 Illinois River at Marseilles (increase sediment sampling frequency)

A04 Illinois River at Valley City (increase sediment sampling frequency)

These monitoring sites were selected for two reasons. First, the locations are distributed along the entire length of the Illinois River. Second, the sites will be collecting sediment samples at existing stream gages. Note, while suspended sediment has been collected at Pekin and is currently being collected at Chillicothe, stream gages do not exist at either of these locations and discharges must be estimated. Hence, it is recommended that future suspended sediment monitoring take place at Henry and Kingston Mines, where stream gages exist.

Proposed monitoring sites on major tributaries to Illinois River, sites on small tributaries not in the mainstem Illinois sub-basin, sites on small- to medium-sized streams in the mainstem Illinois River sub-basin, and sites representing different morphologic and physiographic regions are presented in the Sub-basin - Hydrologic and Sediment Monitoring Plan section.

The mainstem locations explained above along with the three types of gages explained in the Sub-basin - Hydrologic and Sediment Monitoring Plan section, create a network composed of 58 monitoring sites throughout the Illinois River Basin. While it is believed that this network provides a sound and reasonable framework for meeting the goals and objectives set forth in this proposal, it is recognized that funding for such a comprehensive network may not be feasible. Consequently, a smaller monitoring network, consisting of 45 monitoring sites, is described. This network is believed to contain the minimum number of monitoring stations that would be needed to significantly improve the existing hydrologic and sediment monitoring network and begin providing data to meet the goals and objectives of this proposal. Following is a comparison of the networks capabilities and associated costs.

Under this option, the monitoring network would comprise of 45 monitoring sites. Like the comprehensive network, this network would provide a much improved sediment budget for the IRB and significantly increase monitoring on small- to medium-sized streams. However, compared to the Comprehensive Network, the minimum network would spend about 32 percent less effort monitoring the Illinois River's major tributaries and about 20% less effort collecting hydrologic and sediment data pertaining to small- to medium-sized streams. Monitoring on the Illinois mainstem under this and the comprehensive network would be the same. Thus, the resulting network still emphasizes the collection of data on small- to medium-sized streams, but also provides significantly more data on the larger tributaries than is currently being collected.

In summary, the critical network would support:

1) All four proposed sites on the Illinois River (A01-A04)

2) Fifteen of the twenty-two proposed sites on the Illinois River's major tributaries

3) Five of the seven proposed sites on small tributaries not in the Illinois River sub-basin

4) Ten of the eleven proposed sites on small- to medium-sized streams in the mainstem Illinois River sub-basin

5) Eleven of the fourteen proposed sites to represent different morphologic and physiographic regions

Estimated cost: $1,118,000 to implement and operate this hydrologic and sediment monitoring network during the first year and $634,000 per subsequent year. These costs reflect the combined cost of the mainstem and sub-basin hydrologic and sediment monitoring plan.

Desirable Response Measures:

This comprehensive network, containing a total of 58 monitoring sites, will provide a much improved sediment budget for the IRB and begin long-term monitoring of a large variety of small- to medium-sized streams consistent with the goals and objectives of this proposal. This network also promotes continued monitoring at sites where data has already been collected and increasing the period of record is desirable. Finally, this network monitors specific watersheds where substantial watershed development and research activities are likely to occur (e.g. Spoon). Focusing our monitoring efforts within areas where restoration efforts are likely to occur is beneficial for a number of reasons. This proposed gage network provides the opportunity for adequately describing baseline conditions. Also by being situated in the sub-watersheds where projects will be placed these gages are optimally suited to detect change. It is reasonable to assume the effects of restoration efforts will first be seen in the tributaries. When comparing tributary sub-basins to the entire Illinois River Basin, the decreases in contributing watershed area, sediment storage capacities and codependency of causative variables should all lead to earlier detection of the benefits from restoration efforts. By having a gaging network that addresses different spatial scales we will improve our ability to provide data to help support project siting and other ecological monitoring activities in settings where resources and results can be shared.

In summary the Desirable Network would support:

1) Four sites on the mainstem of the Illinois River (A01-A04)
2) Twenty-two sites on the Illinois River's major tributaries (B01-B22)
3) Seven sites on small tributaries not in the Illinois River sub-basin (C01-C07)
4) Eleven sites on small- to medium-sized streams in the mainstem Illinois River sub-basin (D01-D11)
5) Fourteen proposed sites to represent different morphologic and physiographic regions (E01-E14)

Estimated cost: $1,423,000 to implement and operate this hydrologic and sediment monitoring network during the first year and $815,000 per subsequent year. These costs reflect the combined cost of the mainstem and sub-basin hydrologic and sediment monitoring plan.

Monitoring Plan
SUB-BASIN

ECOLOGICAL MONITORING PLAN - AQUATIC

Most studies on the effects of restoration practices have been implemented on small spatial (e.g. reach-scale) and temporal scales (e.g., Magette et al. 1989). Very few studies have documented the effectiveness of restoration practices in wadeable streams at spatial scales larger than the reach or local scale (Wang et al. 1996; Wang et al. 1997; Wang et al. 2002). In the few studies that were completed at larger spatial (e.g., sub-basin) and temporal scales, the emphasis has been on the effects of stream restoration on chemical/physical parameters (e.g., nutrient concentration, sediment yield) (Trimble and Lund 1982; Gale et al. 1993; Walker and Graczyk 1993; Park et al. 1994; Cook et al.1996; Edwards et al. 1996; Meals 1996; Bolda and Meyers 1997). Responses of the biota to sub-basin wide or watershed wide implementation of restoration practices have been considered only in more recent studies and much less frequently than physical parameters (Fitzpatrick et al. 2001; Stewart et al. 2001; Wang et al. 2002). Currently, there is a lack of understanding on how ecological processes operating at large spatial and temporal scales affect stream fish populations (Schlosser 1995; Roni et al. 2002) and invertebrate assemblages (Richards et al. 1996). However, it is clear that processes operating at large scales (e.g., land use in a sub-basin) can strongly affect the integrity of stream fish and invertebrate communities (Roth et al. 1996; Fitzpatrick 2001; Stewart et al. 2001).

Monitoring responses of a stream system to restoration using several spatial scales (reach, sub-basin, and basin) improves the ability to detect meaningful changes in the integrity of the aquatic community and to discover mechanistic explanations for linkages between abiotic and biotic parameters operating at different scales. By monitoring lotic systems at the sub-basin scale, an intermediate spatial scale, we can assess the collective effects of individual restoration practices implemented at the reach scale to make predictions on potential effects of restoration at the basin scale. Although the sub-basin is an intermediary scale between individual projects and the mainstem of the Illinois River, changes in stream quality at this scale can be better understood by determining mechanisms for changes in stream conditions at an even smaller watershed and sub-watershed scale. To better comprehend the collective effects of restoration at the sub-basin scale and link those with effects of individual projects, monitoring at the sub-basin scale in addition to the sub-basin scale is essential. We are defining sub-basins as large tributaries to the Illinois River mainstem (HUC 8 scale) with watersheds (HUC 10 scale) nested in sub-basins and sub-watersheds (HUC 12) nested within watersheds (Figure 3).

The aquatic ecology monitoring framework focuses on documenting changes in both biotic and abiotic factors in sub-basins of the Illinois River as well as determining immediate and local effects of various practices on the overall stream community. Documenting these changes at various scales (sub-basin, watershed, and sub-watershed) will require the use of different sampling protocols and study design/analytical methods. At the watershed and sub-watershed scale, the Before-After-Control-Impact (BACI) study design will be used to assess changes in physical habitat and aquatic biota (see description in Study Design - Statistical Approaches section in the Introduction). This design accounts for temporal variability increasing the likelihood of detecting true changes in lotic systems at smaller scales and allowing improvements in stream quality to be attributed to restoration practices instead of other events such as changes in climate conditions during the study. With increased scale to the sub-basin level, the BACI design is more difficult to implement due to the challenge of finding a suitable reference sub-basin in the Illinois River basin that will have little or no restoration practices implemented. In this case, trend analysis/repeated measures and regional reference sites (Rasmussen et al. 1993; von Ende 1993; see Study Design - Statistical Approaches section in the Introduction) will be used to evaluate the effectiveness of restoration on aquatic communities. Regional reference sites are least disturbed areas within the same region as the treated sub-basin. Abiotic and biotic indicators of stream quality at the regional reference sites are used as benchmarks to assess changes in treated sub-basins once restoration practices are implemented.

To accurately monitor the combined effects of restoration practices on stream quality, critical parameters need to be identified and collected. Below, we identify those parameters which must be collected (i.e., critical metrics) to accurately detect changes in stream integrity as a result of restoration practices. We also discuss parameters that should be incorporated into a monitoring program (i.e., desirable metrics) in order to obtain a more mechanistic understanding on how changes in one parameter (e.g., habitat quality) affects another (e.g., fish abundance).

Critical Response Measures:

It is crucial that water quality parameters (those related to sampling efficiency and condition of biota), habitat, fish assemblages, and invertebrate (including mussels) communities be monitored at least once a year for several years before and after implementation of restoration practices. Within each sub-basin designated for practices, multiple sites must be monitored at the sub-basin scale (i.e. both upper and lower portions of the mainstem of major tributaries to the Illinois River) as well as at the watershed and sub-watershed scale. For the sub-basin sites, regional references will be used to assess improvements in stream integrity. At both the watershed and sub-watershed scale, reference watersheds within the same sub-basin (when possible) will be monitored to determine improvements in lotic communities. To utilize historical water quality, habitat, and biotic data, we will collect data at sites previously sampled during IEPA/IDNR basin surveys where possible and use qualitative and quantitative collection methods similar to protocols used by these agencies (IEPA 1994; IDNR 2001). Length of each sampling site must include at least one riffle-run-pool sequence (i.e., approximately 35 times the mean stream width) (Lyons 1992; IDNR 2001) with non-channelized sites being no less than 150m and channelized sites being no less than 300m in length (Holtrop and Dolan 2003). For non-wadeable sub-basin sites, station length will be sampled for a given time (30 minutes) instead of a given distance as described in IDNR protocols (IDNR 2001).

Habitat - Chemical/physical habitat data must be collected using two levels of sampling: site-scale and transect-scale. Site-scale parameters (Table 14) will be collected at one location in the site (e.g., water temperature, discharge) or are based on maps of the entire site (e.g., drainage area, stream order) and are assumed to be representative of the entire site. For chemical/physical habitat, efforts will be made by each discipline to sample the same sites in order to collect a more complete dataset on water quality and channel morphology data without duplicating efforts. At locations were this is not feasible, water quality data as it pertains to sampling efficiency, biotic health, and productivity of the stream (temperature, dissolved oxygen, conductivity, periphyton concentrations, etc; Table 14) and channel morphology data using point/transect methods (Table 15) should be collected during biotic assessments.

Transect-scale variables are those which are expected to vary considerably within a site (Table 15). These variables, which pertain to stream channel morphology, bottom substrate, cover for fish, macrophyte abundance, condition of stream banks, and riparian land use/vegetation, should be measured on at least ten, equally spaced transects perpendicular to flow. A modified Stream Assessment Protocol for Ontario (Stanfield et al. 1998) will be used to sample these habitat variables. This protocol is similar enough to IEPA habitat protocol (IEPA 1994) to allow for comparisons with IEPA/IDNR basin survey data. However, in the Ontario protocol, in-stream substrate is measured instead of visually estimated and bank/riparian conditions are assessed. This protocol has been rigorously tested and found to provide consistent and reliable results on repeated habitat sampling of stream systems (Stanfield and Jones 1998). In addition to utilizing habitat data from IEPA/IDNR basin surveys to supplement baseline data, landuse data will be used to assess improvements in system integrity due to implementation of restoration practices at the sub-basin scale.

Fish and Macroinvertebrates - Fish and invertebrate assemblages must also be monitored at least once a year at the same time and site locations as habitat data collection. Every effort will be made to select sites with historical data to obtain additional baseline data and to coordinate sampling among each discipline to collect water quality and channel morphology data that will be useful in predicting and explaining biotic integrity. At sites where water depth is too deep to wade safely with electrofishing gear (i.e. sub-basin sites), boat electrofishing gear will be used to collect fish assemblage data and site length will be determined primarily by electrofishing run time (IDNR 2001). To detect changes in fish populations and assemblage structure at watershed and sub-watershed sites, quantitative collection of fish data is necessary using a single pass with an electric seine and block nets to prevent fish escapement (IDNR 2001). Species richness, abundance, percent composition, and the Index of Biotic Integrity (IBI) metrics will be used to assess changes or shifts in integrity of fish assemblage structure as a result of restoration practices at each of the spatial scales.

Invertebrate communities must be assessed through a randomly stratified design whereby habitat types are sampled in proportion to their occurrence within each site. Both quantitative (Dodd et al. 2003) methods to obtain relative abundance and percent composition of each taxa and qualitative (IEPA 1987; IEPA 2002) methods will be used to compare current invertebrate communities with historical data. At the watershed and sub-watershed sites, quantitative samplers (i.e. Hess sampler in riffles and core samplers in pools/runs) and qualitative samplers (kicknets) used for wadeable sites will be employed. At sub-basin sites, where water depth may be too great to wade, ponar grabs should be used to quantitatively assess invertebrate communities in deep pools and runs in addition to Hess and core samplers (quantitative methods) and kicknets (qualitative methods) in the wadeable margins. Invertebrates should be identified to family when possible in order to allow for distinctions in stream quality/integrity among restored and reference sites. Taxa richness, densities, percent composition, biotic indices (Family Biotic Index and Macroinvertebrate Biotic Index), and percent of intolerant taxa (Ephemeroptera, Plecoptera, and Trichoptera, %EPT) will be used to assess responses of invertebrates to restoration practices. Mussels, which are also good indicators of sedimentation in a system, should also be assessed at least once a year using IDNR's semi-qualitative wading technique (IDNR 2002) to obtain additional baseline data and to assess changes in mussel populations after restoration. Although mussels are long-lived and, therefore, may have a longer lag time in terms of changes in taxa richness, relative abundance of mussels should increase within a relatively short time frame.

Very few studies have examined effects of restoration practices on fish and invertebrate communities as well as physical habitat at the watershed or sub-basin scale, and therefore, it is uncertain as to the time frame in which significant improvements will occur at these spatial scales. However, based on power analysis of baseline data in the Pilot Watershed Program, we feel confident that improvements in habitat, fish, and invertebrate indicators of stream integrity will be detected within 5-10 years after restoration (with at least 5 years of baseline data) at the sub-watershed and watershed scale (Dodd et al. 2002). This preliminary power analysis is supported by a Wisconsin study which examined the effects of best management practices on habitat and fish assemblages where changes in stream quality were reported after only 4-5 years of implementation at the sub-watershed scale (Wang et al. 2002). Because the sub-basin scale is much larger than the watershed or sub-watershed scale, we estimate that improvements in stream integrity will take longer than the 5-10 years we propose for the watershed scale.

Estimated cost: $ 100,000 per sub-basin/year (cost will vary depending on number of sub-basins).

Desirable Response Measures:

Supplemental data collection on chemical/physical habitat, fish, and invertebrates is desired in order to provide further understanding of relationships occurring between abiotic and biotic factors and how they interact under implementation of restoration practices at various spatial scales (sub-basin, watershed, and sub-watershed). To improve our ability to detect improvements in system integrity within sub-basins of the Illinois River, additional sites should be monitored throughout treated sub-basins (including at the watershed and sub-watershed scale) before and after restoration.

Water quality - Water quality parameters of stream integrity should be monitored continuously (see numbers 4-6 in Table 14) when possible by using gaging stations.

Habitat - Physical habitat, including periphyton abundance (see number 7 in Table14), should be monitored seasonally (Table 15). Habitat types (riffles, runs, pools, side-channels, back-waters, etc.) should be measured and mapped within each site to indicate changes or shifting of these habitats which are critical for different life stages of organisms. More detailed bank and riparian data should be collected by quantitatively sampling vegetation using quadrats in randomly selected locations to obtain percent composition and dominance of plant taxa as well as overall condition of the bank and riparian corridor.

Fish and macroinvertebrates- Because composition, structure, and life stages present in the biotic communities of lotic systems change with seasons, particularly for invertebrates, we propose to sample fish and invertebrate assemblages seasonally at the same time as physical habitat collection. Seasonal sampling (spring, summer, and fall) will allow a greater understanding on how restoration practices affect biotic communities at different times of year under different habitat conditions (e.g. higher flow, low percent overstory cover, and low temperatures in spring versus low flow, high overstory cover, and higher temperatures in summer).

To assess effects on relative abundance of fish communities more completely, it would be desirable to quantitatively sample fish using a multi-pass method at longer stream reaches, particularly at sites where habitat complexity makes it difficult to get a reliable estimate of taxa richness and relative abundance using electrofishing gear (i.e. stream reaches with lots of woody debris and root snags where fish can hide) (Holtrop and Dolan 2003). A single pass method is critical and will provide a reliable estimate for species richness and percent composition, but a multi-pass method is desirable in that it will give a more reliable estimation of abundance and densities (Simonson and Lyons 1995).

To improve our understanding of which abiotic and biotic factors directly or indirectly affect fish communities, we also propose collecting and analyzing boney-structures to estimate changes in growth rates and overall health of the fish populations due to restoration practices. Changes in habitat suitability, prey availability, and fish health resulting from restoration practices can be evaluated through analysis of growth rates because growth is affected by both endogenous and exogenous conditions (DeVries and Frie 1996). Species composition, abundance, and size structure are used to describe changes in the population dynamics of stream fish communities, but the results of these metrics alone offer little insight into which factors or how these factors regulate communities. For example, these fish metrics do not give an indication of how well the habitat meets the needs of the species and does not provide information about the length of time it took for the individuals in a population to reach their current size. Besides improving our understanding of the mechanisms regulating stream fish communities, growth rates also gives us an idea of the stream conditions before a study commences. Age and growth analysis will add a much needed mechanistic understanding of how fish integrity is affected by restoration practices in Illinois River sub-basins with minimal effort. Boney structures will be collected from fish during fish community sampling and processing/analysis of these structures will take minimal time (approximately 1 – 1 ½ months a year).

By including additional data metrics beyond those described as “critical”, our monitoring framework will increase knowledge of how changes in abiotic and biotic factors interact at different spatial scales and allow agencies and managers to better predict how restoration practices will collectively influence stream systems in future restoration projects.

Estimated cost: An additional $20,000 per sub-basin/year (cost will vary depending on number of sub-basins).

ECOLOGICAL MONITORING PLAN - TERRESTRIAL

For terrestrial monitoring, the Illinois Natural History Survey Critical Trends Assessment Program (CTAP; Milano-Flores 2003) provides a useful framework for monitoring vegetation and terrestrial wildlife. The CTAP program is designed to monitor the condition of forests, grasslands, wetlands, birds, insects, and streams in Illinois. For each habitat type, 150 sites are monitored on a rotating, 5-year cycle. Site selection is based on randomly selected patches within randomly selected townships throughout the state. Because townships do not provide a suitable sampling framework within the Illinois River basin, we recommend a slightly modified CTAP protocol in which the sample unit is a habitat patch stratified by sub-basins (i.e., eight digit USGS Hydrologic Catalog Units).

In the proposed modified CTAP approach, data will be collected at 30 sample points in each of three habitat categories (i.e., forest, grassland, wetland) in each sub-basin. This framework results in 1,710 monitoring sites (19 sub-basins x 90 points per sub-basin). The spatial sampling frame for our modified framework is the Federal Emergency Management Agency 100 year flood-zones (Illinois State Water Survey 1996) or 300m from USGS digital line graph streams, whichever is wider. Iverson et al. (2001) demonstrated the potential of using 300m buffers to evaluate wildlife habitat in riparian zones for small streams with relatively narrow floodplains. Sampling in each sub-basin will occur once every 5 years.

The proposed monitoring design will support tracking conditions and restoration progress at site and sub-basins scales, while allowing integration up to the entire Illinois River basin. Specific sampling considerations are outlined below. Sub-basins can be combined based on geographic location and landscape characteristics to decrease number of monitoring sites and therefore costs.

A. Landscape habitat composition and metrics - Land use throughout the watershed has an effect on the status and function of the river and the species present. Land use composition is easily assessed using remote sensing and geographic information systems (GIS). Regular assessment documents landscape change and indicates increasing or decreasing watershed protection (Wang et al. 1997; Snyder et al. 2003). Spatial configuration of habitat provides a better indication of landscape quality for organisms but relationships are complex and difficult to quantify (Gustafson 1998).

Land cover should be regularly monitored to evaluate changes in landscape composition and pattern over time. Land use statistics should be summarized by HUC unit (sub-basin), for the entire watershed, and within the defined riparian zone where species monitoring will occur. Increasing amounts of forest, wetland, and grassland reduce soil erosion, filter contaminants, and increase wildlife habitat. The amount of cropland and urban areas in a watershed have been shown to negatively affect aquatic systems (Wang et al. 1997; Snyder et al. 2003). Important measures of habitat spatial pattern for riparian wildlife include forest (including bottomland) patch size and connectivity, wetland (non-forested) patch size and nearest neighbor distance, grassland patch size, width of natural cover along streams, and connectivity of all natural cover along channel.

Land cover classification and assessment is a powerful tool that relates directly and indirectly to many Illinois River restoration goals. The information provided by analyzing landscape habitat composition and pattern relates to diversity and sustainability of habitats and communities, and habitat suitability for species. Species or community level modeling can be applied using land cover data to determine habitat deficiencies that may be limiting distribution or abundance. Analysis of classified satellite imagery will allow tracking of restoration success for general land cover categories over broad spatial scales, including habitat connectivity.

The ability to measure change in land cover is limited primarily by classification level and accuracy. The Illinois land cover data (IDNR et al. 2003) has a pixel size of about 30m x 30m and therefore cannot be used to monitor changes at a very small spatial scale. The tradeoff between classification detail and accuracy results in broad habitat classifications. Land cover changes for patches greater than 30m x 30m can be detected throughout the basin and individual pixels compared over time to track changes. Change can be summarized from the pixel level up to the entire Illinois River watershed at important levels of spatial organization and related to restoration objectives. Land cover data and analysis, in conjunction with the IDNR Comprehensive Wildlife Conservation Plan that is currently being developed, could be used to guide restoration efforts that will provide the greatest benefit to wildlife species of interest.

Estimated cost: $3,000.

C. Site-specific habitat/vegetation monitoring - Intensive vegetation sampling compliments landscape and community level assessment. Much of the wildlife habitat along the Illinois River and its tributaries has been lost due to land use change, hydrologic alteration, or sedimentation, and these are changes that can be measured by landscape and community level assessment. Much of the remaining habitat suffers from changes in vegetation structure or species composition. For example, many of the floodplain forests have lost their mast producing species component and suffered high mortality of mature trees resulting from altered hydrology (Nelson and Sparks 1998; Havera 1999). Vegetation sampling at randomly selected sites provides a means for evaluating diversity at the species level, for monitoring rare species, and for detecting invasive species. Monitoring vegetation at specific sites also provides the opportunity to collect detailed information on vegetation structure that relates to wildlife habitat suitability.

Site selection for intensive vegetation monitoring will follow the protocols described at the beginning of the sub-basin section. Vegetation data generally will be collected using a standard transect approach following CTAP protocols (Milano-Flores 2003). Data collected for all three habitat types (i.e., forest, grassland, wetland) includes plot species composition/richness, ground cover by species, stems of woody species <5cm dbh, and stems and dbh of woody species >5cm dbh. Additional details of the CTAP program can be found in the Critical Trends Assessment Program Monitoring Protocols manual (Milano-Flores 2003). Some vegetation types, like forest and scrub-shrub wetlands, are expected to respond slowly to restoration activities, but intensive vegetation monitoring should be able to detect subtle changes and indicate habitat trajectories.

Guidelines for specific habitat types:

<u>Forest monitoring</u> – Forest patches will be selected using Illinois land cover data forest types (IDNR et al. 2003). CTAP requires a 20 acre forest patch size minimum with a radius of 150m of homogenous forest type, and actual sample sites must be surrounded by a 114m forest buffer, but

that restriction could be relaxed if necessary for our program to reach the desired sample size. This may be necessary in smaller watersheds, those with a high proportion of urban area, or watershed units dominated by intensive agriculture.

Grassland monitoring – Grassland patches will be selected from rural and urban grassland types from Illinois land cover data (IDNR et al. 2003) and subject to additional criteria determined by site visits. The only patch size constraint is there must be at least 500m^2 of suitable habitat area that is ≥10m wide. Suitable grasslands must have <50% shrub and <50% canopy cover.

Wetland monitoring – Wetland sites are selected from Illinois Wetlands Inventory data (IWI; Suloway and Hubbell 1994). The CTAP wetland program monitors only emergent palustrine wetlands that can safely be sampled on foot. Our program will also include scrub-shrub palustrine wetland types and can be extended to include areas on islands that can only be reached by boat. Wetlands must be ≥ 2 acres in size with a minimum of 500m^2 of suitable habitat area that is at least 10m wide. Because wetland alteration has continued at a rapid pace even since the IWI was completed, an additional criteria is that sample sites must have ≥ 50% obligate, facultative wetland, or facultative plants. Wetland vegetation monitoring should compliment LTRMP vegetation monitoring.

Intensive vegetation monitoring relates to Illinois River restoration goals similar to both community and landscape level assessment but at a higher spatial resolution. Intensive vegetation monitoring will provide a source of information lacking for the Illinois River watershed and provide detailed information on vegetation composition and structure over time. For most restoration practices, subtle changes in vegetation should be detected in the first cycle after implementation. Intensive monitoring will also allow tracking of rare, exotic, and invasive species. Monitoring of vegetation at specific sites can be utilized to ground truth landscape and community level data for classification accuracy.

K and L. Bottomland/riparian forest & grassland birds - Passerine birds have been proposed as excellent multi-scale biological indicators because they are usually easily detected, widespread, many exist in relatively high numbers, and they integrate multiple factors across a landscape (U.S. EPA 2002a; O'Connell et al. 1998). Bird species and communities are sensitive to vegetation composition and pattern, landscape pattern, hydrology, water quality, disturbance, predation, and parasitism (U.S. EPA 2002a). The Illinois River basin is an important area for passerine birds and many rare species rely on habitat found in the riparian zones of the river and its tributaries. Bottomland forests along large rivers are particularly important and support a highly diverse and unique bird community (Knutson et al. 1996). Rare species and bottomland forest obligates include brown creeper, red-shouldered hawk, cerulean warbler, prothonotary warbler, and red-eyed vireo. Species may serve as indicators at different spatial scales based on their size and ecology. For example, raptors and waterfowl range more widely and therefore serve as indicators at larger spatial scales than species like rails or sparrows that wander over a relatively small area during the breeding season (U.S. EPA 2002a). Riparian grasslands could provide habitat for many of the rare grassland species still found in Illinois.

Existing programs such as the North American Breeding Bird Survey "BBS" (U.S. Geological Survey 1998) provide much data. However, because BBS is a road-based survey, little sampling is done in riparian areas where road density is typically low. Therefore, riparian associates and obligate species remain undetected or are detected in very low numbers. We propose a monitoring program following CTAP bird monitoring protocol (Milano-Flores 2003) at the same randomly selected sampling locations where intensive vegetation data will be collected. CTAP methodology is comparable to BBS data collection and much of the same data is collected, however CTAP is designed to relate the bird community and species abundance to habitat conditions at the site. Differences between the two bird monitoring programs include CTAP counts lasting 10 minutes compared with 3 minutes for BBS. CTAP ornithologists record direction and distance to each calling individual allowing the use of distance sampling techniques to estimate bird densities, whereas BBS observers only collect data on numbers. After the ten minute call-count is complete, CTAP ornithologists use a tape to broadcast calls of Illinois marsh birds followed by a one minute listening period for responses. BBS protocol does not allow call solicitation. CTAP protocol requires collection of call data for at least two sample points at each site with a minimum distance between points (300m for grassland and wetland, 150m for forest). If the habitat patch is too small for two sample points, a second sample point is located in the closest similar habitat patch of suitable size. Multiple sample points provide an estimate of local variation.

Monitoring will occur at 30 randomly selected sample points per habitat (forest, grassland, and wetland) in each watershed unit. Abundance should only be assessed at the species level for those species that are generally abundant. Presence/absence or analysis by habitat guild (i.e., riparian forest associates) provides a sound basis for analysis of rare species or those normally only present in low numbers. Data collected within a watershed can be summarized by habitat type in the monitoring year.

Restoration practices that will benefit riparian forest and grassland birds include managing for large habitat tracts, increasing tree species diversity in bottomland forests, and managing for mature forests (Knutson et al. 1996).

F. Marsh birds - Marsh birds are a secretive group of birds that live primarily in emergent or floating leaved vegetation. Their habitat requirements tend to be specific with respect to wetland area and/or vegetation structure. Most species are rarely seen or heard and therefore require specialized sampling techniques. Abundance can be difficult to measure because most species naturally exist at low densities. Therefore species presence, particularly during the breeding season indicates good quality marsh habitat. Presence and breeding activity, particularly of rare species, are good indicators of suitable habitat conditions, and the number of sites where they are found is a more appropriate measure than abundance at a site. Presence/absence data can be summarized across watershed units to provide an indication of distribution and habitat quality.

With the widespread loss of wetland habitat in Illinois, few marsh birds breed in the state. The rarest species, such as the black rail, require short emergent vegetation. This type of habitat is the first to be destroyed by flooding and therefore is rare within the Illinois River watershed.

Monitoring will occur in conjunction with passerine bird monitoring at intensive vegetation sampling points. Observers will use taped calls of marsh birds found in Illinois to solicit call responses. Number of calls and number of individuals responding should be recorded. Because all sample points will be within the riparian zone and because mesic grasslands or forests with well developed herbaceous understories could provide habitat for marsh birds, marsh bird monitoring will occur at all vegetation sample points. While abundance data will be collected, initially data will be summarized based on the number of sample points where species are present within a watershed unit. If restoration supports a numeric response, abundance data can be utilized as an index to track restoration progress.

Marsh birds are good indicators of their specific habitat type and therefore indirectly of hydrologic conditions. Species that use tall emergent vegetation, such as American bittern, may respond more rapidly because we anticipate their habitat will respond more quickly to habitat restoration than short emergent communities. Successful restoration should also result in increasing numbers of marsh birds nesting within the Illinois River basin.

M. Amphibians - There has been considerable interest in using amphibians as indicators of wetland condition (Micacchion 2002; US EPA 2002b). Ecological and life history characteristics that make amphibians desirable as bioindicators include they have both aquatic and terrestrial life stages; they are vulnerable to habitat fragmentation, water chemistry, hydrology, pollution, and climate change; they have a complex life history; and they require fishless ponds for successful reproduction. In addition, most frogs and toads are vocal during the breeding season and call indices can be used to infer changes in abundance.

The relative abundance of frogs and toads can be monitored at concentration areas using frog call surveys (U.S. EPA 2002b, U.S. Geological Survey 2001). We recommend collecting frog and toad call count data at intensive vegetation monitoring points. This will allow efficient selection and monitoring of sites and relation of abundance and species richness to habitat conditions. The protocol uses 2 counts conducted during evenings in the spring. Suitable conditions for conducting surveys and data collected generally follow North American Amphibian Monitoring Program protocol (USGS 2001). Since only 2 surveys will be used, survey dates should be at least two weeks apart and should be carefully selected to account for the most species possible. The first count can be conducted when the minimum night-time air temperature reaches 41˚F. The second count can be done once the minimum night-time air temperature reaches 50-55˚F. Counts begin ≥ 30 minutes after sunset and last for five minutes. Multiple sample points should be surveyed at each site according to CTAP bird monitoring protocol for selection and spacing of points (Milano-Flores 2003).

Unless wetlands are a considerable distance from existing amphibian populations, the most common frog and toad species respond very quickly to habitat restoration. Species richness for a particular wetland or within a sub-watershed is expected to respond more slowly depending on distance to source populations, annual hydrologic variation, and probably many other factors. Frog and toad communities using isolated wetlands indicate conditions primarily at the patch level, whereas amphibians in connected riverine wetlands integrate conditions over larger scales. Salamander population parameters should be considered as well.

Estimated cost for site-specific habitat/vegetation ©), Bottomland/riparian forest and grassland birds (K&L), marsh birds (F), and amphibians (M) - $945,000.

J. Bats - Bats have not been well studied relative to other wildlife species groups (Arnett 2003) but they are good indicators of riparian system integrity and disturbances (Fenton 2003).

Relatively little quantitative data are available regarding the current abundance of most species found in Illinois but clearing of riparian forests, stream channelization, rural housing development, and organochlorine insecticides have contributed to long-term population declines for many species (Herkert 1992). Life history traits provide evidence bats are adapted to stable and predictable habitats (Kunz and Pierson 1994). All Illinois bat species are insectivores and many forage in forested riparian areas. Some species rely entirely on caves for wintering, nesting, and summer roosting, while others utilize trees and shrubs for roost sites and maternity colonies. Most bats forage within a few miles of their roost site. These factors, combined with presence of the Federally Endangered Indiana bat within the Illinois River basin makes bats an attractive indicator species of integrity for the riparian zones of small to medium sized, forested streams.

Foliage and tree roosting bats provide the best indication of forest conditions because multiple aspects of their ecology are dependent on riparian habitat conditions. However, this group of bats poses special challenges for monitoring because they live in small colonies that are widely dispersed (O'Shea et al. 2003). The most effective means of monitoring bats is nocturnal trapping. Trapping provides data on species richness and can allow abundance estimation using multiple trapping sessions and mark-recapture models. However, trapping is very intensive and therefore difficult to implement over a large spatial scale. Technological advances have led to acoustic monitoring devices that combined with software analysis and calibration by trapping permits species discrimination and potentially the development of species specific bat population indices. Gannon et al. (2003) provide a discussion of methodology for acoustic monitoring and data analysis.

Bats should be monitored at randomly selected sub-watershed riparian forest sites. Two approaches can be used. Trapping alone provides information on presence/absence, species richness, and forest obligate species. Trapping combined with acoustic monitoring will permit calibration of species calls and the development of indices using acoustic monitoring alone. For both approaches, data should be analyzed to determine the number of sites where bats are present within each sub-watershed and the species found at each. Annual monitoring will show trends over time at the sub-basin level.

Bats are an important biodiversity component within the Illinois River watershed and an indicator of riparian forest integrity for small to medium sized streams. Bats would be expected to respond, but slowly, to riparian forest restoration. A more rapid response (within 10 years) could be anticipated following projects that protect existing habitat, reduce disturbance and insecticide application. Such projects may include retiring of agricultural fields, preventing forest clearing and stream dredging practices, and protection of riparian areas from housing development. Progression of restoration would likely follow bats feeding in areas first, followed by greater roosting and reproduction as older trees and snags become available.

Estimated cost: $119,000.

I. Terrestrial mammals - Because of their large range size and high trophic position, medium to large mammals integrate a range of environmental conditions over large scales. Riparian mammals like muskrat, beaver, mink, and river otter are sensitive to habitat, water quality, and pollutants. Bobcats require large habitat areas that are relatively free from human disturbance. Some mesopredators, like raccoons and opossums, have shown a positive numeric response to human alterations of the landscape and are now ubiquitous. These species are important nest predators of bird and reptile nests and at unnaturally high numbers or in small habitat patches they impair habitat function.

Major challenges to using mammals as indicators are low abundance and detection rate, particularly for positive indicators. The terrestrial mammal monitoring component will utilize existing data surveys and expand on current monitoring programs. Mammal monitoring will rely on summary analysis of data collected from several IDNR surveys and addition of sample sites to the IDNR Furbearer Sign Survey. A combination of methods is recommended to monitor rare and widely distributed species like river otters and bobcats (Melquist and Dronkert 1987; Rolley 1987). IDNR archery deer hunter surveys and trapper surveys provide data that can be used to monitor population trends for most furbearer species, and the IDNR firearm deer hunter survey provides data on bobcat sightings. However, additional funds are needed to increase the number of sample sites for the Furbearer Sign Survey. Another component to be considered is counts of muskrat houses at marsh sites.

Many IDNR surveys are based at the spatial scale of counties. Watershed level analysis should include summaries of all counties entirely or partly within the Illinois River basin. Riparian level analysis should include only those counties partly within the riparian zone of the Illinois River and its tributaries. Expanding the Furbearer Sign Survey will allow trends and distribution of species to be analyzed for smaller watershed units.

Bobcats and riparian/wetland associated mammals are the positive target indicators. The initial response of target species to restoration will likely be functional. Individuals will probably begin using more area following restoration before there is a response in species numbers. Therefore, positive indicators probably will not show significant changes until at least 20 years into the restoration program and then only with significant increases in habitat. Caution should be exercised in interpreting trends and there should be an attempt to differentiate response from restoration to adaptability and range expansion.

Estimated cost: $17,000.

Desirable Response Measures:

O. Avian reproduction - Abundance of breeding birds does not necessarily indicate functional habitat quality. Reproductive success may be low even where adult abundance is high (i.e., sink habitat). High quality habitat patches may suffer from landscape or patch fragmentation effects due to high rates of nest predation and parasitism. Therefore, avian reproductive success integrates many factors and provides a good indication of functional habitat quality at the patch and landscape levels.

To evaluate nest success, five sites per habitat (i.e., forest, grassland, wetland) in each sub-basin should be monitored from roughly April to July. Similar to bird monitoring, each sub-basin will be monitored once every 5 years. Nests should be monitored once every 3 days during the active nest cycle and analyzed using the Mayfield method (Mayfield 1975). Nest success should be analyzed by species, reproductive guild, and community, and can be summarized within watershed units.

Avian reproductive success integrates large spatial scales but is expected to respond slowly to restoration efforts. Wetland or grassland breeding avian species will respond more quickly than forest breeding species because herbaceous communities develop more quickly following restoration than forests. A detectable response in reproductive success will probably only be seen following significant increases in habitat patch size and a long period of time for habitat development. Detectable changes in forest bird reproductive success may not be observed for at least 30 years.

Estimated cost: $122,000.

P. Amphibian reproduction - Amphibian embryos are extremely sensitive to environmental conditions. Successful reproduction by amphibians depends on hydrology, water chemistry, and specific habitat requirements (U.S. EPA 2002a). Amphibians require fishless wetlands for successful reproduction and different species prefer different microhabitats for egg deposition. Counts of egg masses provide an indication of breeding effort and the proportion of viable egg masses indicates wetland health (U.S. EPA 2002a). Amphibian adults and embryos are sensitive to many of the same factors with embryos more sensitive than adults. Amphibian egg masses can be used to detect non-vocal species, including salamanders, not detected using call-based surveys.

To monitor amphibian reproduction, a random sub-sample of 15 of the selected amphibian monitoring sites in each sub-basin should be selected. Potential sample sites can be from any of the three habitat types (i.e., forest, grassland, wetland) where calling amphibians were detected. Data collected should include egg mass counts by species and proportion of viable eggs per egg mass. Two visits should be made to each site to detect all breeding species at a site.

Similar to frog and toad call counts, amphibian reproductive effort is expected to respond quickly to improving habitat conditions, particularly hydrology and water quality. Diversity of breeding amphibians provides an additional indicator of habitat complexity. Viability of amphibian eggs generally provides and indication of environmental conditions, potentially at a scale beyond the Illinois River basin.

Estimated cost: $16,000.

HYDROLOGIC AND SEDIMENT MONITORING

A list of monitoring sites that compose the proposed network that would provide data to achieve the objectives listed in the "Goals and Objectives" section (see Mainstem - Hydrologic and Sediment Monitoring section) is provided below. Following the name/location of each proposed discharge and sediment monitoring site are comments describing which actions need to be implemented at that location. At locations where discharge and sediment are currently being monitored a recommendation is made to "increase sampling frequency." For stations that currently have active streamflow gages, but need sediment monitoring, a recommendation to "monitor sediment" is made. At sites where neither discharge nor sediment is currently being monitored a recommendation is made to "activate" or "reactivate" discharge and sediment monitoring. To "activate" a station implies no prior data has been collected at that site, whereas to "reactivate" a station means previous discharge and/or sediment data was collected at that site. The locations of all of the proposed monitoring sites within the Illinois River Basin are shown in Figure 11.

Tributary Watershed Locations:

<u>Sites on major tributaries</u>

B01 Des Plaines River at Riverside (increase sediment sampling frequency)
B02 Fox River at Dayton (increase sediment sampling frequency)
B03 Iroquois River at Iroquois (monitor sediment)
B04 Iroquois River near Chebanse (monitor sediment)
B05 Kankakee River at Momence (increase sediment sampling frequency)
B06 Kankakee River near Wilmington (increase sediment sampling frequency)
B07 La Moine River at Colmar (increase sediment sampling frequency)
B08 La Moine River at Ripley (increase sediment sampling frequency)
B09 Mackinaw River near Congerville (increase sediment sampling frequency)
B10 Mackinaw River near Green Valley (monitor sediment)
B11 Macoupin Creek near Kane (monitor sediment)
B12 Mazon River near Coal City (increase sediment sampling frequency)
B13 Salt Creek near Greenview (monitor sediment)
B14 Sangamon River at Monticello (increase sediment sampling frequency)
B15 Sangamon River at Riverton (monitor sediment)
B16 Sangamon River near Oakford (increase sediment sampling frequency)
B17 South Fork Sangamon River near Rochester (monitor sediment)
B18 Spoon River at London Mills (increase sediment sampling frequency)
B19 Spoon River at Seville (increase sediment sampling frequency)
B20 Spoon River in Stark County (activate)
B21 Vermilion River at Pontiac (monitor sediment)
B22 Vermilion River near Leonore (increase sediment sampling frequency)

The IRB as reflected in Figures 4-6 and Figures 8-11 can be subdivided into 12 major sub-watersheds (as originally defined by McConkey and Brown, (2000)). In the previous section, the monitoring site A04 (Illinois River at Valley City) monitors the downstream end of the mainstem Illinois River sub-basin. Here monitoring sites B02, B04, B06, B08, B10, B11, B16, B19, and B22 were chosen to monitor the discharge and sediment loads at the downstream ends of nine of the remaining major sub-basins. B12 was selected to monitor the Mazon River, which is the largest stream contained within the mainstem Illinois River sub-basin. Monitoring sites B13, B15, and B17 were selected to monitor the major tributaries of the Sangamon River, which drains a large portion of the area within the IRB. B01 was selected to monitor flow and sediment conditions within the Des Plaines River. B05, B07, B09, B14, and B18 were chosen because substantial flow and sediment data already exists at these locations. B03, B20 and B21 would monitor sediment inputs from Indiana on the Iroquois River, at the upper portions of the Spoon and Vermilion Rivers, respectively.

<u>Sites on small tributaries not in the mainstem Illinois River sub-basin</u>.

C01 Big Ditch near Fisher (reactivate)
C02 Court Creek near Appleton (increase sediment sampling frequency)
C03 Cox Creek near Newmansville (increase sediment sampling frequency)
C04 Friends Creek near Argenta (monitor sediment)
C05 Haw Creek near Maquon (increase sediment sampling frequency)
C06 North Creek near Oak Run (increase sediment sampling frequency)
C07 Panther Creek at Site M (increase sediment sampling frequency)

The above sites are included in the proposed network for three reasons. First, these sites monitor streams draining less than 100 square miles. Second, these sites are currently collecting discharge and/or sediment data (except for C01 which recently became inactive). Sites C02, C03, C06, and C07 are located within CREP or Pilot Watersheds where the effects BMP implementation are being investigated.

<u>Sites on small- to medium-sized streams in the mainstem Illinois River sub-basin</u>.

D01 Apple Creek in Greene County (activate)
D02 Aux Sable Creek in Grundy & Kendall Counties (activate)
D03 Crow Creek (East) near Washburn (reactivate)
D04 Crow Creek (West) near Henry (reactivate)
D05 East Branch Bureau Creek near Bureau (reactivate)
D06 Indian Creek in Morgan & Cass Counties (activate)
D07 Kickapoo Creek at Peoria (reactivate)
D08 McKee Creek at Chambersburg (monitor sediment)
D09 North Fork Mauvaise Terre Creek near Jacksonville (reactivate)
D10 Quiver Creek-Main Ditch in Mason & Tazewell Counties (activate)
D11 Sugar Creek in Schuyler County (activate)

These sites were selected to be incorporated into the monitoring network because they drain areas < 400 square miles and lie within the Illinois River sub-basin. Currently there is little or no information on bluff streams of this size that flow directly into the Illinois River. Previous research on sediment loads within the mainstem of the Illinois and the presence of large delta formations at the confluences of these streams with the river indicate these streams are major contributors of sediment to the river.

Sites to represent different morphologic and physiographic regions.

E01 Coop Branch in Macoupin County (activate)
E02 Drowning Fork at Bushnell (reactivate)
E03 Flat Branch near Taylorville (reactivate)
E04 Horse Creek in Kankakee County (activate)
E05 Indian Creek in LaSalle County (activate)
E06 Indian Creek near Wyoming (monitor sediment)
E07 Kickapoo Creek near Waynesville (monitor sediment)
E08 Mackinaw River near Lexington (activate)
E09 Missouri Creek in Schuyler County (activate)
E10 North Fork Salt Creek near LeRoy (activate)
E11 North Fork Vermilion River near Charlotte (reactivate)
E12 Salt Fork Vermillion River at Forrest in Livingston County (activate)
E13 Spring Creek near Onarga (activate)
E14 Sugar Cr. at Auburn (Lake Springfield) (activate)

These sites are proposed for two reasons. First, they drain areas less than 400 square miles. Second, by including these sites in the network, at least one stream draining less than 400 square miles will be monitored in every major sub-basin (except in the Des Plaines and Chicago/Calumet sub-basins). Thus, the network as a whole will be monitoring the different physiographic areas within the IRB.

Critical Response Measures:

In summary, the critical network would support:

1) All four proposed sites on the Illinois River (A01-A04)

2) Fifteen of the twenty-two proposed sites on the Illinois River's major tributaries

3) Five of the seven proposed sites on small tributaries not in the Illinois River sub-basin

4) Ten of the eleven proposed sites on small- to medium-sized streams in the mainstem Illinois River sub-basin

5) Eleven of the fourteen proposed sites to represent different morphologic and physiographic regions

Estimated cost: $1,118,000 to implement and operate this hydrologic and sediment monitoring network during the first year and $634,000 per subsequent year. These costs reflect the combined cost of the mainstem and sub-basin hydrologic and sediment monitoring plan.

Desirable Response Measures:

In summary the Desirable Network would support:

1) Four sites on the mainstem of the Illinois River (A01-A04)
2) Twenty-two sites on the Illinois River's major tributaries (B01-B22)
3) Seven sites on small tributaries not in the Illinois River sub-basin (C01-C07)
4) Eleven sites on small- to medium-sized streams in the mainstem Illinois River sub-basin (D01-D11)
5) Fourteen proposed sites to represent different morphologic and physiographic regions (E01-E14)

Estimated cost: $1,423,000 to implement and operate this hydrologic and sediment monitoring network during the first year and $815,000 per subsequent year. These costs reflect the combined cost of the mainstem and sub-basin hydrologic and sediment monitoring plan.

GEOMORPHIC MONITORING PLAN

A baseline dataset for project monitoring would be largely developed during preliminary watershed assessment as is discussed elsewhere in this document. The assessments comprise syntheses of existing data and acquisition of data about the contemporary environment across each target watershed. Assessment identifies the existing static condition as well as establishes intrinsic rates of change (e.g., meander migration), and may reveal some long-term system responses to historical change. In addition, the assessment will identify critical data gaps, potential problems for remediation, sampling locations and appropriate techniques, and tune sampling protocols (c.f., Osterkamp and Schumm 1996). The data examined would include at least surficial geology, landscape history over 100 years or more, channel pattern, channel morphology, and climate or flow, though the exact form will be conditioned by data available for the target watershed.

A wide variety of potential projects are envisioned in the Restoration plan, ranging from stream bank stabilization to wetlands creation. The goals of these projects in turn range from protecting target natural areas to improving water quality to preventing channel incision. Indicators for these various projects must be directed at the specific project objectives. Nevertheless, in many instances a standard set of measurements could feed a range of geoindicators.

Table 9 lists monitoring studies that could be used as a basis for developing indicators once specific projects are identified. Wide varieties of qualitative and quantitative methods were used, and were applied over a range of temporal and spatial scales. The objectives of the monitoring programs ranged from generalized trend analysis (e.g., Swanson Hydrology & Geomorphology 2002) to the more desirable evaluation of integrated and linked indicators (e.g., Rhoads and Miller 1999).

Several temporal phases of monitoring may be necessary for each project, depending upon the nature of response of the target feature. Stream channels, for example, often respond to perturbation as a dampening wave. That is, channel conditions may change rapidly and complexly immediately following project implementation, but over time will change more slowly as a new equilibrium condition is reached. Phased monitoring would also allow survey crews to cycle project monitoring: the higher frequency monitoring of new projects could be picked up as less frequent monitoring is phased in on older projects.

Critical Response Measures:

Channel Geomorphology - White et al. (2004) have outlined a detailed method for measuring channel geomorphology (their Phase II, Reconnaissance Characterization). These are recommended as the fundamental measurement protocols for projects directed at affecting channel processes. Surveys should occur along three reaches, one each downstream, within, and upstream of the project reach.

The Phase II measurements are not a set of indicators, however. The development of indicators to gauge channel geomorphic evolution must, again, be specific to project goals and so must wait until specific projects are proposed. Several of the monitoring plans reviewed in Table 8 provide examples. White et al. (2004) have an indicator-oriented Phase I (Rapid Characterization) channel stability scoresheet that could be used to show evolution of a channel throughout an entire watershed by periodic mapping. Such trend analysis might be useful in gauging overall progress towards restoration goals because it would capture effects of channel restoration projects as well as the totality of watershed changes with time. It must be determined, however, whether the indicators are suitable for gauging response of specific projects (c.f., Doyle et al. 2000). Likewise, a project response indicator could be developed from the Relative Bed Stability index of Olsen et al. (1997) if project goals are appropriate.

Three periods of monitoring are suggested for projects directed at channel processes. Monitoring surveys should be conducted annually for several years after project implementation, followed by less frequent surveying (2-3 yr) until project success or failure is demonstrated. A third period of monitoring would be included in decadal sub-basin-wide mapping surveys using the Phase I methods of White et al. (2004).

Estimated cost: $5,000 per project for 10 year monitoring period (total of 6 surveys).

Wetlands - Specific plans must follow project proposals, but a range of standard techniques are currently used by ISGS, IDNR, and other agencies to monitor wetland functions. The basic measurements can be used to develop a variety of project-specific indicators such as sedimentation rate, frequency and duration of flooding, and water quality.

Estimated cost: Not identifiable at present time.

Desirable Response Measures:

Stream Channel Dynamics - The determination of historic rates of change in channel pattern using the air-photo analysis methods of Urban and Rhoads (2000) and Phillips et al. (2002) has been recommended as part of baseline watershed assessment. Stream channel dynamics are expected to be affected by restoration project implementation as well as non-controlled forcings like climate and landuse changes. Understanding the evolution of stream channel dynamics is essential to assessing whether measured sediment loads are "excessive" or not. Channel pattern and rates of change should be reassessed periodically to determine if channel dynamics are evolving across watersheds in the IRB. The analysis would show both project and non-point source responses.

Potential indicators metrics are meander migration rates and avulsion frequency. The air-photo analysis method shows statistically significant channel evolution only over several decades for very low power, low bedload streams, but shows shorter-term changes in other settings (Phillips et al. 2002; Landwehr and Rhoads 2003). The analysis could be applied at various watershed scales. Targeting selected paired subwatersheds (e.g., HUC12) from across the IRB would be an effective combination of scale and resources. Airphotos have been collected every 5-7 years historically by the NAPP. If this pattern continues, an approximately 20 yr period of reassessment is recommended to allow for acquisition of several sequential photos across each target watershed.

Estimated cost: $25,000 per watershed pair.

ECOLOGICAL MONITORING PLAN - AQUATIC

Critical Response Measures:

Use of restoration practices for reducing nonpoint source pollution are well known (Gale et al. 1993). Instream practices for stabilizing stream banks, increasing habitat diversity, etc., have received some study, mostly in coldwater streams (Edwards et al. 1984; NRC 1992; Hunt 1993). Little information is available on how various individual restoration projects affect lotic systems, particularly the biotic community. Therefore, it is important to assess a variety of individual projects at the local scale. In some cases, the effectiveness of specific restoration practices (e.g., riparian buffer strips, Muscutt et al. 1993; Osborne and Kovacic 1993; Hill 1996) has been well documented, but the vast majority of these studies were conducted over relatively short time frames (Edwards et al. 1984; Magette et al. 1989; Habersack and Nachtnebel 1995; Lee et al. 2001). Based on the few studies which have looked at individual practices (riffle structures, channel modification, and wetlands), changes in river morphology/habitat and improvements in fish and invertebrate communities were documented within 3 years of implementation (Carline and Klosiewski 1985; Fuselier and Edds 1995; Habersack and Nachtnebel 1995; Brown et al. 1997). Thus, abiotic and biotic parameters may respond quickly (within 1-5 years) to certain types of restoration practices although other projects (i.e., on-field practices) may take longer to produce a significant improvement in system integrity. How the performance of individual practices change over longer time periods is largely unknown (Muscutt et al. 1993; Osborne and Kovacic 1993). This monitoring framework extends previous investigations of stream restoration practices by evaluation of individual management practices in warmwater systems over a longer time period. By examining effects of individual practices combined with collectively monitoring practices at the sub-basin and basin scale, this monitoring protocol will help determine which practices have the greatest effect on abiotic and biotic indicators and potentially determine the amount needed to obtain the greatest improvement in system integrity.

To examine the effects of individual restoration practices, the Before-After-Impact-Control Pairs design (described in the Introduction - Study Design and Statistical Approaches section) will be used. When possible, reference or “control” sites in nearby watersheds not receiving extensive restoration practices should be used to account for temporal variability. However, sites immediately upstream of the reach being affected by restoration practices should also provide a suitable reference condition before and after implementation. Within a watershed, multiple sites where the same practice will be implemented should be monitored to determine how longitudinal changes along the stream gradient (i.e., discharge, drainage area, etc.) influences the effectiveness of individual practices. It is also important to sample as many years as possible before implementation of the practice to gain a more accurate picture of baseline conditions and to determine the effectiveness of each restoration practice. Since many of the techniques proposed for the Illinois River basin have not been extensively studied (instream structures, bank/channel stabilization, sediment removal, etc.), it is critical to sample many different practices for several years after implementation to evaluate different responses of stream parameters to various practices and establish at what point in time these practices improve stream conditions. To determine immediate and short-term responses in abiotic and biotic conditions, more frequent sampling (i.e., seasonal) directly after implementation of the practice is critical, while long-term effects can be assessed through annual monitoring over several years.

We propose a level of monitoring similar to that described for monitoring sub-basins in order to assess how individual restoration practices effect habitat and biotic communities and how these practices combined effect the entire basin. Both treated and reference sites should be no shorter than 35 times mean stream width such that at least one riffle-run-pool sequence is included in the site (Lyons 1992; IDNR 2001). Physical habitat data must be collected using site-scale and transect-scale levels of sampling (Tables 13 and 14) with site-scale parameters collected at one location in the site (e.g., water temperature, discharge) and transect-scale variables (e.g., width, depth, substrate, etc.) measured along equally spaced transects. These data requirements are not unique to those needed in the geomorphic monitoring section and are therefore not a redundant sampling effort. Depending on the type of practices implemented, more detailed monitoring of in-stream habitat (i.e., mapping of percent habitat types) or bank/riparian vegetation and condition (i.e., quantitative assessment using quadrats to obtain percent composition and dominance of plant taxa) is critical to determine shifts in physical habitat and provide a mechanistic understanding for changes in the biotic community.

Estimated cost: $10,000 - $30,000 per practice (depending on practice type and other biotic monitoring efforts in the sub-basin).

Desirable Response Measures:

To completely understand how restoration practices directly (e.g., creation of habitat by instream structures) and indirectly (e.g., improvements in water quality affecting prey availability) affect the biotic community, it is essential that fish and invertebrates are monitored in both the treated and reference site at the same time as habitat data collection. Quantitative collection of fish and macroinvertebrate data is necessary, and sampling protocols used to assess effects at the sub-basin scale is critical to assess individual practices. However, additional sampling either through more rigorous methods (i.e., multi-pass fish sampling) or increased frequency of sampling (i.e., seasonal sampling of fish and invertebrates) may be necessary depending on the type of practice implemented. As percent of various habitat types shift or types of habitats become more dominate in the reach due to implementation of a restoration technique (i.e., increase in riffles as a result of decreased sedimentation), this framework will allow us to better assess the changes in overall fish and invertebrate communities by sampling more often and by sampling at locations in the watershed where these habitats are newly formed. By including both abiotic and biotic parameters in the monitoring framework, we can better understand how changes in one parameter as a response to restoration practices interacts with and effects other parameters of the system.

Estimated cost: An additional $10,000 per practice (depending on practice type and other biotic monitoring efforts in the sub-basin).

ECOLOGICAL MONITORING PLAN - TERRESTRIAL

Monitoring should begin at least one year prior to project initiation. Monitoring should be done at randomly selected sites within the project area and an equal number of sites in similar "pre-treatment" habitat outside the project area according to the BACI approach (described in the Study Design - Statistical Approaches section in the Introduction). The number of monitoring and control sites for each project should be determined by project size. Specific monitoring components to be used at project sites depend on location and should match components used for the appropriate watershed unit and habitat type. Data collected at project sites should be included in summary analysis for appropriate watershed units.

HYDROLOGIC AND SEDIMENT MONITORING PLAN

The Illinois River Restoration Project proposes a comprehensive array of restoration measures designed to enhance and protect the ecological integrity of the Illinois River. Many of the proposed efforts are new to the Illinois River and never in Illinois has there been an attempt to integrate such diverse projects into a comprehensive plan with the goal of improving the ecological integrity of a system the size and complexity of the Illinois River Basin. For this effort to be successful it will be necessary to determine if specific projects are performing as envisioned, what the cumulative impact projects are having on both biotic and abiotic systems, and if restoration techniques are sustainable over their project lives. Consequently, as restoration projects are implemented, it will be necessary to begin monitoring specific projects in order to assess the impacts, performance, and sustainability of these techniques. In many cases hydrologic, sediment, and bathymetric data will be crucial to interpreting the biological and other forms of data collected by the various agencies participating in the Illinois River Restoration Project.

Specifically, hydrologic and sediment monitoring along with bathymetric surveys will provide managers with data that can be used in a multi-disciplinary setting to define and refine management strategies that enhances synergy between projects, improves efficiencies and unit costs, and allocates resources to those areas where benefits can be maximized. Moreover, such data will be critical in the adaptive management process, which will be a necessary component in the success of the Illinois River Restoration Project.

In addition to providing the information necessary for adaptive management of specific restoration strategies, hydrologic, sediment, and bathymetric data collected through project specific monitoring will expand and complement the data being collected for system monitoring. Thus, as projects are implemented our ability to refine discharge and sediment budgets for sub-watersheds and hence the entire Illinois River basin will be improved. In turn, this will improve our ability to site resources and specific projects in those areas where benefits can be maximized.

To better assess overall sedimentation rates, it is recommended that bathymetric surveys be performed prior to and periodically after the implementation of any dredging projects on the Illinois River mainstem. Likewise, to better assess how specific projects affect hydrologic and sediment regimes, it is also recommended that hydrologic and sediment monitoring be performed for tributary projects that incorporate best management practices designed to reduce sediment loads or control water levels.

Until specific projects have been proposed and sited only a general outline of the goals, needs and methods of project specific monitoring can be provided. However, it is envisioned that project specific monitoring will be conducted more frequently during the initial years of the Illinois River Restoration Project. Once design plans and techniques have been developed and refined for common scenarios the need to assess proven strategies and methodologies will diminish. It is also known that any future mix of project specific hydrologic and sediment monitoring efforts should share certain design elements. These elements include:

- All data must be collected following accepted practices and methodologies. Specifically, the measurement and computation of streamflow will follow guidelines established by Rantz (1982a, 1982b), while methods for measuring/sampling fluvial sediment will follow methods established by Edwards and Glysson (1999). Likewise, bathymetric surveys will be conducted following USACOE protocols (USACOE 2002).
- Data collection design, frequency, and duration are sufficient to meet defined goals for precision and uncertainty.
- Data formatting, identification, processing and archiving will be done so that compatibility with other Illinois River Restoration Project data as well as traditional and historical data sets is maximized.
- Lastly, a defined methodology should be developed that will ensure that all final monitoring data are available to other researchers, managers and the public in a timely manner.

A brief description of the types of monitoring efforts that are likely to be incorporated into the project specific monitoring component of this plan follows:

Discharge and Sediment Transport Monitoring - This monitoring would include traditional discharge and/or sediment monitoring stations, although bed load monitoring may at times be desirable, particularly for bluff streams draining directly to the Illinois River. Typically, two stations will be required to monitor a specific project site. This number may be reduced if projects are sited near existing gages. The types of information and samples collected would include stage/discharge data and suspended sediment samples utilizing both manual and automated pump samplers for concentration and manually collected samples for particle size analysis. In addition, channel cross section data, bed and bank materials and particle size distribution and channel slope would be defined for the stream reach where the gage(s) are located. Those projects requiring this type of monitoring could include bed/bank stabilization projects, sediment detention sites, channel grade control and projects utilizing buffer strips or wetlands to reduce sediment inputs. Also included in this type of monitoring are those projects implemented for water level management. The volumes actually stored for given runoff events and the time over which this volume is released and the subsequent downstream effects of those releases will be important data in the continued development and refining of the hydrologic models necessary to help attain the stated project goals for water level management.

Estimated cost: Assuming 5 active projects requiring hydrologic and sediment monitoring, the estimated annual budget would be $300,000.

Bathymetric and Sediment Characterization Monitoring - Significant amounts of dredging have been proposed as part of the Illinois River Restoration Project. Once sites have been identified and the desired use of dredge materials has been proposed, it will be necessary to sample existing sediments to ascertain their chemical and geotechnical properties to ensure that the dredge material is suitable for the intended use and to provide information relevant to designing the dredge cut. In addition to providing information necessary for project design, data on particle size distribution, unit weight and sedimentation rates provide insight into the sedimentation processes occurring within Illinois River backwaters which will allow for better more efficient design of dredge projects. The bathymetry of initial dredge projects will need to be determined so that "as built" plans can be developed. Through subsequent resurveys of the project site we can determine what locations and which areal extents, bank slopes and footprints can enhance the sustainability of these projects. Coincident with the bathymetric surveying for any project involving on site use of dredge materials would be the traditional land survey of all constructed landforms such as islands and floodplain ridges. Survey and topographic profiling of constructed land features will be necessary to determine which shapes, heights, orientations, construction sequencing and vegetative/protection schemes hasten and increase the use of these land forms by the biota and improve the longevity of these features.

Locations for bathymetric and sediment characteristic surveys will be identified with input from the agencies conducting ecological monitoring and implementing specific projects (e.g., dredging, water retention, and habitat restoration).

Estimated cost: $200,000 per year.

CONCLUSION

The final component to this framework is the incorporation of an appropriate reporting structure so that information is relayed to decision makers and the general public in a timely manner. In order for the information and data generated by this long term monitoring effort to be effectively utilized, it will be necessary to provide some means by which the various resource managers, researchers, and stakeholders involved in the IRER can access this information. This will be accomplished through a WEB-based data inventory and analysis systems containing collected monitoring data, analysis tools, and mapping products. This site will be designed and maintained to help ensure an efficient transfer or information between various user groups.

We anticipate differential responses within the Illinois River basin that may vary in both spatial and temporal aspects across disciplines. Therefore it is difficult to pinpoint a specific reporting frequency that would provide a meaningful synthesis. Clearly, much of the data will be used as soon as available to provide feedback into the restoration process and will be documented as this occurs. However, we feel it reasonable to have a reporting structure that consists of intermediate data compilation (summary) reports on a 5-year cycle with a much more intensive data analysis report analyzing cumulative status, trends, and goal-specific accomplishments on a 10-year cycle.

The monitoring, watershed assessment, and focused research topics discussed in this report are intended to be an integrated and iterative approach that will assist the Illinois River Ecosystem Restoration program. Generally, we expect to measure ecosystem responses to evaluate goal-specific accomplishments across disciplines by monitoring trends at the larger spatial scales or through more comparative analyses at the project-specific scale. Restoration practices will continually be revised as additional information is gained through this framework through the adaptive management process that has been incorporated into the entire program.

FOCUSED RESEARCH

Focused research is a critical element of the monitoring framework because it provides an avenue to gather issue-specific information and refine collection efforts specific to the assessment of restoration goal accomplishments. Therefore, the following focused research summaries highlight several projects that will provide immediate information that can be integrated into the IRER process. There are certainly many other projects that could and will be developed, but these highlight some immediate information needs beyond the scope of the monitoring framework. Each project has a cost and length of project estimate. These estimates are made under the premise that they could be "stand alone" projects. However, if concurrent monitoring or research efforts are occurring in the same general vicinity, cost sharing among the projects will likely reduce the focused research project costs.

Pilot Project for Estimating Bed Load

To determine total sediment yield at a gaging station it is necessary to measure or estimate the bed load in addition to the suspended sediment load Bed load measurements are very rare and limited in Illinois. There are no standard procedures and equipment to sample bed load accurately for different type streams. Graf used a bed load sampler developed by the USGS (Helley and Smith 1971) to measure bed load for nine streams in Illinois and identified many of the difficulties in measuring bed load (Graf 1983). She also recommended using those results with great caution. Nakato (1981) concluded that bed load of tributary streams in the Rock Island District's reach of the Mississippi River ranged from 6 to 26 percent with an average of 11 percent of the total suspended load. Water Survey researchers have generally used the 5 to 25 percent estimate given by Simons and Senturk for large and deep rivers (Simons and Senturk 1977). However, such a practice introduces undesirable uncertainty to sediment budgets. Several factors contribute to the difficulties in determining bed load. Bed load transport is not initiated to a significant degree until some critical shear velocity is reached with maximum bed load transport occurring during high flows. Data collection is complicated by the necessity of collecting samples during extreme flow conditions coupled with the transient nature of the flows being sampled. In addition, bed load transport is highly variable both temporally and spatially even at constant discharges. This variability requires a relatively intense sampling scheme to accurately quantify bed load.

In this plan we do not recommend a particular method, budget for, or plan to perform bed load sampling at proposed streamflow and suspended sediment monitoring sites. Instead, it is recommended that in the near future a separate pilot study be developed and funded to address bed load sampling and bed load transport processes in the IRB. This pilot study could investigate new techniques by comparing the results of an intensive sampling routine using standard techniques to the results gained from using new technologies such as Doppler instruments to determine the velocities of bed load particles coupled with scour chains to ascertain to what extent the bed became entrained. This information could then be applied to sediment budget estimates for other similar streams to refine our calculations of sediment loads. This pilot study would help narrow the 5 to 25 percent estimates we currently use thereby reducing the uncertainty of our estimate of total sediment load. Moreover, bed load transport rates are believed to be important to channel forming processes and are routinely estimated and incorporated into effective discharge computations (e.g. Andrews 1980; Pickup and Warner 1976).Once suitable methods for determining bed load in Illinois streams have been established, funding should be made available to expand the monitoring activities described in this plan to include bed load monitoring at selected sites.

Estimated cost: $300,000 for three year project.

Comparability of Results from Depth-Integrated and Automated Point Sampling for Suspended Sediment.

Traditionally suspended sediment data for larger rivers in Illinois have been collected using depth-integrating samplers following established USGS protocols. As a means of lowering the cost of sediment monitoring associated with the Illinois River Basin Project the use of automated pump samplers, which collect a sample from a single point, has been proposed. While this strategy may offer potential cost reductions at selected sites it is not known how this data would compare to data collected using traditional protocols. Data collected, processed, and analyzed using consistent protocols are comparable in time and space. Conversely data contained using different protocols may not be comparable (Grey et al. 2000).

Determining how data collected using pump samplers compares to data generated from traditional methods will be necessary before these data could be compiled for future assessment or used in conjunction with historical data to determine sediment transport trends in the Illinois River and its tributaries.

The proposed research would provide pump sampling at 3-5 sites where depth-integrated samples are currently being collected in order to assess the comparability of the resulting data sets. Sufficient particle size analyses would be conducted to determine how the differences in sampling protocols may be causing any persistent bias in results. Once the relationship between these sampling methodologies has been determined automated sampling could be employed to reduce costs or expand the number of sites where data is being collected.

Estimated cost: $365,000 for six year project. Data would be collected for five years to help ensure representative yearly precipitation and run-off during data collection.

What is effectiveness of BMPs in the Illinois River Basin?

In addition to reduction of sediment delivery of tributary streams by restoration projects implemented in the IRER plan, progress towards Goal 5 is expected to be helped through the reduction in sediment yield by implementation of BMPs across the IRB. Indeed, one of the selected indicators in the Geomorphology Mainstem/Sub-basin Monitoring Plan is the % area of crop land in BMP. The BMPs implemented are intended to have several and independent effects. These include reduction of soil erosion (e.g., no till), reduction of direct sediment input to streams (e.g., buffer strips, dry dams), mitigation of chemical inputs (e.g., buffer strips), improvement of riparian habitat (e.g., buffer strips). Further, individual BMPs are implemented in a variety of settings and may have different effects in each of those settings. However, the actual affect of each BMP is not often measured after implementation.

There should be research as to whether or not BMPs have the effect they are intended, and thus whether the recommended indicator of % area crop land in BMP is useful to this monitoring plan. Recent studies by Yang et al. (2003) and Khanna et al. (2003) concluded that the CREP program has been ineffective in Illinois. Several major flaws in their analysis have been pointed out, however (M. Demissie, pers. com. 2004). A confounding issue is that Richards and Grabow (2003) found that sediment yield had to be reduced by 7-9 % over 10 years in three Ohio watersheds in order for that reduction to be sensed in monitoring programs. Can that goal be met in Illinois? It is essential to determine what the actual effectiveness of BMP implementation is both to gauge its contribution towards reducing overall sediment delivery. If it is indeed shown to be effective and sensible at desired scales, then it is justified to use % area BMP as an indicator.

This research could be conducted in several ways. On a meso scale, several of the few existing watersheds with continuous discharge and sediment monitoring for several decades could be analyzed for correlation to time-series trends in % area in BMP. This analysis would be supported by air-photo interpretation of stream dynamics over the same period. The most suitable watersheds for study are those within the ISWS' WARM network of gauging stations. Data from the ISWS gauging stations directed at CREP program should be analyzed, but the period of record is relatively short. Because it may be difficult to identify control watersheds within the IRB, resolution of confounding affects may be also difficult. If a set of control-implemented watersheds can be found, the statistical analysis of Richards and Grabow (2003) would be a useful approach to follow.

Estimated cost: $150,000 total cost for two year project.

Monitoring selected individual or a small collection of CREP projects in a BACI sampling program could also demonstrate BMP effectiveness either as an independent study or in complement to trend analysis of historical data. Specific methods employed would depend upon the BMP (-s) selected for study, but would probably include stream gauging, suspended sediment sampling, and topographic mapping to measure gully and rill erosion. An abbreviated 5 yr monitoring program would follow protocols suggested for restoration projects in this document.

Estimated cost: $200,000 total cost for five year project.

A third approach would be to simulate impacts of BMPs on sediment yield using a computer model. M. Demissie (pers. com. 2004) has suggested several ways to improve upon the analysis of Yang et al. (2003), including use of data of appropriate scale (≥1:24,000) and use of an appropriate continuous simulation model.

Estimated costs: $200,000 total cost for four year project.

Pilot Project to Determine Impervious Cover from Digital Ortho Quarter Quads (DOQQs)

Impervious cover, including roads, sidewalks, rooftops and other built features, is a critical feature of the landscape, and is a recommended metric for monitoring landuse effects (Zielinski 2002). The impervious cover class from existing landcover maps, however, is valid only at small (regional, >1:100,000) scale. Because of the small scale, issues such as connectedness of impervious surfaces (e.g. isolated building within grassed area versus building connected to driveway-street-drainage network) or, conversely, the patchiness of non-impervious areas within generally built regions (e.g., yards, parks in urban areas) cannot be distinguished. Accurate impervious cover data are needed at much larger scale for reliable ecosystem monitoring, hydrological modeling, and watershed assessment. Such a dataset could be developed from DOQQs, which are currently the most complete, high resolution, remotely sensed dataset in Illinois.

Endreny et al. (2003) demonstrated the value of extracting impervious cover from color DOQQs with 0.3 m resolution for large scale work on ecosystem restoration activities in New York. Impervious features were recognized by reflectance and geometry. The Lake County (Illinois) Department of Information Technology created a similar dataset by analyzing color imagery and LIDAR data. A pilot project is recommended to create protocols and validate the methods of Endreny et al. (2003) for the grayscale, 1 m DOQQs available for all of the IRB, as well as for the color, sub-meter imagery available in limited regions of the IRB. The project would also estimate costs for basin-wide dataset development. A selection of DOQQs from high, medium, and low density urban, and rural areas from across the Illinois River Basin would be analyzed. Digital results would be compared to results from on-screen digitization of built areas.

Estimated cost: $25,000 for one year project.

Does high sediment load necessarily lead to ecosystem degradation?

A fundamental assumption in development of the ecosystem restoration plan for the Illinois River basin is that excessive sediment loads in tributary streams are degrading riparian ecosystems. Indeed, there is considerable research supporting this assumption, especially in wetlands along the mainstem of the Illinois River. By contrast, portions of McKee Creek in western Illinois are considered some of the highest quality riparian ecosystems in the state, yet recent research has shown that bedload has been actively transported at least through one reach in southeastern Brown County since the 1930's (Phillips et al. 2002), and very active mass wasting and gully development were recently mapped in tributary watersheds in the upper reaches (M. Barnhardt, pers. comm. 2002). How can these two conditions co-exist?

The research project is envisioned as a comprehensive study of channel dynamics since the 1930's in concert with an assessment of biotic change. Stream channel dynamics would be quantified following the methods of Urban (2000) and Phillips et al. (2002). A longer term record of sedimentation would be established through sedimentological analysis of a series short (~1 m) sediment cores obtain from the McKee Creek floodplain in upstream and downstream reaches. The results will show the variability in processes affecting channel pattern along the length of McKee Creek, and whether or not the location, modes, or rates of channel pattern evolution have changed with time. Observed channel evolution will be correlated to reconstructed land use practices and a synthetic discharge history tuned with data from the recently installed flow gauge at McKee Creek.

Characterizing biotic change is a more difficult task because there are few, if any, historical data sets available. It may be possible to construct pre-settlement ecosystems from work of Styles (1980) and others. The existing ecological condition will be obtained from assessment and monitoring activity undertaken for the IRER program. These data will then be interpreted as the cumulative response to changing environmental conditions.

Although McKee Creek will be the target of a watershed assessment over the next few years and is the assumed site of future ecosystem restoration projects, the envisioned research would be targeted to the goal of linking watershed sediment transport history to ecological condition. Considerable feedback is expected between this research and assessment activities and monitoring associated with project implementation under IRER.

Estimated cost: $100,000 for three year study.

Can a useful sediment yield computer model be developed?

Development of an upland sediment yield computer model is highly desirable because it has the potential to predict potential interactions between climate and landcover changes and estimate sediment storage. Sediment yield models appropriate to patches or small subwatersheds (<1 mi2) include the empirical RUSLE (Renard et al. 1997) and the process-based WEPP (USDA 2003). Empirical models have been successfully applied but also regularly misused (Wischmeier 1976). They have received important criticism in Illinois for overestimating sediment yields from gullies and rills with respect to in-channel sources. Nonetheless, Renschler (2003) suggested that these models could be scaled to larger areas.

By contrast, the SWAT model is a process-based model that has shown considerable promise and is part of the BASINS model that ISWS has implemented for its sediment budget. SWAT is a physically-based subwatershed to regional scale model (USDA-ARS 2003). It was developed for modeling long-term sediment yields and thus is appropriate for long-term monitoring applications. A feasibility study is proposed to implement the SWAT model on a small watershed or subwatershed (e.g. Ten Mile Creek, Woodford and Tazewell counties), demonstrate the extent of validation and tuning needed for successful implementation at a relatively large scale, and then estimate the work necessary to scale the model down to larger watersheds up to sub-basin size.

Estimated cost: $150,000 for five year study.

What is the effect of data scale on slope determinations?

Slope data are essential for many applications. They are particularly a concern for hydrological and sediment routing computer models because runoff and stream power are highly sensitive to slope. Slope data are available statewide as 10 m and 30 m DEMs, and as 0.6 m DEMs in the Desplaines watershed and Peoria County. There has also been success at ISGS the Indiana Geological Survey creating 5 m DEMs from USGS Digital Line Graphs (DLG); though that method does not change the vertical resolution from 10 m DEMs, slope determinations may be more or less accurate. Not only do the 10m, 30m, and custom 5 m data vary in resolution, but some of the source DLG data are decades old and thus their accuracy is suspect. There is anecdotal evidence from ongoing geological mapping at the ISGS that DEMs are significantly different from the current landscape because portions of Illinois are geomorphically active.

How do channel and valley slope determinations vary between those data sources and field measurements? A study is necessary to demonstrate the statistical uncertainty in slope determined from each data source and to show the potential value of acquiring new remotely sensed elevation data, possibly at higher resolution. The investigation should target three subwatersheds, one with relatively high relief on the west side of the Illinois River, another of relatively lower relief on the east side, and a third within the DesPlaines watershed to take advantage of LIDAR data there. Slope maps would be constructed from the available DEM and DLG data. These maps would be tested against field data collected using high-resolution GPS along channel slopes, valley slopes, and selected transects of upland sideslopes.

Estimated cost: $50,000 for two year study.

Analyze Data from Existing Sources

Compile and analyze data from existing sources and relate to watershed conditions over time. The Illinois Department of Natural Resources (IDNR), Illinois Natural History Survey (INHS), other agencies and individuals have collected wildlife and habitat data within the Illinois River watershed over time. Many of these existing resources could provide insights into current and historical conditions along the river and its tributaries, and throughout the watershed. Some existing monitoring programs have been incorporated into the recommended monitoring program but previously recorded data and other programs could aid in tracking wildlife species and habitat conditions. Sources could include:

- IDNR Hunter Harvest Surveys
- IDNR and INHS Waterfowl Surveys and Investigations
- IDNR Wildlife Surveys and Investigations
- IDNR and INHS Wildlife Harvest and Human Dimensions Research
- IDNR Fur-bearing and Non-game Mammal Investigations
- IDNR Mid-winter Eagle Survey
- IDNR heron rookery, shorebird migration, and eagle nest surveys
- IDNR frog and toad monitoring
- IDNR wood duck and Canada goose banding studies
- INHS intensive mallard studies
- National Audubon Society Christmas Bird Count
- USGS North American Breeding Bird Surveys
- US FWS Mourning Dove Call-count Survey
- US FWS Woodcock Singing-ground Survey

Estimated cost: $40,000 per year for three year project.

Intensive annual monitoring of marsh birds and vegetation

Habitat for marsh birds and shorebirds has declined significantly within the Illinois River basin with a resulting decline in bird distribution and abundance. Under the proposed monitoring program shorebirds will be monitored annually but marsh birds will only be monitored at selected sites once every 5 years. Similarly, intensive monitoring of wetland habitat for both species will occur only once very 5 years at selected sites. To assess annual variation in marsh birds and habitat conditions, intensive vegetation monitoring should occur annually at selected sites along the mainstem. Sites should be selected to capitalize on past monitoring of specific sites or in critical habitat areas.

Estimated cost: $50,000 per year for ten year project.

Illinois River Index of Biotic Integrity

Multimetric indices that incorporate aquatic organisms, are the most widely used approach for establishing biocriteria and measuring river health (Karr 1981; Barbour et al. 1995; Simon 1999, Jungwirth et al. 2000; Simon 2003). However, the transferability of IBIs among catchments without considerable modifications may be limited (Angermeier and Karr 1986). Furthermore, Suter (1993) listed 10 criticisms of the IBI approach, including ambiguity, eclipsing (low values of one metric can be dampened by high values of another metric), arbitrary variance, unreality, post hoc justification, and unitary response scales. Reactions to these and other criticisms have been vociferous (e.g., Simon and Lyons 1995; Karr and Chu 2000), but suitable alternatives have not been offered. Therefore, we propose to objectively develop and test an Index of Biotic Integrity for the Illinois River that can be used as one tool to monitor ecosystem responses. We will use both existing and new data as they become available to develop the metrics used to calculate such an index.

Estimated cost: Range from $35-50,000 per year for five year study.

Investigate scalability of Indices

Little is known about how sensitive multi-metric indices are to various spatial scales of an ecosystem. Many of the available indices are largely directed to a certain spatial scale and it is unknown how responsive these indices are at other spatial scales. Indices that are useful at several scales will likely provide a more representative characterization of the ecosystem being studied and will also likely provide cost efficiencies in data collection. We propose to evaluate how scalable existing and newly developed indices are when compared at the spatial scales identified in the monitoring framework (mainstem, sub-basin, project-specific).

Estimated cost: Range from $35-50,000 per year for five year study.

Walleye Habitat Use and Movements

Additional data on habitat utilization of important fish species throughout the Illinois watershed would provide valuable information to help guide restoration practices. We propose to conduct movement studies of walleye (an important sportfish species) using radio-telemetry. Efforts would be focused on determining movement and important spawning areas, summer, and overwintering habitats. Tracking would occur in the mainstem of the Illinois River and in an important tributary, such as the Kankakee River. Information collected in this study will increase our understanding of seasonal movement patterns and help guide development of management practices that will have the greatest benefit for fish populations.

Estimated cost: $100,000 per year for three year project.

Over-winter Fish Habitat Use

Habitat availability and use by fish during critical seasonal periods like winter have been a major concern on the Illinois River in recent years due to the loss of well oxygenated, deep water habitats that are not exposed to high water velocities. Many of the restoration efforts along the mainstem Illinois River will focus on providing more of this type of habitat in backwaters and side channels through dredging and other physical modifications. We propose to evaluate fish use before and after project implementation of the first few projects to verify the newly created habitat is being used to its full potential.

Estimated cost: $100,000 per year with a project life that will cover 2-3 years before and 2-3 years after project construction.

Aquatic Organism Population Genetics
Defining management units in terms of characterizing the distributional extent of distinct populations can be a critical factor when making decisions about the basin. One means to quantify exactly what the distribution limits of unique populations are can be determined using common population genetic practices (allozyme and DNA analyses). This can be especially important for mobile species like fish. We propose to evaluate the population structure of selected fish species from the Illinois River in the context of an appropriate distributional range of the species in question. This approach will put the Illinois River populations into a useful geographical context. Ultimately, this information will be useful in providing guidance on inferences of Illinois River fishes. Likely candidate species for study could include, but are not limited to, *Sander* spp. complex, *Morone* spp. complex and other fish known to move relatively large distances. Cost estimates will vary depending on the number of samples needed.

Estimated cost: Range from $50-75,000 per year for each species and/or species complex for a 2-3 year study.

Limiting Factors for Aquatic Vegetation
Establishing and maintaining populations of aquatic vegetation has been a major issue in the mainstem portion of the lower Illinois River for several decades. We propose to study growth rates and establishment potential of select species of aquatic vegetation in the Illinois River using an experimental design that protects plants from biotic, physical and both forms of limitations for establishment. This information will be valuable to the restoration process in that it will provide insight into how to protect areas where aquatic vegetation is desired.

Estimated cost: $75,000 for year one and $50,000 for years two and three.

Establishing Backwater Structure and Function
A critical issue associated with floodplain and backwater connectivity is understanding the relation these habitats have in contributing to the structure and function of the Illinois River ecosystem. Therefore, we propose to study backwater and floodplain lakes to establish a range of variability in determining what aspects of each type of water body (e.g., connected or not connected, restored or not restored, etc.) contributes to the ecosystem. This information will provide meaningful information that can be used to assist in identifying restoration approaches for specific needs.

Estimated cost: $75,000 per year for three to five years.

Development of Habitat Metrics and Indices for Use in the Illinois River Basin

Metrics and indices to assess changes in habitat can be an important component of the Illinois River restoration monitoring program. Before these metrics can be usefully applied, there is a need to assess current quantitative habitat methods which are used to establish indicators of stream quality and to assess metrics for habitat indices that reflect improvements and deterioration in aquatic systems. In wadeable streams, Illinois EPA currently uses a point/transect method for quantitatively assessing physical habitat as well as the Stream Habitat Assessment Procedures (SHAP) index for qualitative assessment. Similarly, the Ohio EPA has developed a Qualitative Habitat Evaluation Index (QHEI) to assess wadeable streams. However, the accuracy of point/transect methods at describing habitat conditions and the applicability of habitat indices at different spatial scales (large rivers to small headwater streams) have not been extensively studied. We propose to address these two important questions through a multi-scale study to determine the accuracy and precision of various quantitative habitat methods and use this data to produce indicators of stream quality for development of an Illinois habitat index. We envision that the developed Illinois habitat index will be a macro-scale approach that measures processes influencing stream habitat (e.g., sinuosity, pool/riffle development) rather than the individual factors that shape these characters (e.g., depth, substrate size) and that a version of the index can be applied to larger rivers as well as wadeable streams. Additionally, the index 1) will allow sufficient resolution to separate high quality and low quality streams, 2) will comprise metrics that vary with stream conditions and biotic conditions (i.e. correlate to fish and invertebrate biotic metrics), 3) will have acceptable reproducibility among different field staff, and 4) can be completed with minimal time, personnel, equipment, and field measurements.

Estimated cost: $100,000 per year for three years.

Effects of Sediment Toxicity on Mussel Populations

The reestablishment of viable mussel populations along the Illinois River and its backwaters depends not only on physical habitat improvements (e.g., dredging) but also on the quality of the remaining bed sediments. Specifically, pore water concentrations of dissolved ammonia and possibly other toxicants including hydrogen sulfide may be high enough at certain times of the year and in certain locations to be toxic to mussels.

Sparks and Ross (1992) attempted to identify the toxic substances that may have been responsible for the rapid decline in several species of aquatic organisms in the upper Illinois River during the mid-1950. Toxicity tests with both the fingernail clam and water flea (*Ceriodaphnia dubia*) using pore waters from various locations between river miles 6 and 248 strongly implicated ammonia as the species primarily responsible for the observed acute toxic effects. The total ammonia concentrations in the pore waters used typically ranged between about 20 and 60 mg/L (as N). However, Sparks and Ross (1992) were unable to precisely characterize ammonia toxicity due to difficulties obtaining the accurate pH measurements required to determine the fraction of the total ammonia that exists in the highly toxic un-ionized form (i.e., NH_3).

Machesky et al. (2004) determined ammonia concentrations in the upper 30 cm of Peoria Lake pore waters (river miles 164 to 179) (Figure 1). These measurements were accompanied by accurate pH measurements determined in the field on separate cores. The primary source of this pore water NH_4-N is typically the solubilization and anoxic metabolism of particulate organic nitrogen (Berner, 1980, DiToro, 2001). Overlying water column values were usually less than the analytical detection limit of 0.07 mg/L as NH_4-N. Mean and median pore water concentrations, however, increased from about 1-2 mg/L NH_4-N at an average sediment depth of 3 cm, to about 10 to 20 mg/L NH_4-N at 27 cm average sediment depth. It is also apparent that average and median NH_4-N concentrations below 15 cm average sediment depth were significantly higher during our October sampling dates than those in April. Consequently, the higher October concentrations could reflect greater microbial activity during this period due to the warmer sediment temperatures.

Methods:
1) Pore water sampling for ammonia, hydrogen sulfide with in situ dialysis samplers and by sectioning sediment cores, followed by centrifugation-filtration to isolate pore water. Important ancillary parameters such as pH, and dissolved- and total organic carbon would also be measured.

2) Detailed, in situ microelectrode measurements of ammonia, pH, D.O., and hydrogen sulfide in the upper 1-2 cm of sediments.

These direct measurements would provide much higher vertical resolution ($\leq$ 100microns) than is attainable with either dialysis or centrifugation-filtration methods ($\leq$ 1 cm vertical resolution). Consequently, ammonia and hydrogen sulfide measurements would be most detailed in the zone most frequently inhabited by mussels.

3) Direct measurements of sediment-overlying water exchange of ammonia and other related constituents with benthic flux chambers.

These measurements would provide important information regarding the sources and sinks of pore water ammonia.

4) Development of diagenetic models for ammonia and hydrogen sulfide, as well as other predictive tools.

Developing these models would aid in forecasting where physical restoration efforts would be most successful.

Estimated cost: $250,000 for three year project. The initial two years will be directed towards sampling, laboratory analysis, and data collection.

Chapter II
WATERSHED ASSESSMENT

INTRODUCTION

Watershed assessments are essential for describing and documenting patterns, processes, and functions within a watershed system (Lessard et al. 1999). Further, watershed assessments will assist in understanding past and present conditions. Although a wide variety of information can and must be used in an integrated watershed assessment, choosing information that corresponds directly to the purpose and needs of the assessment is necessary to assure efficient use of resources and funding.

The information included in a watershed assessment depends on the issues addressed, agencies involved, targeted audience, etc (Lessard et al. 1999). Jensen et al. (2001) proposed three steps for ensuring that appropriate information is included in a watershed assessment. First, major policy questions or resource issues to be addressed in a program need to be clearly identified. The identification of specific resource issues to be addressed (e.g., decreased habitat function due to sedimentation) depends on posing appropriate questions. Through many discussions with state and federal partners, seven goals have been identified for the Illinois River Ecosystem Restoration Program (IRER). They are:

- Restore and maintain ecological integrity, including habitats, communities, and populations of native species, and the processes that sustain them,
- Reduce sediment delivery to the Illinois River from upland areas and tributary channels with the aim of eliminating excessive sediment load,
- Restore aquatic habitat diversity of side channels and backwaters, including Peoria Lakes, to provide adequate volume and depth for sustaining native fish and wildlife communities,
- Improve floodplain, riparian, and aquatic habitats and functions,
- Restore and maintain longitudinal connectivity on the Illinois River and its tributaries, where appropriate, to restore or maintain healthy populations of native Species,
- Restore Illinois River and tributary hydrologic regimes to reduce the incidence of water level conditions that degrade aquatic and riparian habitat, and
- Improve water and sediment quality in the Illinois River and its watershed.

Therefore, watershed assessments must identify resource status as it relates to the goals listed above.

Second, Jensen et al. (2001) propose selecting the appropriate scale of analysis. The appropriate scale depends on the resource, function or process being assessed in a watershed. Certain assessment tools such as the U.S. Environmental Protection Agency's (USEPA) Know Your Watershed or Index of Watershed Indicators are useful at national or regional scales (USEPA 2002). Similar tools applied to Illinois specifically, namely, the Illinois EPA Water-body Tracking System (IEPA 2004), provide more detailed information at the state level. These comparative assessments give insight into the relative condition of watersheds within their respective regions. Comparative assessments at small scales already have been conducted for the Illinois River Basin (IEPA 1998b) and can aid in focusing where best to scale-up to more detailed, comprehensive watershed assessment (watershed characterization). Therefore simultaneous discipline-specific watershed assessments focusing on integration and synthesis of information (hydrologic, geomorphic, and biologic) at site, sub-basin, and the Illinois River Basin scales are necessary.

Third, Jensen et al. (2001) suggest identifying a set of scale-specific, measurable, and mappable features that relate to the issues being addressed. Previous watershed assessment methodologies, such as the Watershed Implementation Plan (IEPA 1998a), require numerous types of information at many scales. However, some of the information required (e.g., air quality) was difficult for local planning groups to gather, and did not relate directly to the issues being addressed (e.g., flooding). Through this project, we intend to identify variables that best relate to the resource issues being addressed through IRER.

While restoration project identification involves many facets (e.g, policy, socio-economic, and scientific justifications), we feel the following may provide a suitable guide for assessing the existing biotic an abiotic conditions. Therefore, based on the steps suggested above and review of existing approaches and protocols, we recommend that the following goals be incorporated into Illinois River Basin watershed assessment:

1) identify defining physical limits of each watersheds or target area) in the Illinois River Basin (physiography, geology, climate, etc.),
2) identify the reference watersheds within targeted sub-basins or areas
3) document past and current conditions in priority watersheds and identify reference conditions in the reference watersheds,
4) identify practices and processes impacting priority watersheds,
5) recommend restoration projects based on identified cause-effect relationships.

Information resulting from meeting these goals will aid practitioners and policy-makers to make more informed, effective, and defensible resource management decisions.

Review of Watershed Assessment Approaches

Watershed assessments have taken place in Illinois through various programs prior to the Illinois River 2020 effort (IEPA 1998b; IDNR 2004). Additional assessments and innovations have recently been developed and/or applied in Illinois watersheds (Keefer and White 2004; White 2004; Locke et al. 2004; and others). While much effort has been focused on unifying and consolidating information for Illinois watersheds in recent years (IEPA 1998b), additional effort needs to be made toward integrating information from various disciplines to evaluate watersheds more effectively. This integration could lead toward a better understanding of the relationships between physical habitat (hydrology, hydraulic, sediment, geomorphology, etc.) and the biotic community (vegetation, fish, macroinvertebrates, etc.).

Several state, federal, and non-governmental organizations have developed watershed assessment procedures. For example, Oregon, Vermont, and Washington have extensive watershed assessment manuals that could serve as models for comprehensive and integrated watershed assessment in the Illinois River Basin. These protocols require varying levels of expertise, data collection, and analysis. Further, some assessment procedures were developed and applied in conditions specific to particular states and regions. Elements of the existing protocols adopted for watershed assessment in Illinois will need to be modified to address the range of conditions in Illinois watersheds.

Watershed Assessment Approaches in Illinois

Illinois Geomorphic Watershed Assessment (IGWA), ISWS

The Illinois State Water Survey (ISWS) is currently developing a geomorphic assessment approach for Illinois watersheds focusing on geomorphology of tributary streams and intended for rapid identification of restoration project sites. The underlying principles behind this effort include systematic assessment, uniform data collection, and quality assurance. Following these principles will aid in the accuracy of assessments. The Vermont Stream Geomorphic Assessment Protocol (VSGAP) serves as the initial foundation for this approach (Kline et al. 2003). The obvious differences in regional geography between Vermont and Illinois necessitated the adaptation of the Vermont protocol to Illinois geography utilizing other studies conducted in the Midwest (Barnard and Melhorn, 1982; Bryan et al., 1995; Kuhnle and Simon, 2000; Rhoads, 2003; Simon and Downs, 1995; Simon and Hupp, 1992; Simon and Rinaldi, 2000; and Rhoads and Urban 1997; Urban 2000). The key goals and principles in the Vermont protocol remain the same in the IGWA approach: determine the past and current physical nature of a stream and its watershed, assess the likely sequence of events that have contributed to initiate a set of stream responses, and assess potential future channel response given past and present conditions. Development of the IGWA approach is ongoing and will be implemented and further tested in 2004.

The purpose of IGWA approach is to provide meaningful guidance in the application of watershed and stream restoration practices (BMPs) that reduce upland, side slope and floodplain or channel erosion, and also address sedimentation or aggradation issues that may result, such as the burial of productive substrates.

The IGWA approach contains two phases 1) Rapid Characterization and 2) Reconnaissance Characterization. This phased approach will integrate progressively detailed levels of investigation at selected stream reaches throughout a watershed. Phase 1 involves gathering existing watershed and stream channel data/information (historical and recent); evaluating watershed characteristics based on geology, soils, hydrology, land cover, and climate; conducting aerial flyovers to quickly assess stream reaches; performing field-based rapid channel stability/physical habitat ranking of many sites distributed throughout a watershed. Based on preliminary evaluation of the Phase 1 information/data, the assessment may continue to Phase 2 when an entire stream system seems to be responding to changes within the watershed. Phase 2 involves a more detailed field reconnaissance of streams reaches at a subset of Phase 1 field sites (Rhoads 2003; Kuhnle and Simon 2000; and Thorne 1998). The data collected at Phase 2 sites is more comprehensive and, when compared and contrasted with historical or recent data (Trimble and Cooke 1991), improves the prediction of potential future channel adjustment. The comprehensive data includes surveyed channel geometries, bed/bank conditions, boundary material descriptions and size distributions, and riparian vegetation as fluvial geomorphic indicators (Hupp 1999; Hupp and Osterkamp 1996).

The IGWA integrates channel stability ranking with stream habitat conditions by collecting data as prescribed in USEPA protocols (Barbour et al. 1999). Over time, relationships and trends between stream channel geomorphology and biotic communities may be drawn from the surveys of biotic communities conducted at the Phase 1 (habitat assessment) sites.

Data included in the IGWA approach include topographic maps, historic aerial photography, GPS aerial video flyovers, geology, a land cover, etc. As the level of assessment increases (from Phase 1 to Phase 2) the scale of assessment remains constant (~1:24000), but stream reach data such as cross-section measurements are collected in greater detail.

<u>Stream Dynamic Assessment (SDA), ISGS and UIUC Dept. of Geography</u>

Phillips et al. (2002) assessed planform changes of representative stream reaches in the Illinois River Basin. Analysis of aerial photographs in time series from 1938 to present was performed to identify mechanisms and rates of planform change, assess the variability of these behaviors across the watershed, and determine the suitability of the method for watershed-scale assessments. The greatest value of SDA for initial watershed assessments is that it quantifies how a given stream changes in a historical perspective giving insight into the concept of stream channel "stability", in particular. Further, the analysis identifies dominant processes and geological targets for more intensive field study, reveals the variability of stream planform dynamics, and demonstrates that total geomorphology of the system needs to be evaluated to understand stream behavior.
In this method, channel centerlines (threads) are traced, rectified, and corrected using GIS methods. Threads were then compared to distinguish "natural" and human-influenced change. These changes were evaluated in context of stream power calculations from gauge data, geology

and soils data, and observed changes in land use and land cover. From GIS analysis mode of stream planform changes (lateral migration, downstream translation, formation and avulsion, and channelization) were characterized and assessed. This assessment provided insight into the mode of planform change and the importance of evaluating the dynamic response of streams, particularly to channelization, for assessing the feasibility of restoration projects. SDA would also aid in evaluating the range extent and rate of planform change.
SDA gives a quantitative understanding of stream change over the past 60 years with limited investment of resources. For the initial study, GIS database for 16 km of reach was compiled and digitized, including calculation of change polygons occurring in less than 20 person-weeks. Analysis of the geological setting and interpretation of change is dependent upon data availability, planform complexity, and the amount of change. The geological setting for initial method testing was developed only generally because of limited data. In most cases geologic maps, are only available at scales of 1:100,000 or smaller. Soil surveys typically give reasonably detailed assessments (~1:16,000) of floodplain materials and their properties, but additional interpretation is required to assess the geological history of the floodplain. As well, only small scale soil surveys are available. The only bed substrate information available was from stream gauge records (USGS, writ. com.) and was mainly anecdotal. Most needed are geological maps at the 1:24,000 scale for establishing the geologic setting, especially the thickness of post-glacial valley fill and depths to older sediments or bedrock. Such maps should be supplemented by focused higher resolution field studies of floodplain and channel sedimentology and river geomorphology.

Channel incision cannot be directly assessed from airphotos. Trends of increasing channel width with time could possibly be surrogate for assessing incision following channel evolution models (Simon 1989), however. We found no such trends, but georeferencing error was quite high relative to channel width for many of the images in this study. Width analysis may be more definitive with expected error reduction through use of crisper source images and georeferencing methods.

Manual methods worked sufficiently well for the initial application of SDA. To examine an entire river or subwatershed would require compiling many more georeferenced digital images. Although our georeferencing method proved adequate for quantification of dominant evolutionary behaviors, more accurate quantification of change and improvement of interpretations are desirable for more precise results.

Methods for Estimating Groundwater Recharge Areas for Illinois Nature Preserves, ISWS and ISGS

The ISWS and ISGS have developed methods assessing and delineating ground-watersheds to determine Class III ground water protection areas for the Illinois Nature Preserves Commission (Locke et al. 2004). The methods for groundwater recharge area estimation have been applied for several nature preserves. Ten preserves were assessed within the Illinois River Basin. Because sufficient groundwater data are typically not available, other data were used to estimate recharge areas. This requires the integration of multiple data sets including best available hydrologic and geologic information, proxy data (e.g., surface watersheds), indicators (e.g., groundwater discharge), raw data when available, and best professional judgment.

Procedures outlined for Class III protection areas are particularly useful in estimating the extent of highly vulnerable (i.e., areas surrounding rare or high quality habitat) sub-watersheds or catchments. An adapted version of this method would be useful for assessing groundwater resources in watersheds.

Data required for this method include 7.5-minute topographic quadrangles, well boring records, local geologic maps information, and local groundwater models. Detailed local information is lacking in many cases where this method has been applied. Datasets should be supplemented by local hydrogeologic studies. This procedure is best applied at scales of 1:24000 or larger.

Ground water recharge areas interpreted from surface watersheds identified much of the estimated regional groundwater recharge area and generally captured the most hydrologically significant areas immediately up-gradient of the preserves were identified. A Class III groundwater area based on an adjusted surface watershed appears to provide significant protection for a preserve even though it will not directly correlate to the groundwater recharge area. Indirect methods are poor in identifying confined groundwater sources, such as where karst terrains exist or in areas influenced by significant groundwater withdrawals. The methods of Locke et al. (2004) allow protection of groundwater recharge areas based on current information, and when additional information is available, delineation of groundwater recharge areas may be amended.

Rapid Assessment Point-Method (RAP-M), Illinois USDA-NRCS

RAP-M (Windhorn 2001)was designed to produce estimates of average annual erosion and sedimentation rates in a watershed. The procedure entails generating initial inventories of physical features, practices, and processes in selected sample areas (e.g., gullying) from existing data. Field information is then collected to identify current practices and conditions within the selected sample areas. Various features identified in office and field inventories are assigned rating factors used in the calculation of sedimentation and erosion estimates. Equations used for the estimates are outlined in the RAP-M manual. In this method, after rate estimates are calculated, it is suggested that results may be summed and extrapolated to illustrate the condition of the larger watershed encompassing the investigation area. The ultimate goal of the RAP-M method is to make local BMP planning decisions based on the rate estimates of erosion and sedimentation.

Data required for RAP-M include topographic maps, aerial photos, and soils maps, land cover and DEMs. Most of these data are available statewide although currentness and scale varies. The suggested scale for RAP-M is not explicitly indicated, but it is recommended that maps are drawn at roughly 1:15000. As with any assessment procedure, results are limited by the smallest scale of data and confidence in results will be reduced at smaller scales and wider sampling distributions.

While interpretation of watershed processes may be inferred, conclusions about geomorphic processes cannot be made using this method. RAP-M is not intended for monitoring purposes. Consistent and uniform application of this method is essential thus workers are urged to be consistent in their field observations. Subjectivity in observation could be a significant source of error in calculations. GIS methods could make RAP-M more systematic but the results still rely heavily on the input from individuals collecting field data. This procedure does not include detailed inventories and evaluation of other environmental and hydraulic parameters and becomes less reliable in larger watersheds. Extrapolation of RAP-M results from larger to smaller scales (smaller watershed to larger watersheds) is tenuous given the likelihood of variability in geology, soils, land cover not captured by sampling. Aspects of RAP-M might be useful as the upland component of a comprehensive watershed assessment protocol in the Illinois River Basin if applied and interpreted at relatively large scales in smaller watersheds.

Rapid Watershed Assessment, USGS

Led by the U.S. Geological Survey, state and federal agencies in Illinois (e.g., USDA-NRCS, IDNR) have co-operated in applying GPS-integrated aerial video technology for rapid watershed assessment (Roseboom et al. 2002). Elements of Rapid Watershed Assessment are currently being incorporated into the Illinois Geomorphic Watershed Assessment approach (White 2004). The technique entails mapping streams with GPS-oriented aerial videotapes acquired during helicopter flyovers. The strongest features of GPS-video mapping are that is provides quick visual documentation of the static condition of long segments of a stream system, and it is useful for communicating with stakeholders. Abrupt changes in channel pattern or form as well as key features of the natural and built landscape can be interpreted from the images.

The weak points of the method are its high cost and a limited ability to distinguish geomorphic process and product. Flyovers are expensive and are most effective during in winter or early spring when canopy conditions are least dense. Interpretations of apparent stream instability would need to be verified by temporal and field studies.

The use of new surveying technology called Light Detection and Ranging (LiDAR) which can be recorded simultaneously with GPS video mapping has been investigated as well. LiDAR is used to obtain continuous channel morphology data (topography) along a particular stream channel. One-time LiDAR flights can provide baseline data, but multiple flights could be used to analyze and document changes in channel morphology from which sediment production and delivery can be estimated. To date, LiDAR has only been applied in a portion of Des Plaines River watershed. Several factors limit the utility of LiDAR, not the least of which is its high cost. Also, the current technology may not have the resolution to obtain accurate bed and bank geometry. Although the level of precision of LiDAR data may be 1-2 orders of magnitude greater than existing DEM data, lack of resolution within stream channels may not warrant the expenditure of monetary and human resources.

Process-based Watershed Assessment Protocol, Herricks et al. (2004)

Herricks et al. (2004) designed a protocol to meet specific reconnaissance study and feasibility study needs, and specifically to integrate these two activities so that reconnaissance study reporting provides direct input to feasibility studies. The objective of this protocol is to make maximum use of existing physical and chemical data while integrating any available biological assessment data into an analysis that will assess location-specific ecosystem vulnerability/impairment issues that will direct ecosystem restoration programs.

The process-based metrics within the protocol are under development. The metrics include formulations that establish source quality and potential, relate the source to the colonization site, identify pathway impediments to organism movement, assess colonization site potential, and provide scale based habitat needs measures for populations and communities. The analysis of performance metrics requires both spatial and temporal integration. Spatial analysis and integration can be as simple as plotting locations on a map, but temporal analysis would be more intensive.

Data requirements for this protocol are broadly defined by necessity. An objective of the protocol is to use existing data and information to characterize state or condition using water quality and biological/ecological quality assessments made as a part of normal water quality analysis under the Clean Water Act. This information is used to both assemble stakeholder groups and provide a focus for discussion at stakeholder meetings. A major objective of the reconnaissance is to identify the opportunities for ecosystem restoration, and provide a foundation for a feasibility assessment. The reconnaissance study is limited by resources, but the resource base may be variable depending on the overall scope of the proposed project. Thus the protocol reflects the need to provide information for initial project review, with a level of effort that reflects a reconnaissance effort and personnel time reflecting overall project size.

The reconnaissance study is intended to provide the foundation for the feasibility study, which is much more complex and comprehensive. It is assumed that the reconnaissance activity has consolidated data/information resources, has identified critical areas in the watershed that are impaired, and from a water quality and general land use perspective has identified general sources of impairment. The protocol is based on the following study objectives: The feasibility study is to develop more detailed data/information from existing data resources to meet the following study objectives: 1) identify specific needs for restoration projects, 2) suggest general design requirements for specific projects, 3) determine the feasibility of ecosystem restoration projects in relation to natural constraints and land use change potential, and 4) assess the long-term potential for project success. These study objectives are achieved by reviewing the basic information resources for the project watershed and making an initial determination as to whether or not new data should be collected. The protocol assumes that there will be sufficient existing data to conduct a general feasibility analysis and that the major need for new data will be associated with specific locations or problems. Development of specific quality assurance documentation before collecting new data is recommended. The basic structure of the feasibility structure protocol is designed to assemble physical, chemical/water quality, and biological/ecological data for use in a range of integrative analyses. The confidence level of assessment would depend on the quality, scale and availability of existing physical and chemical data.

National Guidance and Generalized Approaches

A Framework for Analyzing the Hydrologic Condition of Watershed, USDA-FS and BLM

The *Framework* was developed to provide national guidance for hydrologic assessment of watersheds. It consists of 6 steps: 1) Characterize the watershed, 2) identify rate factors, 3) identify important factors, 4) establish current levels, 5) establish reference levels, 6) identify changes and interpret results. A precursor to these six steps is development of a case file index. The case file index is a data gathering and assessment procedure that can indicate the level of confidence of analysis of a watershed.

Data categories required for watershed characterization are climate, surface water flow, groundwater (location of springs and wells, and aquifers), watershed morphometry (area, topography, etc.), wetlands and riparian areas (NWI-maps), soils, geology, vegetation cover, and human influence. The scale of assessment suggested in the Framework is 1:24000. Much of the required data for this approach are available Illinois although at varying scales and with varying coverage. Soils and topography are among the few data sets have complete statewide coverage. Topography is available at 1:24,000 scale and the scale of soil maps range from 1:63,000 to 1:15,000.

The limitations of the Framework include subjectivity in applying rating factors and treatment of data gaps. Watershed hydrology parameters are rated 1- high influence, 2-moderate influence or 3- low/slight influence. The rating procedure is highly arbitrary. It would be difficult to get uniform results, especially if people from different disciplines and varying levels of expertise are practicing this method. Data gaps are addressed by incorporating surrogate information into the assessment (e.g., road density as a surrogate for infiltration reduction) methodology for use of surrogates would have to be developed prior to implementation of watershed assessment prior to using this procedure. Further, adaptations such as a more detailed rating system are recommended prior to implementing this procedure to for the Illinois River Basin.

Stream Visual Assessment Protocol, USDA-NRCS

Stream Visual Assessment Protocol (SVAP, USDA-NRCS 1998) is not a watershed assessment procedure but rather a channel reach assessment procedure. This procedure is designed for use by conservationists to evaluate stream health. The method relies on ranking using comparator charts for various factors such as channel condition, hydrologic alterations, and barriers to fish movement. Ranking criteria are outlined, somewhat reducing the subjectivity of the assigned numerical values. Ratings are then averaged for a total score which is the index of overall condition of a particular stream reach.

No specific scale of assessment is given in the SVAP, however the protocol suggests assessed stream reaches be 12 times the active channel width. The only data required for this assessment procedure are rudimentary field observations and landowner input.

The crude characterization of channel condition limits the utility of SVAP in comprehensive geomorphic assessment. While guidance is given for the assigning numerical rating, the rationale of the numerical weighting is unclear.

Watershed Vulnerability Analysis

The Center for Watershed Protection (Zielinski 2002) developed Watershed Vulnerability Analysis (WVA) as a rapid planning tool for larger watersheds. It has been used in instances where it was necessary to group and prioritize up to 20 sub-watersheds for restoration and protection. Results of WVA as outlined by the Zielinski (2002) are A) a defensible rationale for classifying sub-watersheds, B) a framework to organize and integrate data, C) a rapid forecast of the most vulnerable watersheds, D) prioritization of watersheds that merit restoration action.

The compartmentalized WVA procedures include initial sub-watershed classification, final sub-watershed classification, watershed vulnerability ranking, and prioritization for implementation.

Suggested size of targeted sub-watersheds is 0.5 to 30 mi^2. The rationale for use of this scale is the relative influence of impervious cover. At smaller scales (larger watersheds) effects of impervious cover and other hydrologic influences may be damped out of the analysis. Of course, confidence of analysis would increase with the scale of data. Essential data include topography, hydrology, impervious cover, current land use (zoning), future land use (zoning master plan), and aerial photos. Auxiliary mapping layers include riparian cover, floodplains, wetlands, forest cover, soils, geology, stormwater management facilities, and others. Aerial photos (DOQQs), topography, soils, and land cover are all available statewide for Illinois at 1:24000 or greater scales. Data such as zoning, geology, and stormwater management are sporadic to non-existent in coverage and scale.

The major limitation of WVA is that is meant as a prioritization tool only. The results of analysis do not lend themselves to interpretation of processes or functions within a watershed. More comprehensive watershed assessment would have to take place in those watersheds that were prioritized for implementation.

Landscape Assessment of Geomorphic Sensitivity (LAGS), State of California

California Environmental Resources Evaluation System (CERES) developed the LAGS procedure to estimate the geomorphic sensitivity of the landscape (watersheds) to land use disturbances. This procedure operates much like WVA however it is more simplistic and incorporates fewer data layer into the analysis. Data used in LAGS are limited to slope, geology, landslide terrain, and unstable and erodible soils. The scale of analysis is limited by the smallest scale data used.

Like WVA, LAGS is design to identify areas that may need further evaluation and is not to be used in a prescriptive sense. An adapted LAGS procedure could be incorporated into a larger comparative assessment procedure for Illinois River Basin watershed assessment.

Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, US EPA

The US Environmental Protection Agency (USEPA 1999) developed a rapid bioassessment protocol to determine physiochemical and habitat conditions along with assessing the quality of biotic communities (periphyton, macroinvertebrates, and fish). This protocol is designed to give a general picture of stream integrity or health with minimal field and laboratory efforts. Physiological data obtained from this protocol provides estimates of in-stream, riparian, and watershed features through observational assessment. Water chemistry parameters focus mostly on conditions that affect the biota (i.e., temperature, dissolved oxygen, etc.). For assessment of physical habitat (in-stream and riparian) and biota (periphyton, macroinvertebrates, and fish), a multi-metric index is used to score stream quality based on that particular indicator (habitat, fish, invertebrates, etc.). Collection of physical habitat data is observational and the index is based on a rating of habitat categories (substrate/cover, embeddedness, bank stability, etc.). Biotic data is collected with minimal sampling and course identification with rating of stream quality determined by composition of the assemblages (i.e. taxa richness, % tolerant taxa, etc.)

There are several limitations to the USEPA rapid bioassessment protocol. Assessment of water quality is a "snap shot" view of water conditions and does not include other parameters which may be limiting or affecting the biota (e.g., nutrients). The limitation of the physical habitat assessment stems from the subjectivity in rating individual physical habitat metrics. While biotic assessment under this protocol is time efficient and gives an overall indication of biotic integrity, it gives few details on processes affecting the biota.

Watershed Assessment Protocols from Other States

Oregon Watershed Assessment

The Oregon Watershed Assessment Manual (OWAM) is a comprehensive assessment guide with the aim of 1) identifying features and processes important to fish habitat and water quality, 2) determining how natural processes are influencing those resources, 3) understanding how human activities are affecting fish habitat and water quality, 4) evaluating the cumulative effects of land management practices over time (Watershed Professionals Network 1999). The OWAM was designed for a widely varying range of landscapes. The method employs ecoregions (large areas each with similar geology, flora, fauna, and landscape) at the broad scale and Channel Habitat Types (CHTs – stream channels with similar gradient, channel pattern and confinement) at the channel reach scale. The OWAM is divided into components that combined comprise "Watershed Characterization". Each component can be completed separately so different specialty teams may work on various assessment components simultaneously. Components are then brought together in the final "Watershed Assessment" phase.

Basic data requirements for OWAM watershed characterization are 7.5-minute topographic quadrangles, land cover maps, ecoregion maps, and aerial photography and topographic maps. Supplemental data for Watershed Characterization include mean annual precipitation maps, habitat assessment maps, street-level road maps, peak flow data, landslide inventories, National Wetlands Inventory maps, FEMA maps, soil surveys, etc. The suggested scale of assessment by the OWAM is at least 1:24000. In some cases (aerial photo interpretation) scales at large as 1:12000 are employed.

This manual would need to be adapted to conditions in the Illinois River Basin. Components of the OWAM could be adapted or replaced by assessment techniques developed specifically for Illinois. For example, the "Channel Modification" component which focuses on location, type, and magnitude of channel disturbance, could be replaced with the IGWA approach outlined above.

Vermont Stream Geomorphic Assessment (VSGAP)

The Vermont Agency of Natural Resources recently designed protocols to assess the geomorphic conditions in streams and watersheds (Kline et al. 2003). Focus on geomorphic principles and physical habitats are key elements in this approach. The VSGAP is divided into three handbooks, Watershed Assessment, Rapid Stream Assessment, and Survey Assessment. Like the OWAM, VSGAP outlines training, personnel, and material needs to conduct each phase of the protocol.

For the Watershed Assessment phase, VSGAP requires aerial photographs (the most recent and historical photos at least 20 years old), 7.5-minute quadrangles for the watershed. For GIS analysis digital layers such as streams, soils, and land cover at 1:5000 are needed. These GIS layers are available for most of Illinois at scale of 1:24000. Methodology for calculating various geomorphic variables from available map resources are given in the Phase 1 handbook.

Limitations of application of VSGAP in Illinois are currently being resolved within the IGWA approach (Keefer and White 2004).

Washington Watershed Analysis Manual (WWAM)

The Washington Watershed Analysis Manual objectives are to assessing resources, define problems, identify sensitivities, produce management prescriptions, and monitor the effectiveness of those prescriptions (Washington Forest Practices Board 1997). A helpful feature of this manual is the use of guidance questions to help keep focus on the objectives of the assessment.

The components of the Washington Manual include "Mass Wasting", "Surface Erosion", "Hydrology", "Riparian" and "Stream Channel". While each of these components is qualitative, guidance matrices give criteria for the assignment of ratings making the procedure somewhat systematic.

Basic data requirements for the geomorphological components of the Washington analysis are: aerial photography, geologic maps, watershed base maps, soils maps, precipitation maps, land use /land cover, vegetation type, streamflow (if available), field observation in stream channels.

As with the OWAM and VSGAP, components of the WWAM would have to be altered to assess the range conditions (climate, physiography, and dominant land use) and policy in the Illinois River Basin. For example, the surface erosion module focuses on assessment of forest practices and hill slope and road erosion and does not address erosion from agricultural or urban land uses in a manner that would be appropriate for the Illinois River Basin. Also, the riparian assessment module treats the supply of large woody debris (LWD) to streams as positive indicator. Policy regarding the treatment of LWD in the Illinois River Basin would need to be resolved prior to conducting watershed assessment.

The stream channel module is executed through classifying streams somewhat similar to the Rosgen (1994) method. The guiding questions in this module focus partially on the "likely responses" of channels to changes in the watershed and this procedure employs the use of "channel response types". Interpretation of "likely response" is not recommended for use as the basis of restoration design.

Proposed Watershed Assessment Framework

The watershed assessment manuals and other procedures reviewed above give valuable guidance for watershed assessment in the Illinois River Basin. The framework we recommend is based on our review of these existing strategies. Comparative techniques such as WVA and LAGS provide logical, systematic procedures using existing data sets (e.g., land cover, DEMs). Though the scale of existing datasets may limit the resolution of assessment, adapted versions of these types of GIS-driven assessment may be sufficient for general, rapid comparison of watersheds in the Illinois River Basin.

The watershed assessments produced by Oregon, Vermont, and Washington state governments are comprehensive assessments that focus on examining those factors that significantly impact a particular watershed. These assessment manuals were developed for regions with geographies that differ vastly from Illinois and would have to be adapted to assess conditions specific to the Illinois River Basin. Nevertheless, these manuals provide guidance for comprehensive watershed assessment (specifically, watershed characterization) for Illinois and are valuable references.

We recommend that watershed assessment in Illinois follow the comprehensive approaches developed by Oregon, Vermont and Washington. We outline the following framework base on synthesis of the reviewed materials:

1) Watershed comparison and prioritization
2) Establishment of reference watersheds
3) Rapid assessment of reference watersheds
4) Watershed characterization of prioritized watersheds

5) Integrated assessment and evaluation
6) Project recommendations

A crucial first step in addressing restoration needs for the Illinois River Basin is identifying watersheds where restoration efforts can be most effectively applied. This approach is aimed solely at scientific evaluation of the watershed. Many other criteria can and should also be involved in the prioritization process to ensure proper site selection. A comparative assessment considers many watersheds (e.g., within a sub-basin) rapidly and simultaneously to quickly identify relative sensitivity, value, or level of degradation. A watershed found to be highly degraded by comparison, might not warrant restoration action in that watershed if degradation is consider irrevocable. Alternatively, restoration may be focused outside of that watershed if functions or processes in other parts of the system are contributing to the degradation. In this case, restoration efforts (priority) would be best focused in a tributary watershed or catchment. Key elements of comparative watershed assessment include systematic assessment, uniform data interpretation, resolution and scale that will uncover contrasts among watersheds, and recognition of systematic impacts. The results of a comparative assessment aid prioritization of watersheds for characterization. Comparative assessments, such as the Unified Watershed Assessment (IEPA 1998), have already been conducted for Illinois. These could be used for the initial comparative assessment, but updates are recommended where significant datasets have been acquired.

After priority watersheds have been identified, we recommend establishing reference watersheds within the sub-basin. The reference watersheds should represent the least impacted, most impacted, and "typical" cases. The establishment of the references will give watershed assessors, contracting agencies, policy makers and local stakeholders a frame of reference for ensuing watershed assessments and future decision making. The purpose of establishing reference watersheds is to justify the prioritization, to document the range of conditions within a sub-basin, and to provide a context for allocating project effort. The reference watersheds would be assessed rapidly to identify basic characteristics in each. This phase is based mainly on GIS and office work rather than on fieldwork, but cursory fieldwork may have to be done to corroborate the office assessment. We suggest that the Unified Watershed Assessment (www.epa.state.is.us/water/unified-watershed-assessment/) be used as a starting point helping to focus on reference watersheds.

Once reference watersheds are established, we recommend conducting watershed characterization in those watersheds that have been identified through the prioritization process. The purpose of watershed characterization would be to identify the processes (e.g. channel degradation) and impacts (e.g. prevalence of invasive species) that contribute to the actionable condition of the watershed. We suggest simultaneous watershed assessments per discipline (hydrology, geomorphology, biology).

After each component of the watershed characterization is complete, integrated assessment and evaluation of the priority watershed is recommended. The purpose of this step is for watershed assessment teams to compare notes, collaborate, and identify consensus issues. If consensus cannot be found then more rigorous and objective techniques may need to be applied before project recommendation.

Project recommendation is the overarching goal and result of the watershed assessment for the Illinois River Basin. Effective use of restoration project funding relies on accurate assessment of causes and effects of degradation in the watershed system. Therefore it is imperative that cause-effect relationships (i.e., processes) be identified prior to project recommendation.

A summary of our recommended watershed assessment framework is as follows. Framework goals are outlined under each step. The outlined tasks under respective headings cannot be considered exhaustive or comprehensive, but rather exemplify the nature of each step in the procedure.

Recommended Framework

1) Compare and prioritize watersheds

Based on existing information, identify priority watersheds largely through GIS and other remote sensing methods

- Suite of watersheds for rapid comparison should be manageable within allotted time frames and funding schedules.
- Existing comparative assessments may need to be updated a significant amount of new data was collected or assessments have been updated (It has been 6 years since the Unified Assessment by IEPA (1998)).

2) Establish a reference *watershed*

Identify a "best" watershed in the target area (e.g., sub-basin) based on the existing knowledge.

- The reference watershed may be derived from the previous step with local stakeholder input and some field corroboration.
- Establishing a reference watershed will aid in resolving questions about restoration priorities raise in Step 5 (below).
- NOTE: At this level of assessment, the reference watershed is a simple identification. Reference conditions cannot be inferred at this level. To obtain reference conditions watershed characterization is necessary.

3) Rapid watershed assessment

Establish initial estimates of the current condition of each of the three reference watersheds in the target area.

- Conduct separate, simultaneous rapid assessments according to discipline.
- GPS-video mapping from helicopter flyovers may be conducted during a rapid watershed assessment to obtain a "quick glance" at conditions in a watershed where data are limited. However watershed characterization is needed to establish inferences about the processes contributing to the conditions observed from

flyovers.

• The purpose of this step is to gather available data from various disciplines to become familiar with the watershed. Several data sources exist in Illinois. Some potentially useful datasets and sources include:

Water quality - The Illinois Environmental Protection Agency (IEPA) conducts a variety of stream monitoring including: a 213-station Ambient Water Quality Monitoring Network (AWQMN), an Intensive Basin Survey Program that covers all major watersheds on a five-year rotation basis, and a Facility-Related Stream Survey Program (FRSS) that conducts approximately 20-30 stream surveys each year (IEPA 2002). The AWQMN includes sampling water chemistry and core pesticides at each site nine times per year on a cycle of once every 6 weeks. Intensive Basin Surveys include sampling water chemistry, habitat quality, fish, macroinvertebrates, sediment chemistry, and fish tissue on a 5-year cycle. This program is a cooperative venture between the Illinois DNR and the IEPA. Each basin survey may consist of approximately 10 to 35 stations. Water Chemistry, effluent, habitat quality, macroinvertebrates, and occasionally fish are sampled as part of the FRSS. Each FRSS consists of sampling conducted upstream and downstream of wastewater treatment plants and the number of sites may vary from three to seven or more.

Aquatic biota - Stream habitat quality, fish, macroinvertebrates, and fish tissue are sampled on a 5-year cycle as part of cooperative Basin Survey Program, administered by the Illinois DNR and the IEPA (Table16, Figure12).

Streamflow Records - In Illinois there are currently 97 active continuous discharge gages in the Illinois River Basin (IRB) of which 89 are operated by the USGS (Figure 12) and 8 are operated by the ISWS. The names and locations of these active gaging stations are presented in Table 11. Also identified in Table 11 are the 80 discontinued gaging stations in the IRB, the number of years over which data have been collected at each station, and whether these data are a full 12-month record (F) or partial (P) record.

Suspended Sediment Records - In Illinois there are 21 active monitoring sites collecting suspended sediment data in the IRB. Figure 4 shows the locations of these sites.

Critical Trends Assessment Program (CTAP) - The CTAP program (Milano-Flores 2003) is designed to monitor the condition of forests, grasslands, wetlands, birds, insects, and streams in Illinois (Figure14). For each habitat type, 150 sites are monitored on a rotating, 5-year cycle. Site selection is based on randomly selected patches within randomly selected townships throughout the state.

Ecowatch - The Ecowatch program relies on trained volunteers to monitor Illinois' forests, rivers, and prairies. Location of existing Ecowatch sites located in the Illinois River Basin are shown in Figure 15.

Inventory of Other Datasets - There are a variety of digital databases available for use by project participants; these include scientific data, infrastructure data, and digital photography (Table 17, Appendix A). These data vary widely in scale, temporal and spatial completeness, quality, and availability.

Known information, specific to the Illinois River Basin, were inventoried to determine what spatial data are currently available to use for baseline watershed assessments as well as to assist with long-term monitoring protocols. This data identification exercise has been run for previous Illinois River-related projects and each effort has added to the accessible knowledge-base associated with the Illinois River Basin. The intention in this effort is not only to identify relevant digital data, but to track down sources of useful information that, as yet, may not be as readily available. There are a variety of potential sources of useful data, some of which may have previously been underutilized by IDNR watershed research. These potential sources include local Soil and Water Conservation Districts (SWCD), County Farm Bureaus (FB), Farm Service Associations (FSA), etc.. Another important objective is to evaluate the resolution of the data sets to determine if they are appropriately-scaled for main-stem, sub-basin, and project specific work discussed elsewhere in this document, so that when utilized for baseline assessment, scientific query, or planning task, will lead the data user to meaningful and defensible conclusions.

Preliminary searches revealed a wide variety of small-scale (ranging from1:15:000 to 1:3,000,000) remotely-sensed and mapped data available in a variety of digital formats that can be readily incorporated into a digital-based analysis (see Appendix A). These small-scale data are suitable for regional studies but are often out of date. Larger-scale data (ranging from sub-meter resolution to 1:10:000) are available in digital format but on a much more limited basis.

These data, and other information, would be used to develop a baseline dataset for monitoring during the preliminary watershed assessment. Assessments would minimally include surficial geology, landscape history (over 100 years or more including changes in land cover (c.f., IDNR et al. 2003; Szafoni et al. 2003)), land use (agricultural practices, modes of urban development, installation of drainage networks, occurrence of levees, channelization, etc.), channel pattern (e.g., Phillips et al. 2002; Collins and Knox 2003), and climate (precipitation or flow). The initial assessment identifies the existing static condition as well as establishes intrinsic rates of change (e.g., meander migration), and may reveal some long-term system responses to historical change. In addition, the assessment will identify additional data gaps that might be filled by monitoring, potential problems for remediation, sampling locations and appropriate techniques, and tune sampling protocols (c.f., Osterkamp and Schumm 1996).

The need for higher resolution data is evident. While high resolution (1:24,000 or greater) geologic mapping establishes a baseline configuration for small scale monitoring, it is insufficient for the large scale assessment and monitoring proposed in this plan. For example, much of the surficial geology on 1:24000 scale maps is derived from interpretation of parent materials from 1:15,000 scale soils maps. Variability in alluvial valley sediments is highly overgeneralized at these scales and, in particular, channel bed and sub-bed materials are not identified. Thus, larger scale (higher resolution) geologic mapping may be needed in sub-watershed and project scale assessment. The mapping is especially important where subsurface units are shallowly buried, and thus streams may tap significantly different geologic materials than occur at the surface of the adjacent floodplain or upland.

The question then becomes, "where will the higher resolution data come from". Some agencies conduct field-scale monitoring, but data are sparse and observations are not necessarily geared towards the indicators we have identified as most suitable for this plan. When it does exist, larger-scale information (ranging from sub-meter resolution to 1:10:000) that are not digital will have to be obtained, permissions granted, and processed before the actual value to assessment and/or monitoring tasks can be determined. Conversely, when a data gap has been identified, the information will have to be gathered in the field, or from high resolution imagery, and processed from scratch. This is where the garnering of distributive database design and compilation efforts will prove to be beneficial. An effort should be made to capitalize on the multi-disciplinary nature of this project to develop digital databases. An excellent example of this kind of opportunism involves the Illinois FSA.

Illinois FSA is in the process of implementing a geographic information system (GIS) in local field offices, where many years of field boundary, nutrient and pesticide application, land use practices influencing erosion, and crop management information (especially BMP lands) have been documented in paper form (IDA 2002). Illinois FSA intends to use the GIS technology to efficiently administer programs, monitor compliance, and respond to natural disasters while making FSA data more accessible to their constituents. Their first step in this implementation has been to establish a common land unit (CLU) data layer. A CLU is the smallest unit of land that has a permanent contiguous boundary, common land cover, and a common owner (i.e. a field containing row crop). To accomplish this, hard-copy aerial maps are being transferred to a digital orthophoto quadrangle (DOQQs) base; then reference lines such as field, track, and farm boundaries, roads, and waterways are being reconciled to the imagery. As the digital CLU layers are processed, the county FSA Offices that generated the common land unit inventory are checking the accuracy of the digital reference lines. Once the CLU data layer is certified by the originating FSA, it will supersede other aerial photos as the official USDA photography (see http://www.fsa.usda.gov/il/GIS.asp). In Illinois, it is anticipated that all county FSA Offices will be using the CLU layers by October of 2004. The spatial data will include an accurate inventory of fields, measure of acres, and land-use categories. The data will also contain areas of environmental concern, including easements, wetlands, and highly erodible land which helps identify and map environmentally sensitive acreage, as well as locate potential environmental hazards. All potentially relevant to watershed biotic (i.e., presence of invasive plant species) and abiotic (i.e., erosion estimates along waterways) metrics.

Access to new high resolution digital data will contribute to the implementation and success of purposed restoration in the Illinois River Basin as well as to future research/restoration activities.

4) Watershed characterization
Identify and assess specific habitats, processes, and functions at work in the priority watershed(s) and the sources of impact (i.e., linking cause and effect).

- Watershed characterization will be conducted for a small subset (2 or 3) of prioritized watersheds that require focused effort.
- A watershed characterization may be conducted due to vulnerability, restoration potential, or relatively high rates of change in habitats, functions or processes.

5) Integrated assessment and evaluation
Gather contracting agencies, stakeholders and scientists to establish consensus on factors affecting watershed habitats, processes and functions. If consensus is reached go on to recommending projects. If no consensus is reached then more evaluation is needed to identify causes of undesirable watershed symptoms.

- Technical personal meet to assess data gaps, supplement data with fieldwork or local data and integrate findings.
- Relate conditions in the priority watershed to reference conditions in the reference watershed.
- Describe factors that have created current conditions.
- Technical personnel and stakeholders should meet at this point to discuss results and determine consensus action base on findings.

6) Project recommendations.
Recommendations follow from the documented conditions of habitats, processes and functions and causes of those conditions identified in the preceding steps.

Recommended Watershed Assessment Approaches

Geomorphic component

- ISWS Illinois Geomorphic Watershed Assessment (White 2004; Keefer and White 2004), and Stream Dynamic Assessment (Phillips et al. 2002)

Hydrologic component

- Adapted guidelines and procedures set out by White (2004), Keefer and White (2004), Rhoads (2003), VSGAP (Kline et al. 2003), Locke et al. (2004), and McCammon et al. (1998).

Aquatic Ecology component

- LTRMP protocols for mainstem (Gutrueter et al. 1995), water quality and biota according to IEPA (1994) and IDNR (2001), macroinvertebrates (Dodd et. al 2003), and instream habitat (modified protocol from Stanfield et al. 1998).

Terrestrial Wildlife component

- Modified protocols set out by (Milano-Flores 2003).

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Table 1. Ongoing restoration programs within the Illinois River Basin. Parenthesis surround the acres enrolled in the State - Conservation Reserve Enhancement Program (CREP) because these acres are also included in the Federal - CREP acres. The Cost column includes both annual allocations ([a]) and total funds spent over several years ([t]).

PROGRAM	ACRES	COST (mill)
Conservation Reserve Program	287,020	$36.46[a]
Conservation Reserve Enhancement Program (Federal)	109,557	$11.08[a]
Conservation Reserve Enhancement Program (State)	(67,110)	$ 6.49[a]
Wetland Reserve Program, Environmental Quality Incentive Program, Wildlife Habitat Incentive Program	296,906	$ 9.88[a]
IL Environmental Protection Agency - 319	variety of practices	$ 2.80[a]
IL Dept. of Agriculture Streambank Stabilization and Restoration Program, Conservation Practices Program	10 stream miles + others	$ 2.38[a]
IL Dept. of Natural Resources - C2000	variety of practices	$ 3.10[a]
U. S. Army Corps of Engineers		-------
Non-Government Organizations (e.g., The Nature Conservancy)	9,000+	$13.00[t]
Total		**$85.19**

Table 2 . Geomorphic monitoring measures for the Illinois River Basin.

Parameter	Ecological Relevance	Assessment Method	Assessment Frequency	Ability to Detect Change	Key References
Groundwater quality	Habit support and human consumption	Monitoring wells	Seasonal to annual	High	Appelo and Postma (1993)
Groundwater chemistry in the unsaturated zone	Reflects changing weathering rates by changing groundwater flow, inputs from human activities; influences habitat and human consumption	Coring or well sampling	5-10 yr	10-100 yr resolution of changing inputs	Appelo and Postma (1993); Geake and Foster (1989)
Karst activity	Affected by natural and human influences on groundwater flow and drift thickness; rapid pollutant transport in groundwater	Water chemistry in caves and springs; surficial mapping	Various, depending on target	Sub-annual to long-term changes in climate and human activity	Beck (1989); Ford and Wiliams (1989)
Sediment sequence and composition	Accumulation rate indicates sediment yield or storage potential; reflects physical, chemical, biological changes in environment from natural and human causes	Various coring techniques in lakes and floodplain sediment, depending on sediment thickness and character	Annually to 10 years, depending on accumulation rate	Potentially high resolution of environmental changes at project to regional scale	Berglund (1986); Goudie (1990)
Slope failure	Stream sediment source; changing frequency reflects changing groundwater flow, landuse, or stream undercutting	Mapping from airphotos, DEM data, or fixed-site photography	5-10 years or after extreme climatic events	Most active after flooding and especially after extreme events; May require detailed mapping. Project to subwatershed scale.	Brabb (1984); Forest Practices Code (1999); Sierra and Straub (in review)
Soil and sediment erosion	Soil productivity reduce if loss is greater than soil formation rate; sediment delivered to streams influences habitat	Soil profile surveys; repeated topographic profiling; modeling; airphoto interpretation of bluff recession; erosion pins	Seasonally to decadal, depending on target, setting, and specific parameters	Erosion occurs irregularly in time and space; high resolution of short- and long-term changes possible; Project to basin scale.	Renard et al. (1997); Commission on Applied Geomorphology (1967); OTHERS
Soil quality	Soils may be degraded by erosion, compaction, addition of pollutants	Soil surveys	1-25 years, depending on target	High variability in 3 spatial dimensions makes selection of representative sites difficult. Project to basin scale	Buol et al. (1997)

Stream channel morphology	Changes caused by direct human modification as well as intrinsic variability, climate, natural and human-induced landscape evolution. Progressive rates of change may indicate habitat instability	Airphoto analysis of stream pattern; repeated cross-sectional surveying and longitudinal profiling; flow and sediment gauging ; fixed-site photography	1-10 years, depending on target and scale of interest	Potentially high, but sampling must be highly targeted. May not be useful for adaptive management. Most useful at project scale.	Osterkamp and Hedman (1982); Phillips et al. (2002); Rhoads and Miller (1991); Rhoads (1995); Schumm et al. (1984); Simon (1989)
Stream flow	Reflects climatic and landscape variability	Gauging stations; regional modeling for ungauged streams	Daily to monthly, depending on target and scale of interest	High, given sufficient understanding of climatic and landscape evolution. Project to basin scale.	Edwards and Glysson (1999); Wolman and Riggs (1990)
Sediment storage and load	Sediment load is a function of stream power, sediment yield, and carrying capacity; Affects channel morphology; stored sediment may be future sediment load or contaminant trap; load ultimately delivered to Illinois River mainstem	Suspended sediment sampling at gauging stations; bedload sampling probably prohibitive except for large-scale, short-term monitoring; supported by direct observations of channel morphology and sediment sequence on floodplains	Daily to monthly, depending on target and scale of interest. Sediment storage observations at least every 5 years	When combined with historical analysis of watershed, potential to distinguish natural and human-induced effects. Project to basin scale	Edwards and Glysson (1999); Robertson and Roerish (1999); Wolman and Riggs (1990)
Surface water quality	Determined by interaction with groundwater, soils, and direct inputs; degraded water quality has direct effect on ecosystems	Testing for targeted physical, chemical, and biological parameters at gauging stations,	Sub-annually	Can indicate both short and long-term changes at project to basin scales	Adolphson et al. (2002); Hirsch et al. (1988); Robertson and Roerish (1999); Sullivan (1999)
Wetlands extent, structure, hydrology	Key ecosystem component, geohydrologic and geochemical buffer; sensitive to landscape evolution and archive of ecological change	Mapping of distribution and extent; intensive monitoring of individual wetlands.	5-10 yr for distribution, extent, and structure; continuously for preliminary observation of hydrology and chemistry	Seasonality must be distinguished from long-term change; Project to basin scale	

Table 3. General aquatic monitoring parameters for the mainstem Illinois River Basin.

Parameter	Ecological Relevance	Assessment Method	Frequency	Ability to Detect Change
Water Quality	Indicates immediate changes in nutrients and other water quality parameters to base other biotic responses.	Standardized USGS water quality sampling protocols	weekly to seasonal	Immediate changes and long term trends
Planktonic Algae	Predictable and quick response to changes in nutrients, habitat alteration, etc.	Chlorophyll a	weekly to seasonal	Rapid biotic response to environmental changes
Aquatic Plants	Provide habitat for several aquatic taxa and can reflect localized improvements in water quality	Remote sensing and field-based assessments	annual	High in local areas but may also reflect systemic changes over longer periods of time.
Zooplankton	Food resource for many aquatic organisms.	Filtered water sample	weekly to seasonal	May be good for systemic responses, but may not integrate local mainstem changes.
Macroinvertebrates	Important food resource for higher trophic levels. Respond to stressors well.	Ponar dredge, emergence traps, kick nets	seasonal	Response may be limited to smaller scales
Fish	Consolidate responses from the lower trophic levels.	Standard fish collection techniques (Electrofishing, fyke nets, gill nets, etc.)	seasonal	Can reflect localized changes relatively rapidly and also systemic changes on longer temporal scales
Amphibians/Reptiles	Can indicate degraded local environmental conditions	Calling surveys, drift nets, funnel traps	seasonal to annual	Assemblages are not as distinctly tied to aquatic areas, but may reflect a composite aquatic-riparian response.

Table 4. Physical habitat and biotic parameters used as environmental indicators in sub-basins and tributaries.

Parameter	Ecological Relevance	Assessment Method	Assessment Frequency	Ability to Detect Change	Key References
Channel morphology	Reflects changes in sedimentation or stream bed degradation as a result of landscape changes from natural or anthropogenic causes; can indicate potential changes in fish and invertebrates communities	Surveying at permanent transects along stream gradient; Point transect method along equally spaced transects	Seasonal to annual	High at project sites; moderate at the sub-basin scale	Platts et al. 1983; Rosgen 1996; Stanfield et al. 1998
Percent Substrate types	Indicates changes in sedimentation and flow resulting from changes in landuse; links improvement in habitat with changes in fish and invertebrate communities	Point transect method along equally spaced transects; qualitative observations along extensive reaches of stream	Seasonal to annual	High at project sites; moderate to low at sub-basin scale	Platts et al. 1983; Rosgen 1996; Simonson et al. 1994; Wang et al. 1996; Stanfield and Jones 1998; Stanfield et al. 1998; Wang et al. 1998
Percent Habitat Types (i.e. riffle, run, pool, etc.)	Gives indication of habitat diversity and shifts in habitat types as a result of changes in sedimentation and peak flows; potenital mechanism for shifts in fish and invertebrates as diversity in habitat types change.	Point transect method along equally spaced transects; measuring and mapping individual habitats within stream	Seasonal to annual	High at project sites; high to moderate at the sub-basin scale	Platts et al. 1983; Simonson et al. 1994; Wang et al. 1996; Stanfield et al. 1998; Wang et al. 1998

Bank Stability	Reflects changes in stream stability and potential for bank erosion as a result of changes in peak flows and riparian landuse; indicates overall channel stability needed for fish and invertebrates.	Surveying at permanent transects; Point transect method at specific locations in watershed; assessment of percent bank/riparian cover types	Frequently at individual practice sites which potentially change riparian vegetation; Annual at permanent transects	Dependant on types of practices; High at project sites; moderate to low at the sub-basin scale	Platts et al. 1983; Simonson et al. 1994; Stanfield et al. 1998;
Fish composition, diversity, and abundance	Indicates shifts in fish assemblages as a result of improved water quality and habitat conditions	Electrofishing - single or multi-pass	Seasonal to annual	High at project sites; moderate at sub-basin scale	Bayley et al. 1989; Simonson and Lyons 1995; Barbour et al. 1999; Attrill 2002
Index of Biotic Intgrity	Gives an overall stream quality rating based on fish assemblage composition, abundance, and health	Based on electrofishing data	Seasonal to annual	High at project sites; moderate at sub-basin scale	Karr et al. 1986; Hite and Bertrand 1989; Attrill 2002
Fish size structure	Indicates habitat quality/conditions, degree of competition, size selective mortality (fishing pressure), and age at maturation	Based on electrofishing data	Seasonal to annual	High at project sites; moderate to low at sub-basin scale	Atrill 2002
Fish age and growth	Changes reflect shifts in habitat suitablilty/quality and prey availability (competition for food) and indicates overall health of fish assemblages	Use of boney structures (scales, fin rays, spines, or otoliths) to count and measure growth rings; backcalculation of growth rates through Fraser-Lee method	At least once before and once after restoration practices; annual for more	Moderate depending on sampling frequency, number of fish analyzed and species of fish	Macina 1992; Putnam et al. 1995; Devries and Frie 1996; Power 2002

Invertebrate composition, diversity, and abundance	Shifts reflect changes in habitat/water quality (sedimentation and nutrients) and stability of the system; gives information on life cycle/life history requirements	Stratified Random sampling using Hess and core samplers (quantitative) and dipnets (semi-quantitative)	Seasonal to annual	High to moderate at the site and sub-basin scale	Rosenburg and Resh 1996; Barbour et al. 1999; Atrill 2002
Invertebrate indices	Indicates stream quality based on invertebrates as indicator taxa; reflects shifts in habitat and water quality	Stratified Random sampling using quantitative and semi-quantitative sampling devices	Seasonal to annual	High at the sub-basin scale and project sites	Hilsenhoff 1982; Rosenburg and Resh 1993; Rosenburg and Resh 1996; Resh et al. 1996; Atrill 2002
Intolerate Invertebrate Taxa	Reflects changes in non-point source pollution (sedimentation; nutrients) as a result of landuse changes	Stratified Random sampling using quantitative and semi-quantitative sampling devices	Seasonal to annual depending on objectives	High to moderate at the site and sub-basin scale	Rosenburg and Resh 1993; Rosenburg and Resh 1996;Barbour et al. 1999; Resh et al. 1996; Atrill 2002

Table 5. Wildlife and terrestrial habitat monitoring parameters for the Illinois River basin.

Parameter / Species Group	Critical Measures	Indicator Species, Measures	Ecological Relevance	Assessment Method	Assessment Frequency	Ability to Detect Change	References
Critical Response Measures							
A. Landscape habitat composition and metrics	Amount of natural vegetation, patch size, connectivity, width of riparian habitat	Positive - wetland, forest, grassland Negative - urban, roads, cropland	Watershed protection and wildlife habitat suitability	GIS analysis of classified satellite imagery	3-5 year intervals	Depends on rate and scale of changes relative to classification accuracy	Illinois Department of Natural Resources et al. 2003
B. Wetland habitat communities in floodplain	Declining communities	Submergent, floating-leaved, emergent, and moist-soil communities	Amounts reflect hydrologic change and wildlife habitat	Photointerpretation and ground truthing	5-10 year intervals	Good, depending on classification accuracy and photographic data	Upper Midwest Environmental Sciences Center – LTRMP High Resolution Land Cover/Use Data, Bellrose et al. 1979, Havera 1999
C. Site specific habitat/vegetation monitoring	Species composition, habitat structure, and presence of exotic species	Positive – mast producing trees, species richness Negative – exotic and/or invasive species	Combined with landscape and community habitat evaluation, provides a multiscale assessment of habitat quality and system function	Transects	Monitoring sites revisited once each 5 years on a rotation	Good for measuring structure and detecting indicators	Rogers and Owens 1995, Mack 2001, Milano-Flores 2003
D. Waterfowl	Waterfowl use days	Dabbling and diving ducks	Trends reflect habitat conditions including hydrology and water quality	Aerial and ground surveys	Weekly during fall and spring migration	Good using trends and comparing to historical data	Havera 1999, Horath et al. 2003
E. Wading birds and cormorants	Rookeries, number of active nests	Black-crowned night heron, great egret, snowy egret, little blue heron, double-crested cormorant	Sensitive to wetland hydrologic conditions, undisturbed nest sites, and drydown fishing opportunities	Aerial and ground complete counts	Annually	Good combining aerial counts and monitoring of rookeries	Gibbs et al. 1988, Dodd and Murphy 1995, Bjorklund and Holm 1997, Bjorklund 1998, Gawlik et al. 2003
F. Marsh birds	Presence and abundance of rare species, breeding species	Marsh – American and least bittern, common moorhen Large marsh - pied-billed grebe Wet meadow - black rail	Wetland obligates requiring declining emergent communities	Point call counts using taped play-back surveys	Monitoring sites revisited once each 5 years on a rotation	Presence/absence during breeding season is a good indicator of habitat suitability	British Columbia Ministry of Environment, Lands and Parks 1998
G. Shorebirds	Seasonal abundance, migration use days	Rare species, breeding species, and those intolerant of disturbance	Utilize unique and rare habitats such as predator free islands and moist soil areas; sensitive to disturbance	Ground counts from vantage points	3 times per month during spring and fall migration	Good with regular monitoring at known and potential habitat areas	de Szalay et al. 2000, Bart et al. 2002, Horath et al. 2002
H. Bald eagles and ospreys H. Cont.	Number of nests, active nests, and mid-winter abundance	Breeding activity	Dependent on large floodplain trees for nesting, sensitive to human disturbance, fish abundance, water quality (clarity)	Documentation and monitoring of nests, winter aerial and ground surveys	Annually	Good with widespread reporting and monitoring of nests; good for winter surveys	Havera and Kruse 1988, Jacques Whitford Environment Limited 2000, IDNR midwinter eagle survey
I. Terrestrial mammals	Wetland/riparian	Otter, beaver,	High on the food chain,	Transects,	Annually	Good for long	Bluett et al. 2001, Illinois

	obligates, mesopredators	muskrat, mink, gray fox, bobcat, coyotes, raccoons, possums, skunks	indicators of system "health" and function, some require large habitat areas	nightlighting, trapper data, archer index, etc.		term programs and utilizing multiple data sources	Department of Natural Resources 2003
J. Bats	Riparian roosting and nesting species	Presence/absence; foraging species richness; Indiana bat, red bat, hoary bat, silver-haired bat	Indicators of riparian system integrity in small watersheds, disturbance, organochlorine contamination	Night trapping and acoustic surveys	Annually	Good; further refinement of methods may provide similar information at less cost	Gannon et al. 2003, O'Shea et al. 2003, Texas Parks and Wildlife 2003
K. Bottomland/riparian forest birds	Presence and abundance of breeding species, obligates and area sensitives	Brown creeper, red-shouldered hawk, prothonotary warbler, cerulean warbler, red-eyed vireo	Indicators of bottomland forest extent, composition, and function	Point call counts	Monitoring sites revisited once each 5 years on a rotation	Best for abundant and widespread species	US Geological Survey 1998, Milano-Flores 2003, Sauer et al. 2003
L. Grassland birds	Presence and abundance of breeding species, obligates and area sensitives	Upland sandpiper, Henslow's sparrow, northern harrier	Grassland habitat quality indicators including patch size and fragmentation	Point call counts	Monitoring sites revisited once each 5 years on a rotation	Best for abundant and widespread species	Herkert 1994, US Geological Survey 1998, Milano-Flores 2003, Sauer et al. 2003
M. Amphibians	Species richness and abundance	Frogs and toads	Good indicators of water and overall habitat quality for fishless wetlands	Point call counts	Monitoring sites revisited once each 5 years on a rotation	Good using long-term programs	Thompson et al. 1998, US EPA 2002, Micacchion 2002
N. Aquatic reptiles	Abundance of snakes, turtles, and basking sites; aquatic turtles sensitive to water quality	Illinois mud turtle, alligator snapping turtle, map turtles, smooth softshell, water snakes (Nerodia spp.)	Sensitive to availability of basking sites; water snakes and some aquatic turtles are sensitive to water quality, dredging, and dam construction	Basking transects, aquatic turtle trapping	Two or more searches and trapping sessions during active months of year	Potentially good in appropriate habitats but methods largely untested	Thompson et al. 1998
Desirable Response Measures							
O. Avian reproduction	Reproductive effort and success, nest parasitism, patch size	All species with emphasis on rare, habitat obligates, and area sensitive species	Incorporates and synthesizes many complex factors to indicate ecosystem habitat quality and function	Nest searches and monitoring	Nest searching and monitoring every 3 days during the nesting season	Requires large sample sizes for accurate assessment	Knutson et al. 1996
P. Amphibian reproduction	Reproductive effort and success	Egg mass counts, viable eggs	Good indicators of water and overall habitat quality for fishless wetlands; highly sensitive to environmental factors like pollution, water temperature, etc.	Egg mass counts, drift fence surveys	Annually	Trends can be detected in areas of concentration	Micacchion 2002, US EPA 2002

Table 6. Estimated costs for the proposed long-term monitoring plan at critical and desirable levels. Desirable costs are additional dollars. The costs estimates for each discipline encompass all spatial scales of monitoring (i.e., mainstem, sub-basin, project). For more detailed cost estimates at each spatial scale, please refer to the text.

	Critical Level		**Desirable Level**	
	Year One	**Subsequent Years**	**Year One**	**Subsequent Years**
Geomorphological Features	$192,000	$192,000	$184,000	$184,000
Hydrological Features	$1,618,000	$1,134,000	$305,000	$181,000
Ecological Features				
Aquatic	$655,000	$605,000	$105,000	$105,000
Terrestrial	$1,486,000	$1,486,000	$185,000	$185,000
Total Estimated Costs:	$3,951,000	$3,417,000	$779,000	$655,000

Table 7. Data needs and objectives for river inventories (Rosgen 1994)

Level of detail	Inventory description	Information required	Objectives
I	Broad morphological characterization	Landform, lithology, soils, climate, depositional history, basin relief, valley morphology, river profile morphology, general river pattern	To describe generalized fluvial features using remote sensing and existing inventories of geology, landform evolution, valley morphology, depositional history and associated river slopes, relief and patterns utilized for generalized categories of major stream types and associated interpretations.
II	Morphological description (stream types)	Channel patterns, entrenchment ratio, width/depth ratio, sinuosity, channel material, slope	This level delineates homogeneous stream types that describe specific slopes, channel materials, dimensions and patterns from "reference reach" measurements. Provides a more detailed level of interpretation and extrapolation than Level 1.
III	Stream "state" or condition	Riparian vegetation, depositional patterns, meander patterns, confinement features, fish habitat indices, flow regime, river size category, debris occurrence, channel stability index, bank erodibility.	The "state" of streams further describes existing conditions that influence the response of channels to imposed change and provide specific information for prediction methodologies (such as stream bank erosion calculations, etc.). Provides for very detailed descriptions and associated prediction/interpretation.
IV	Verification	Involves direct measurements and observations of sediment transport, bank erosion rates, aggradation/degradation processes, hydraulic geometry, biological data such as fish biomass, aquatic insects, reparian vegetation evaluations, etc.	Provides reach-specific information on channel processes. Used to evaluate prediction methodologies; to provide sediment, hydraulic and biological information related to specific stream types and to evaluate effectiveness of mitigation and impact assessments for activities by stream type.

Table 8. Channel morphometrics in channel evolution model of Schumm et al. (1984).

Stage	Location	Top Width (ft)	Depth (ft)	Width Depth Ration (ft)	Thalweg Slope (ft/ft)	Depth of Sediment (ft)	Dominant Process
I	Upstream of headcut (580+00)	82	17.3	4.7	0.0020	0	Transport of sediment
II	Immediately down-stream of headcut (560+00)	82	21,6	3.8	0.0018	variable 0-2	Degradation
III	Downstream of II (520+00)	100	20.1	4.9	0.0018	1.5	Rapid widening
IV	Downstream of III (450+00)	115	19.2	6.0	0.0016	2.5	Aggradation and development of meandering thalweg
V	Downstream of IV (435+00)	119	15.3	7.8	0.0010	6.3	Aggradation and stabilization of alternate bars

Table 9. Elements of selected ecosystem monitoring and baseline investigations.

Reference	Practice Evaluated	Setting	Target Area or Length	Data Types	Spatial Scale	Temporal Scale
Simon (1989)	channel response to dredging, straightening, clearing, & snagging	Western TN	1.3 km to 75.1 km reaches	channel morpology data (width, slope, depth, gradient, stage, soil mechanics variables (cohesion, friction angle, field density of stream banks	Western 1/4 of TN	2 years of current monitoring data compared to 19 years of surveys for channel modifications
Collins and Knox (2003)	Long term modification of land use, climate fluctuation, channel navigation improve - ments to quantify mag- - nitude, direction, and rates of floodplain change	Upper Mississippi River Pool 10	52.8 km	GIS coverage of scanned USGS reports, stage data, climate data, floodplain, water &geomorphic features	205,567 km^2 drainage basin	1866 - 1989
Adolphson et al. (2002)	Landuse affects on stream habitats	rural to urban settings along Fox, DesPlaines Rivers, Illinois	12-36 km^2 subwatersheds	GIS watershed morphology, geology, landcover; channel morphology, bed material, habitat inventory	28K km^2	3 year (1999-2001) baseline investigation for long term monitoring
Erskine (2001)	Clearing, Channel Shaping, diking, bank armoring	relatively steep, large capacity, gravel bed channel with in channel benches, gravel and bedrock bars	Individual sites = 0.1 to 7.8 km	Plans, tabular, Photographic, theoretical models	+1000 km^2	30 years
Harvey (2001)	Coupling between hill-slopes & channels in upland fluvial systems	Pleistocene glacial and periglacial sediments over folded Silurian mudrocks Northwest England	mainstream length approx 4 km, valley was appox. 3.5 km long by 1-2 km wide	1948 photos 1:30K, 1960 photos 1:10K, rainfall, dating, various large scale sediment and geomorphic studies	1:10K to 1:30K with large scale studies probably larger scale then 1:10K	30 year monitoring program
Owens and Walling (2002)	Landuse, climate effects on sediment yield	River Tweed watershed, gravel bed river in Scotland	160 km river; 4390 km^2 watershed	sediment cores, flow, precipitation, landuse, geochemistry	1:20K to 1:100K, with larger scale supporting studies	85-140 yr of records
Hession et al. (2003)	Urbanization of forested watersheds	26 paired stream reaches (urban vs. forest) alluvial channels, gravelly beds & cohesive banks of sandy silt	0.34 - 50 km^2	tabular stream characteristics 9width, slope, xsec, etc) land cover from aerial photos, Landsat	sample reach approx = 100-200 meters	2 years
Spittler (1995)	Monitoring hillslope processes following logging activity	CA Coastal Range watersheds	40-170 km^2 (sub-) watersheds	Geology, geomorphology features, climate types, logging activity	1:24K, 1:12K maps of wtrsheds from aerial photos, slope stability maps	2 year pilot watershed study

Reference	Practice Evaluated	Setting	Target Area or Length	Data Types	Spatial Scale	Temporal Scale
Rae (1995)	test of in-stream monitoring techniques	CA Coastal Range watersheds	40-170 km^2 (sub-) watersheds	habitat inventory, channel morphology, bed material, floodplain/hillslope landcover and landuse	1000 m reaches	2 year pilot watershed study
Rhoads (2003)	Bendway weirs	Illinois	project reaches	channel morphology, bed material	1:24K to reach scale (topographic maps, airphotos, soil surveys, site photographs, field measurements	Manual for site assessment; indefinite temporal scale
Rhoads and Miller (1991)	River Channel response to various short-term flow variability including 100yr flood, multiple bankfull floods and 1 extreme low flow event	River channel in glacial sediments in NE IL	7.2 km of stream channel	Flow, discharge, Width & depth at 26 cross sections, gradient, calculated stream power, bed and bank sediment particle size.	7.2 km of channel	2 years, 1986-1988.
Swanson Hydrology and Geomorphology (2002)	evaluation of management and restoration actions in a watershed	freshwater stream to estuary, California	3.5km stream segment	Historic vegetation, wildlife, birds, reptiles, aquatic macro-invert, Water Quality, flow, bed material, monumented cross sections		15 years in 5 year increments with annual monitoring of baseline data set information
Landwehr and Rhoads (2003)	depositional response of headwater Ag Stream to Channelization with oversized channel bottoms	100 meter reach of Spoon River near Gifford IL	100 meter length with 19 km^2 drainage basin	series of historical air photos. Field surveys of micro topography, soil core description	1:20K & 1:40K photos converted to digital form by scanning	1940 - 1998
Stewardson (1999)	Channel stabilization with addition of Large woody debris and boulders with rip-rap banks and rock-riffle construction	NE Victoria, Australia	2 stream reaches, a 300 m sand and gravel bed stream and a 350 m cobble bedded stream	X-sections, profiles, modeling	300 and 350 meter reach of stream channel	2 years (1996 - 1998)
Aust et al. (2003)	Evaluation of various vegetation management methods on Civil War Earthworks by USLE modification by Dissmeyer and Foster 1984	Civil War Battlefields on Atlantic Coastal Plain	Plots for all treatments were 5 meters wide with variable length slopes. Plots extended top to bottom of slope.	Rainfall, runoff, soil erodibility, slope length, slope steepness, cover management, support practices	plots were 10s of meters square	1 year, March 2000 through February 2001

Table 10. Spatial structure for high resolution monitoring framework by Hydrologic Catalog Unit. Critical response measures shaded white and desirable response measures shaded gray.

Monitoring (HUC) Unit	Catalog Number	Land Area (sq. mi.)	Subregion	Monitoring Parameters A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Project Areas	-			Monitoring components determined by project location and habitat type.															
Kankakee	07120001	3,010	Upper Illinois	X		X			X			X	X	X	X	X		X	X
Iroquois	07120002	2,110		X		X			X			X	X	X	X	X		X	X
Chicago	07120003	622		X		X			X			X	X	X	X	X		X	X
Des Plaines	07120004	1,440		X		X			X			X	X	X	X	X		X	X
Upper Illinois	07120005	1,010		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Upper Fox	07120006	1,570		X		X			X			X	X	X	X	X		X	X
Lower Fox	07120007	1,090		X		X			X			X	X	X	X	X		X	X
Lower Illinois – Senachwine Lake	07130001	1,950	Lower Illinois	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Vermilion	07130002	1,290		X		X			X			X	X	X	X	X		X	X
Lower Illinois – Lake Chautauqua	07130003	1,520		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Mackinaw	07130004	1,130		X		X			X			X	X	X	X	X		X	X
Spoon	07130005	1,860		X		X			X			X	X	X	X	X		X	X
Upper Sangamon	07130006	1,420		X		X			X			X	X	X	X	X		X	X
South Fork Sangamon	07130007	1,130		X		X			X			X	X	X	X	X		X	X
Lower Sangamon	07130008	928		X		X			X			X	X	X	X	X		X	X
Salt	07130009	1,890		X		X			X			X	X	X	X	X		X	X
La Moine	07130010	1,340		X		X			X			X	X	X	X	X		X	X
Lower Illinois	07130011	2,280		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Macoupin	07130012	966		X		X			X			X	X	X	X	X		X	X

Table 11. Gaging Stations in the Illinois River Watershed including the periods of record.

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Drainage area (sq. miles)	Records (F)ull (P)artial	Period of record
Active gages							
5536290	Little Calumet River at South Holland	Chicago/Calumet	USGS	54	208	F	1948-2003
5536105	Nb Chicago River at Albany Avenue at Chicago	Chicago/Calumet	USGS	11	113	F	1990-1998,2000-2003
5536275	Thorn Creek at Thornton	Chicago/Calumet	USGS	54	104	F	1948-2003
5536000	North Branch Chicago River at Niles	Chicago/Calumet	USGS	51	100	F	1951-2003
5536215	Thorn Creek at Glenwood	Chicago/Calumet	USGS	53	24.7	F	1949-2003
5536255	Butterfield Creek at Flossmoor	Chicago/Calumet	USGS	54	23.5	F	1948-2003
5536235	Deer Creek near Chicago Heights	Chicago/Calumet	USGS	54	23.1	F	1948-2003
5535070	Skokie River near Highland Park	Chicago/Calumet	USGS	35	21.1	F	1967-2003
5534500	North Branch Chicago River at Deerfield	Chicago/Calumet	USGS	50	19.7	F	1952-2003
5535000	Skokie River at Lake Forest	Chicago/Calumet	USGS	50	13	F	1952-2003
5536340	Midlothian Creek at Oak Forest	Chicago/Calumet	USGS	51	12.6	F	1951-2003
5535500	West Fork of North Branch Chicago River at Northbrook	Chicago/Calumet	USGS	50	11.5	F	1952-2003
5536500	Tinley Creek near Palos Park	Chicago/Calumet	USGS	51	11.2	F	1951-2003
5536265	Lansing Ditch near Lansing	Chicago/Calumet	USGS	54	8.84	F	1948-2003
5536995	Chicago Sanitary and Ship Canal at Romeoville	Des Plaines	USGS	18	739	F	1984-2003
5532500	Des Plaines River at Riverside	Des Plaines	USGS	58	630	F	1944-2003
5529000	Des Plaines River near Des Plaines	Des Plaines	USGS	61	360	F	1941-2003
5540500	Du Page River at Shorewood	Des Plaines	USGS	61	324	F	1941-2003
5528000	Des Plaines River near Gurnee	Des Plaines	USGS	46	232	F	1946-1958,1969-2003
5527800	Des Plaines River at Russell	Des Plaines	USGS	35	123	F	1967-2003
5531500	Salt Creek at Western Springs	Des Plaines	USGS	56	115	F	1946-2003
5539000	Hickory Creek at Joliet	Des Plaines	USGS	57	107	F	1945-2003
5531300	Salt Creek at Elmhurst, IL	Des Plaines	USGS	13	91.5	F	1989-2003
5540095	West Branch Du Page River near Warrenville	Des Plaines	USGS	33	90.4	F	1969-2003
5540250	East Branch Du Page River at Bolingbrook, IL	Des Plaines	USGS	13	75.8	F	1989-2003
5527950	Mill Creek at Old Mill Creek	Des Plaines	USGS	12	61	F	1990-2003
5530990	Salt Creek at Rolling Meadows	Des Plaines	USGS	29	30.5	F	1973-2003

Table 11. (continued)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Drainage area (sq. miles)	Records (F)ull (P)artial	Period of record
Active gages							
5539900	West Branch Du Page River near West Chicago	Des Plaines	USGS	41	28.5	F	1961-2003
5540160	East Branch Du Page River near Downers Grove, IL	Des Plaines	USGS	12	26.6	F	1990-2003
5537500	Long Run near Lemont	Des Plaines	USGS	51	20.9	F	1951-2003
5528500	Buffalo Creek near Wheeling	Des Plaines	USGS	50	19.6	F	1952-2003
5540060	Kress Creek at West Chicago	Des Plaines	USGS	16	18.1	F	1986-2003
5532000	Addison Creek at Bellwood	Des Plaines	USGS	51	17.9	F	1951-2003
5533000	Flag Creek near Willow Springs	Des Plaines	USGS	51	16.5	F	1951-2003
5530000	Weller Creek at Des Plaines	Des Plaines	USGS	51	13.2	F	1951-2003
5533400	Sawmill Creek near Lemont	Des Plaines	USGS	16	13	F	1986-2003
5540195	St. Joseph Creek at Route 34 at Lisle, IL	Des Plaines	USGS	13	11.1	F	1989-2003
5540275	Spring Brook at 87th Street near Naperville, IL	Des Plaines	USGS	14	9.9	F	1988-2003
5529500	McDonald Creek near Mount Prospect	Des Plaines	USGS	50	7.93	F	1952-2003
5540091	Spring Brook at Forest Preserve near Warrenville, IL	Des Plaines	USGS	10	6.83	F	1992-2003
5552500	Fox River at Dayton	Fox	USGS	87	2642.24	F	1915-2003
5551540	Fox River at Montgomery	Fox	USGS	0	1732	F	2003
5550000	Fox River at Algonquin	Fox	USGS	86	1403	F	1916-2003
5548280	Nippersink Creek near Spring Grove	Fox	USGS	35	192	F	1967-2003
5551700	Blackberry Creek near Yorkville	Fox	USGS	41	70.2	F	1961-2003
5551675	Blackberry Creek near Montgomery, IL	Fox	USGS	4	55	F	1998-2003
5551200	Ferson Creek near St. Charles	Fox	USGS	41	51.7	F	1961-2003
5550300	Tyler Creek at Elgin, IL	Fox	USGS	4	38.9	F	1998-2003
5550500	Poplar Creek at Elgin	Fox	USGS	51	35.2	F	1951-2003
5551330	Mill Creek near Batavia	Fox	USGS	4	27.6	F	1998-2003
5547755	Squaw Creek at Round Lake, IL	Fox	USGS	12	17.2	F	1990-2003
5550130	Brewster Creek at Valley View	Fox	USGS	0	14	F	2003
5587060	Illinois River at Hardin	Illinois	USGS	0	28690	F	2003
5586100	Illinois River at Valley City	Illinois	USGS	63	26744	F	1939-2003

Table 11. (continued)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Drainage area (sq. miles)	Records (F)ull (P)artial	Period of record
Active gages							
5568500	Illinois River at Kingston Mines	Illinois	USGS	62	15818	F	1940-2003
5558300	Illinois River at Henry	Illinois	USGS	21	13543	F	1981-2003
5543500	Illinois River at Marseilles	Illinois	USGS	82	8259	F	1920-2003
5542000	Mazon River near Coal City	Illinois	USGS	30	455	F	1940-1966,1999-2003
5585830	McKee Creek at Chambersburg	Illinois	USGS	0	341	F	2003
5556500	Big Bureau Creek at Princeton	Illinois	USGS	66	196	F	1936-2003
5560500	Farm Creek at Farmdale	Illinois	USGS	53	27.4	P	1949-2003
5561500	Fondulac Creek near East Peoria	Illinois	USGS	54	5.54	P	1948-2003
5526000	Iroquois River near Chebanse	Iroquois	USGS	79	2091	F	1923-2003
5525000	Iroquois River at Iroquois	Iroquois	USGS	57	686	F	1945-2003
5525500	Sugar Creek at Milford	Iroquois	USGS	54	446	F	1948-2003
5527500	Kankakee River near Wilmington	Kankakee	USGS	86	5150	F	1915-1933,1935-2003
5520500	Kankakee River at Momence	Kankakee	USGS	89	2294	F	1905-1906,1915-2003
5585000	La Moine River at Ripley	La Moine	USGS	81	1293	F	1921-2003
5584500	La Moine River at Colmar	La Moine	USGS	57	655	F	1945-2003
5568000	Mackinaw River near Green Valley	Mackinaw	USGS	50	1073	F	1921-1956,1988-2003
5567500	Mackinaw River near Congerville	Mackinaw	USGS	57	767	F	1945-2003
5587000	Macoupin Creek near Kane	Macoupin	USGS	74	868	F	1921-1933,1941-2003
5583000	Sangamon River near Oakford	Sangamon	USGS	75	5093	F	1910-1911,1915-1919, 1922,1929-1933, 1940-2003
5576500	Sangamon River at Riverton	Sangamon	USGS	62	2618	F	1909-1912,1915-1956,1986-2003
5582000	Salt Creek near Greenview	Sangamon	USGS	60	1804	F	1942-2003
5573540	Sangamon River at Rt. 48 at Decatur	Sangamon	USGS	19	938	F	1983-2003
5576000	South Fork Sangamon River near Rochester	Sangamon	USGS	53	867	F	1949-2003
5572000	Sangamon River at Monticello	Sangamon	USGS	93	550	F	1908-1912,1914-2003
105*	Sangamon River near Mahomet (Shiverly Bridge)	Sangamon	ISWS	11	368	P	1993-2003
5578500	Salt Creek near Rowell	Sangamon	USGS	59	335	F	1943-2003
5570910	Sangamon River at Fisher	Sangamon	USGS	23	240	F	1979-2003

Table 11. (continued)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Drainage area (sq. miles)	Records (F)ull (P)artial	Period of record
Active gages							
5580000	Kickapoo Creek at Waynesville	Sangamon	USGS	54	227	F	1948-2003
5579500	Lake Fork near Cornland	Sangamon	USGS	54	214	F	1948-2003
5572450/102*	Friends Creek at Argenta	Sangamon	ISWS	28	112	F	
5577500	Spring Creek at Springfield	Sangamon	USGS	54	107	F	1948-2003
101*	Long Creek near Decatur (Twin Bridge Road)	Sangamon	ISWS	11	46	P	1993-2003
5580950	Sugar Creek near Bloomington	Sangamon	USGS	27	34.4	F	1975-2003
201*	Panther Creek at Site M	Sangamon	ISWS	5	15	F	1999-2003
202*	Cox Creek near Newmansville (CR 2830N)	Sangamon	ISWS	5	9	F	1999-2003
5570000	Spoon River at Seville	Spoon	USGS	88	1635.8	F	1914-2003
5569500	Spoon River at London Mills	Spoon	USGS	59	1072	F	1943-2003
5568800	Indian Creek near Wyoming	Spoon	USGS	42	62.7	F	1960-2003
303*	Haw Creek near Maquon (CR 550N)	Spoon	ISWS	5	55	F	1999-2003
301*	Court Creek near Appleton (CR 1500E)	Spoon	ISWS	5	44	F	1999-2003
302*	North Creek near Oak Run (CR 1700N)	Spoon	ISWS	5	26	F	1999-2003
5555300	Vermilion River near Leonore	Vermilion	USGS	31	1251	F	1931-1931,1972-2003
5554500	Vermilion River at Pontiac	Vermilion	USGS	59	579	F	1943-2003
Inactive Gages							
5536325	Little Calumet River at Harvey	Chicago/Calumet	USGS	17	252	F	1917-1933
5536210	Thorn Creek near Chicago Heights	Chicago/Calumet	USGS	17	17.2	F	1964-1980
5536270	North Creek near Lansing	Chicago/Calumet	USGS	32	16.8	F	1948-1979
5539660	Des Plaines River Ab Kankakee R. nr Channahon, IL	Des Plaines	USGS	1	2093	F	1903-1903
5538000	Des Plaines River at Joliet	Des Plaines	USGS	18	1503	F	1915-1932
5533500	Des Plaines River at Lemont	Des Plaines	USGS	30	684	F	1915-1944
5528230	Indian Creek at Prairie View, IL	Des Plaines	USGS	7	36	F	1990-1996
5531000	Salt Creek near Arlington Heights	Des Plaines	USGS	23	32.1	F	1950-1971,1973-1973
5530500	Willow Creek near Park Ridge	Des Plaines	USGS	8	19.7	F	1951-1958
5538500	Spring Creek at Joliet	Des Plaines	USGS	10	19.6	F	1925-1934

Table 11. (continued)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Drainage area (sq. miles)	Records (F)ull (P)artial	Period of record
Inactive gages							
5540200	St. Joseph Creek at Lisle	Des Plaines	USGS	4	11.8	F	1986-1989
5528030	Bull Creek near Libertyville, IL	Des Plaines	USGS	7	6.3	F	1990-1996
5551000	Fox River at South Elgin	Fox	USGS	9	1556	F	1990-1998
5548500	Fox River at Johnsburg	Fox	USGS	2	1205	F	1998-1999
5547350	Grass Lake Outlet at Lotus Woods, IL	Fox	USGS	2	919	F	1998-1999
5548110	Nippersink Creek below Wonder Lake	Fox	USGS	4	97.3	F	1994-1997
5548105	Nippersink Creek above Wonder Lake	Fox	USGS	7	84.5	F	1994-1997,1999-2001
5549850	Flint Creek near Fox River Grove, IL	Fox	USGS	7	37	F	1990-1996
5549000	Boone Creek near McHenry	Fox	USGS	36	15.5	F	1948-1983
5584000	Illinois River at Beardstown	Illinois	USGS	18	24229	F	1921-1938
5570500	Illinois River at Havana	Illinois	USGS	11	18299	F	1922-1927,1985-1989
5560000	Illinois River at Peoria	Illinois	USGS	32	14165	F	1904-1906,1910-1938
5553500	Illinois River at Ottawa	Illinois	USGS	1	10949	F	1903-1903
5558000	Big Bureau Creek at Bureau	Illinois	USGS	11	485	F	1941-1951
5563500	Kickapoo Creek at Peoria	Illinois	USGS	30	297	F	1942-1971
5563000	Kickapoo Creek near Kickapoo	Illinois	USGS	18	119	F	1945-1962
5559500	Crow Creek near Washburn	Illinois	USGS	28	115	F	1945-1972
5557500	East Bureau Creek near Bureau	Illinois	USGS	31	99	F	1936-1966
5557000	West Bureau Creek at Wyanet	Illinois	USGS	31	86.7	F	1936-1966
5562000	Farm Creek at East Peoria	Illinois	USGS	39	61.2	F	1943-1981
5558500	Crow Creek (West) near Henry	Illinois	USGS	24	56.2	F	1949-1972
5586000	N Fk Mauvaise Terre Creek near Jacksonville	Illinois	USGS	26	29.1	F	1950-1975
5568660	Duck Creek near Liverpool	Illinois	USGS	4	20	F	1972-1975
5561000	Ackerman Creek at Farmdale	Illinois	USGS	27	11.2	F	1954-1980
5559000	Gimlet Creek at Sparland	Illinois	USGS	24	5.66	F	1946-1947,1950-1971
5586500	Hurricane Creek near Roodhouse	Illinois	USGS	26	2.3	F	1950-1975
5527000	Kankakee River at Custer Park	Kankakee	USGS	20	4810	F	1915-1934

Table 11. (continued)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Drainage area (sq. miles)	Records (F)ull (P)artial	Period of record
Inactive gages							
5526500	Terry Creek near Custer Park	Kankakee	USGS	27	12.1	F	1950-1976
5584685	Grindstone Creek near Birmingham	La Moine	USGS	1	46.5	F	1981-1981
5584680	Grindstone Creek near Industry	La Moine	USGS	1	35.5	F	1981-1981
5584400	Drowning Fork at Bushnell	La Moine	USGS	24	26.3	F	1960-1983
5584683	Grindstone Creek Trib. near Doddsville	La Moine	USGS	3	0.22	F	1980-1982
5584682	Grindstone Creek Trib. NO. 2 near Doddsville	La Moine	USGS	3	0.17	F	1981-1983
5567510	Mackinaw River below Congerville	Mackinaw	USGS	3	776	F	1984-1986
5567000	Panther Creek near El Paso	Mackinaw	USGS	13	93.9	F	1950-1960,1997-1998
5565500	Money Creek at Lake Bloomington	Mackinaw	USGS	2	69.1	F	1957-1958
5564500	Money Creek above Lake Bloomington	Mackinaw	USGS	26	53.1	F	1933-1958
5564400	Money Creek near Towanda	Mackinaw	USGS	26	49	F	1958-1983
5566500	East Branch Panther Creek at El Paso	Mackinaw	USGS	34	30.5	F	1950-1983
5565000	Hickory Creek Above Lake Bloomington, IL	Mackinaw	USGS	20	10.1	F	1939-1958
5566000	East Branch Panther Creek near Gridley	Mackinaw	USGS	11	6.3	F	1950-1960
5586800	Otter Creek near Palmyra	Macoupin	USGS	22	61.1	F	1960-1981
5578000	Sangamon River at Petersburg	Sangamon	USGS	2	3063	F	1948-1949
5573500	Sangamon River at Decatur	Sangamon	USGS	3	925	F	1949-1951
5572500	Sangamon River near Oakley	Sangamon	USGS	16	774	F	1952-1962,1964-1964,1974-1977
5575500	South Fork Sangamon River at Kincaid	Sangamon	USGS	29	562	F	1917-1927
5575000	South Fork Sangamon River near Taylorville	Sangamon	USGS	10	434	F	1908-1917
5579000	Salt Creek near Kenney	Sangamon	USGS	5	390	F	1908-1912
5571000	Sangamon River at Mahomet	Sangamon	USGS	32	362	F	1948-1979
5581500	Sugar Creek near Hartsburg	Sangamon	USGS	28	333	F	1945-1972
5581000	Sugar Creek near Armington	Sangamon	USGS	2	314	F	1948-1949
5580500	Kickapoo Creek near Lincoln	Sangamon	USGS	28	306	F	1945-1972
5574500	Flat Branch near Taylorville	Sangamon	USGS	35	276	F	1949-1983
5575800	Horse Creek at Pawnee	Sangamon	USGS	18	52.2	F	1968-1985

Table 11. (concluded)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Drainage area (sq. miles)	Records (F)ull (P)artial	Period of record
Inactive gages							
5571500	Goose Creek near De Land	Sangamon	USGS	9	47.9	F	1951-1959
104*	Camp Creek near White Heath	Sangamon	ISWS	10	47	F	1993-2002
103*	Goose Creek near Deland	Sangamon	ISWS	8	45	F	1993-2000
106*	Big Ditch near Fisher	Sangamon	ISWS	11	38	P	1993-2003
5575830	Brush Creek near Divernon	Sangamon	USGS	10	32.4	F	1974-1983
5582500	Crane Creek near Easton	Sangamon	USGS	26	26.5	F	1950-1975
5574000	South Fork Sangamon River near Nokomis	Sangamon	USGS	26	11	F	1951-1976
5570370	Big Creek near Bryant	Spoon	USGS	21	41.2	F	1972-1992
5570350	Big Creek at St. David	Spoon	USGS	15	28	F	1972-1986
5569968	Turkey Creek near Fiatt	Spoon	USGS	3	11.5	F	1978-1980
5570380	Slug Run near Bryant	Spoon	USGS	18	7.12	F	1975-1992
5570360	Evelyn Branch near Bryant	Spoon	USGS	21	5.78	F	1972-1992
5570330	West Branch Big Creek near Canton	Spoon	USGS	3	4.31	F	1978-1980
5555500	Vermilion River at Lowell	Vermilion	USGS	40	1278	F	1932-1971
5555000	Vermilion River at Streator	Vermilion	USGS	17	1084	F	1914-1920,1922-1931
5554000	N Fork Vermilion River near Charlotte	Vermilion	USGS	20	186	F	1943-1962

Table 12. Suspended sediment monitoring sites in the Illinois River Watershed.

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Currently monitoring Sediment (Y)es, (N)o	Currently monitoring Discharge (Y)es, (N)o	Drainage area (sq. mi)	Combined Periods (USGS, USACOE & ISWS) of sediments sampling
Active Suspended Sediment Monitoring Sites within the Illinois River Watershed								
5532500	Des Plaines River at Riverside	Des Plaines	USGS	4	Y	Y	630	1979-82,2003
5552500	Fox River at Dayton	Fox	USGS	1	Y	Y	2642	1981,2003
5586100	Illinois River at Valley City	Illinois	USGS	22	Y	Y	26743	1980-2003
5559600	Illinois River at Chillicothe	Illinois	USGS	9	Y	Y	13543	1993-2003
5543500	Illinois River at Marseilles	Illinois	USGS	1	Y	Y	8259	2003
5542000	Mazon River near Coal City	Illinois	ISWS	21	Y	Y	455	1981-2003
5527500	Kankakee River near Wilmington	Kankakee	ISWS	27	Y	Y	5150	1979-2003
5520500	Kankakee River at Momence	Kankakee	ISWS	23	Y	Y	2294	1979-85, 88-90, 93-2003
5585000	LaMoine River at Ripley	La Moine	ISWS	21	Y	Y	1293	1981, 83-90, 93-2003
5584500	LaMoine River at Colmar	La Moine	ISWS	17	Y	Y	655	1981-88, 93-2003
5567500	Mackinaw River near Congerville	Mackinaw	USACOE	1	Y	Y	767	1983, 97-2003
5583000	Sangamon River near Oakford	Sangamon	USACOE	8	Y	Y	5093	1981, 83-86, 95-97
5572000	Sangamon River at Monticello	Sangamon	ISWS	21	Y	Y	550	1981-2003
201*	Panther Creek at Site M	Sangamon	ISWS	3	Y	Y	15	1999-2003
202*	Cox Creek near Newmansville (CR 2830N)	Sangamon	ISWS	3	Y	Y	9	1999-2003
5570000	Spoon River at Seville	Spoon	USGS	4	Y	Y	1636	1981, 95-97,2003
5569500	Spoon River at London Mills	Spoon	ISWS	15	Y	Y	1072	1981-87, 94-2003
303	Haw Creek near Maquon (CR 550N)	Spoon	ISWS	3	Y	Y	55	1999-2003
301*	Court Creek near Appleton (CR 1500E)	Spoon	ISWS	3	Y	Y	44	1999-2003
302*	North Creek near Oak Run (CR 1700N)	Spoon	ISWS	3	Y	Y	26	1999-2003
5555300	Vermilion River near Lenore	Vermilion	ISWS	21	Y	Y	1251	1980-81, 84-2003
Inactive Suspended Sediment Monitoring Sites within the Illinois River Watershed								
5536000	North Branch Chicago River at Niles	Chicago/Calumet	USGS	2	N	Y	100	1985-86
5529000	Des Plaines River near Des Plaines	Des Plaines	ISWS	1	N	Y	360	1981
5539000	Hickory Creek at Joliet	Des Plaines	ISWS	1	N	Y	107	1981

Table 12. (continued)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Currently monitoring Sediment (Y)es, (N)o	Currently monitoring area (sq. mi)	Drainage area (sq. mi)	Combined periods (USGS, USACOE & ISWS) of sediment sampling
5540500	DuPage River at Shorewood	Des Plaines	ISWS	1	N	Y	324	1981
5551540	Fox River at Montgomery	Fox	ISWS	3	N	N	1732	1981-83
5550000	Fox River at Algonquin	Fox	ISWS	2	N	Y	1403	1981-82
5548500	Fox River at Johnsburg	Fox	USGS	2	N	N	1205	1998-99
5547350	Grass Lake Outlet at Lotus Woods	Fox	USGS	2	N	N	919	1998-1999
5546500	Fox River at Wilmot, WI	Fox	USGS	2	N	N	868	1998-1999
5548280	Nippersink Creek near Spring Grove	Fox	USGS	2	N	Y	192	1998-99
5548110	Nippersink below Wonder Lake	Fox	USGS	4	N	N	97.3	1994-97
5548105	Nippersink above Wonder Lake	Fox	USGS	7	N	N	84.5	1994-97; 1999-2001
5551200	Ferson Creek near St. Charles	Fox	ISWS	2	N	Y	51.7	1981-82
5563800	Illinois River at Pekin	Illinois	USGS	3	N	N	14585	1995-97
5558300	Illinois River at Henry	Illinois	USGS	5	N	Y	13543	1984-1986: 1999
5556500	Big Bureau Creek at Princeton	Illinois	ISWS	10	N	Y	196	1981-90
5526000	Iroquois River near Chebanse	Iroquois	ISWS	9	N	Y	2091	1979-83, 93-96
5525000	Iroquois River at Iroquois	Iroquois	ISWS	8	N	Y	686	1979-82, 93-96
5525500	Sugar Creek at Milford	Iroquois	ISWS	3	N	Y	446	1981-83
5584685	Grindstone Creek near Birmingham	La Moine	USGS	1	N	N	45.4	1981
5584680	Grindstone Creek near Industry	La Moine	USGS	1	N	N	35.5	1981
5568000	Mackinaw River near Green Valley	Mackinaw	ISWS	4	N	Y	1073	1981, 1995-1997
5567510	Mackinaw River below Congerville	Mackinaw	ISWS	6	N	N	776	1981-86
5564400	Money Creek near Towanda	Mackinaw	ISWS	1	N	N	49	1981
5566500	East Branch Panther Creek at El Paso	Mackinaw	ISWS	2	N	N	30.5	1981-82
5587000	Macoupin Creek near Kane	Macoupin	ISWS	1	N	Y	868	1981
5576500	Sangamon River at Riverton	Sangamon	ISWS	3	N	Y	2618	1981-83
5582000	Salt Creek near Greenview	Sangamon	ISWS	3	N	Y	1804	1981-83
5576022	South Fork Sangamon River below Rochester	Sangamon	ISWS	2	N	Y	870	1981-82

Table 12. (concluded)

Station ID	Station name	Major river basin (sub-basin)	Primary monitoring agency	Years of record	Currently monitoring Sediment (Y)es, (N)o	Sediment (Y)es, (N)o	Drainage area (sq. mi)	Combined periods (USGS, USACOE & ISWS) of sediment sampling
5578500	Salt Creek near Rowell	Sangamon	ISWS	3	N	Y	335	1981-83
104*	Camp Creek near White Heath	Sangamon	ISWS	3	N	N	47.2	1999-2002
106*	Big Ditch near Fisher	Sangamon	ISWS	3	Y	Y	38.2	2000-2003
5568800	Indian Creek near Wyoming	Spoon	USGS	1	N	Y	62.7	1981
5570370	Big Creek near Bryant	Spoon	USGS	15	N	N	41.2	1972-86
5570350	Big Creek at St. David	Spoon	USGS	9	N	N	28	1972-80
5570380	Slug Run near Bryant	Spoon	USGS	5	N	N	7.1	1976-80
5554490	Vermilion River at McDowell	Vermilion	ISWS	2	N	N	551	1981-82

Table 13. Summary of active suspended sediment and discharge monitoring sites by major river basins.

Major sub-basins	*Sediment sites*	*Stream-gages*	*Major physiographic region(s) of the sub-basin*
Chicago/Calumet	0	14	Chicago Lake Plain
Des Plaines	1	26	Wheaton Morainal Country
Fox	1	12	Bloomington Ridged Plain & Wheaton Morainal Country
Illinois	4	10	Bloomington Ridged Plain, Galesburg Plain, & Springfield Plain
Iroquois	0	3	Kankakee Plain
Kankakee	2	2	Kankakee Plain
La Moine	2	2	Galesburg Plain
Mackinaw	1	2	Bloomington Ridged Plain
Macoupin	0	1	Springfield Plain
Sangamon	4	17	Bloomington Ridged Plain & Springfield Plain
Spoon	5	6	Galesburg Plain
Vermillion	1	2	Bloomington Ridged Plain
Total	21	97	

Table 14. Summary of site-scale habitat variables. Each site is approximately 35 times mean stream width to sample at least one riffle-run-pool sequence (Lyons 1992; IDNR 2001).

Variable	Sample Frequency	Method
1) Drainage area (km^2)	1 time only	1:24,000 topographic maps; GIS
2) Stream order	1 time only	1:24,000 topographic maps
3) Site length (m)	annual	Site length = 35 times mean stream width
4) Water temperature (ºC), Dissolved Oxygen, pH, conductivity, turbidity	Critical: annually during biotic sampling Desirable: continuous	Hand held meters for temperature & DO, pH, conductivity, and turbidity (INHS) YSI Hydrolabs (INHS/ISWS)
5) Nutrients and sediment	Critical: biweekly Desirable: continuous	Water samples taken manually (ISWS) Gaging Stations (ISWS)
6) Discharge (m^3/s)	Critical: annual Desirable: continuous	Ten-transect method (INHS) Gaging Stations (ISWS)
7) Periphyton (m2)	Critical: annual Desirable: seasonal	Artificial substrates for algae colonization; chlorophyll a content of sampled substrates

Table 15. Summary of transect-scale habitat variables. Variables must be sampled once/year using the ten transect method and should be completed when fish and invertebrate sampling is conducted.

Variable	Description
Width of Top of Bank (m)	Horizontal distance along transect, measured perpendicular to stream flow, from top of left to top of right bank. Measured at three transects at a site.
Stream width (m)	Horizontal distance along each of 10 transects, measured perpendicular to stream flow from bank to bank at existing water surface
Depth (mm)	Vertical distance from water surface to stream bottom, measured at 6 equally spaced points along each of 10 transects
Velocity (m/s)	Measurement of stream velocity at 6 points along each of 10 transects using a flow meter
Bottom substrate type (mm)	Composition of stream bed measured at each point (point particle) and in a 30 cm circle around each point (maximum particle) where stream depth & velocity is measured; particle diameters in each category are: Clay: 0.004 mm Silt: 0.004 – 0.062 mm Sand: >0.062 – 2 mm Gravel: >2 – 64 mm Cobble: >64 – 256 mm Small boulder: >256 – 512 mm Large boulder: >512 mm
Cover (%)	Object(s) that are 10 cm wide along median axis and blocks greater than 75% of sunlight; the largest object which is partially or wholly within a 30 cm circle around each point along the transect are measured. Cover types: wood, flat rock, round rock, bank, other
Shading (%)	Proportion of densiometer grid squares covered at the center of each transect to indicate amount of canopy cover over the stream.
Bank vegetation cover (%)	Proportion of bank which is covered with live vegetation; based on number of 5 X 6.25cm grids out of 16 grids that contain live vegetation.
Undercut bank (mm)	Distance at each side of transect between maximum extent that streamside overhangs channel to furthest point under the bank, to nearest 5 millimeters.
Bank height (m)	Height from bottom to top of bank; measured using a rangefinder and an Abney level at 3 transects
Riparian land use (left and right bank)	Composition of riparian zone at distances of 1.5-10 m, 10-30 m, and 30-100 m along each transect: largest land use category is recorded and is estimated visually; categories are: Cultivated, Herbaceous, Woody, Mature Trees, Tree roots.

Table 16. List of agencies and projects collecting physical habitat and biotic information in sub-basins and tributaries of the Illinois River basin. Ceratin agencies collect data once every five or ten years (i.e., five to ten year rotation).

Agency	Project	Data Collected	Frequency
Illinois Environmental Protection Agency	Basin Surveys (Quantitative and Qualitative data)	water quality, habitat and invertebrates	1981-1995; 10 yr rotation 1995-present; 5yr. rotation
Illinois Department of Natural Resources	Basin Surveys (Quantitative and semi-quantitative data)	fish community mussels (recently added)	1952 – present; 1981-1995 10 yr. rotation; 1995-present 5 yr. rotation
	Jim Edger - Panther Creek Fish & Wildlife (Quantitative data)	habitat and fish	1995-1998, 2001, 2003 habitat, fish - each year
	Ecowatch - Riverwatch (Qualitative data)	habitat; invertebrates	1995-present; annually
	Harvest Surveys (Quantitative data for indices)	harvest by species; sightings of other species by hunters	long term data, varies depending on species; annually
	Riparian Mammal Survey	riparian mammals, habitat	annually
	Upland Wildlife Survey	upland wildlife	annually
Illinois Natural History Survey	Pilot Watershed Program Spoon River – Court and Haw Creeks (Quantitative data)	habitat; invertebrates; fish water quality (ISWS gauging)	1998 - present habitat, fish - annually invertebrates - seasonal
	Evaluation of Dam Removal on Fox River (Quantitative and qualitative data)	water quality; habitat; invertebrates; mussels; fish	2002 – present water quality – biweekly in summer habitat, fish – annually fish movement - seasonal invertebrates - summer & fall

Table 16. (Continued)

	Critical Trends Assessment Program (CTAP)	habitat; birds; invertebrates	1997-present; 5 yr rotation
Nature Conservancy (in cooperation with IDNR and INHS)	Mackinaw River Restoration (Quantitative and semi-quantitative data)	invertebrates; mussels; fish	1998-2000; 2002-2003 mussels - annually 1999-2003 fish - annually invertebrates - seasonal
U.S. Geological Survey	Breeding Bird Survey	birds	1966-present; annually
National Audubon Society	Christmas Bird Count	birds	1900-present; annually
U.S. Fish and Wildlife Service	Mourning Dove Call-count Survey	mourning doves	1966-present; annually

Table 17. Inventory of available data sets and agencies involved in watershed related research.

Database Parameter and Title for the IL River Basin	Resolution	Format	Access	Original Source or Current Accessible Location
Land Cover:				
Land Cover - Early European Settlement (1804 - 1843)		digital	open	*INHS data - will be available from open source*
Land Use and Land Cover 1970s & 1980s (LULC)	1:100,000	hdcpy/digital	open	http://edcwww.cr.usgs.gov/products/landcover/lulc.html
Illinois Land Cover Data Set - 1992	30 M		open	http://edcsgs9.cr.usgs.gov/pub/data/landcover/states/
Land Cover of Illinois 1991 - 1995		digital	open	http://www.agr.state.il.us/gis/landcover91-95.html
Land Cover of Illinois 1999-2000		digital	open	http://www.agr.state.il.us/gis/landcov99-00.html
NASS Cropland Data Layer		digital		http://www.nass.usda.gov/research/Cropland/
Illinois Common Land Units (CLU) 2004		digital	restricted	*under construction*
Bank-side Land Cover		dig/photo	open	*ISIS Project Data - will be available from open source*
Pre-settlement Vegetation				*INHS data - will be available from open source*
Photography:				
Illinois Historical Aerial Photography 1036 -1941	1:20,000	hdcpy/digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/ilhap
Digital Ortho-Quarter Quads 1998 - 1999	1:12,000	digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/doqs/
Large Scale Photos from Local Governments	1:100-400	hdcpy/digital	restricted	*census bureau is gathering this data*
Des Plaines River Watershed High Resolution Orthophotography	1 x 1 ft	digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/desplaines/
Color Infrared Aerial Photos				USGS
B&W 1973 IL River Bank Photos		9in photos		IL State Water Survey - bogner@sparc.sws.uiuc.ed
B&W 1938 - 1973 County Photos		9in photos		Water Resources - vrichardson@dnrmail.state.il.us
NAPP Panchromatic Photographs	1:40,000	hdcpy	open	ISGS Library, U of I Map &Geography Library
NAPP and other aerial photos from 1940's	1:20-40,000	hdcpy	open	http://mapping.usgs.gov/digitalbackyard/
Visualizations/Video:				
Illinois River Videos -Sediment handling and Use.		digital	open	http://www.wmrc.uiuc.edu/special_projects/il_river/videos.cfm
3-D animation IL River Basin - Emiquon Series		digital	open	http://ilrdss.sws.uiuc.edu/maps/gis_anim.asp
3-D animation IL River Basin - Lower Peoria Lake		digital	open	http://ilrdss.sws.uiuc.edu/maps/gis_anim.asp
3-D animation IL River Basin - IL River Basin Series		digital	open	http://ilrdss.sws.uiuc.edu/maps/gis_anim.asp
3-D animation IL River Basin - Kankakee River Series		digital	open	http://ilrdss.sws.uiuc.edu/maps/gis_anim.asp
Raster Graphics:				
Digital Raster Graphics - USGS 7.5 Minute Quadrangles		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/drgs/
Land Ownership by Plat Map		hdcpy/digital	restricted	*can be purchased from NRCS and vendors*
Related to Digital Elevations:				
Digital Elevation Model - 30M	30 meter	digital	open	*ISGS derivative data - not available on-line as yet*
Digital Elevation Model - 60 M	60 meter	digital	open	*ISGS derivative data - not available on-line as yet*
Digital Elevation Model - 90 M	90 meter	digital	open	*ISGS derivative data - not available on-line as yet*
Color Shaded Relief of the Illinois River Basin	30 meter	hdcpy/digital	open	*ISGS derivative data - not available on-line as yet*
Terrain Slope Map of the Illinois River Basin	30 meter	digital	limited	*ISGS derivative data - not available on-line as yet*

Local Relief from 30 Meter DEM of the Illinois River Basin	30 meter	digital	limited	*ISGS derivative data - not available on-line as yet*
Terrain Aspect from 30 Meter DEM of the Illinois River Basin	30 meter	digital	limited	*ISGS derivative data - not available on-line as yet*
Landslide Inventory	1:500,000	hdcpy/digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolq.html
Elevation Changes Along Streams	NA	digital	NA	*under construction*
Streams in Bedrock	NA	digital	NA	*under construction*
Surface and Groundwater Related Data Sets:				
Hydrologic Model of Illinois River Basin		digital	NA	*under construction*
Hydrographic Model of IL River Basin (Stream Order)		digital	NA	*under construction*
Gauging Station Locations		hdcpy/digital	open	*will be extracted from available data*
One-hundred and Five-hundred Year Floodzones		hdcpy/digital	limited	*will be extracted from available data*
Wetlands in the Illinois River Basin		digital	open	http://www.nwi.fws.gov/
Drainage and Levee Districts		digital	open	*will be extracted from available data*
Channelized River Segments		digital	open	*will be extracted from available data*
Reservoirs in IL River Basin		digital	open	*will be extracted from available data*
Levees		digital	open	*will be extracted from available data*
Locks, Dams, and Bridges in the Illinois River Basin		digital	open	*will be extracted from available data*
Field Drainage Tiling Data		hdcpy/digital	limited	*under construction*
Sub-watershed USGS Hydrologic Unit Code - 8		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Sub-watershed USGS Hydrologic Unit Code - 10		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Sub-watershed USGS Hydrologic Unit Code - 12		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Hydrography - 1:100,000 in IL River Basin		digital	open	*will be extracted from available data*
Hydrography - 1:24,000 or better (DLG) in the IL River Basin		digital	open	*will be extracted from available data*
Tributaries of the Illinois River		digital	open	*will be extracted from available data*
Tributaries of the Major Rivers in the IL River Basin		digital	open	*will be extracted from available data*
IL River Pools		digital	open	*will be extracted from available data*
IL River Mileage with Pools		digital	open	*will be extracted from available data*
Surface Impoundments		hdcpy/digital	restricted	*will be extracted from available data*
USEPA Historical Water Quality Data (STORET)		hdcpy/digital	open	http://oaspub.epa.gov/storpubl/warehousemenu
USGS Watershed Contamination from Agri-chemicals		hdcpy/digital	restricted	http://toxics.usgs.gov
USGS Groundwater Data		hdcpy/digital	open	http://tocics.usgs.gov
USGS Surfacewater Data		hdcpy/digital	open	http://www.water.usgs.gov/nsip
IEPA 305(b) Assessed Lakes (Last updated: Mar 5, 2003)		hdcpy/digital	open	http://www.maps.epa.state.il.us/website/wqinfo/layers/
IEPA 305(b) Assessed Streams (Last updated: May 20, 2002)		hdcpy/digital	open	http://www.maps.epa.state.il.us/website/wqinfo/layers/
IEPA 305(b) Stream Monitoring Sites (Last updated: Sept 24, 2001)		hdcpy/digital	open	http://www.maps.epa.state.il.us/website/wqinfo/layers/
IEPA 305(b) Watersheds (Last updated: Apr 16, 2001		hdcpy/digital	open	http://www.maps.epa.state.il.us/website/wqinfo/layers/
IEPA 305(b) Monitored Basins (Last updated: Sept 25, 2001)		hdcpy/digital	open	http://www.maps.epa.state.il.us/website/wqinfo/layers/
IEPA 303(d) Streams (Last updated: Sept 11, 2002		hdcpy/digital	open	http://www.maps.epa.state.il.us/website/wqinfo/layers/

IEPA 303(d) Lakes (Last updated: Mar 5, 2003)		hdcpy/digital	open	http://www.maps.epa.state.il.us/website/wqinfo/layers/
Public Waterwells and Surface Water Intakes		hdcpy/digital	restricted	IEPA, ISWS, ISGS
ISGS Wells Database		hdcpy/digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Bedrock Aquifers in the IL River Basin		hdcpy/digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Coarse-grained Materials within 50ft of Ground Surface		hdcpy/digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Sources of Potential Water Flow Impairments		photo	limited	under construction
Nitrate Leaching Classes of Soils		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Aquifer Sensitivity to Contamination by Nitrate Leaching		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Pesticide Leaching Classes of Soils		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Aquifer Sensitivity to Contamination by Pesticide Leaching		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-hydro.html
Related to Biologic Resources:				
IL Biological Stream Characterization		digital	open	*INHS data - when extracted from available data*
IL Natural Areas Inventory		digital	restricted	INHS
Threatened and Endangered Species		digital	restricted	IDNR, INHS, US Fish and Wildlife Service
USGS Bird Survey Data		hdcpy/digital		http://www.mbr-pwrc.usgs.gov/bbs/bbs.html
IDNR Bird Survey Data		hdcpy/digital		http://www.inhs.uiuc.edu/chf/pub/ifwis/birds/
IL Autobahn Bird Survey Data		hdcpy/digital		Illinois Autobahn
Inventory of Research Rich Areas		digital		INHS
IL Gap Analysis Project Data		digital		INHS
Distribution of Amphibians and Reptiles in the IL River Basin		hdcpy/digital		INHS
Related to Geologic Resources:				
Quaternary Deposits of Illinois, 1996		hdcpy/digital		http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolq.html
Quaternary Deposits of Illinois, 1979		digital		http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolq.html
Surficial Geology 1:24,000		hdcpy/digital		ISGS
Surficial Geology 1:63,360		hdcpy/digital		ISGS
Drift Thickness		digital		http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolq.html
Glacial Boundaries		digital		http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolq.html
Bedrock Geology Map of Illinois		hdcpy/digital		*ISGS under construction*
Bedrock Surface Topography of Illinois		hdcpy/digital		http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolb.html
Bedrock Outcrop (near where streams lay in bedrock)		hdcpy/digital		*ISGS under construction*
Earthquake Potential		hdcpy/digital		http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolb.html
Bedrock Valleys in the IL River Basin		hdcpy/digital		http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolb.html
Soils:				
STATSGO Soil Database			open	http://www.il.nrcs.usda.gov/technical/soils/index.html
SSURGO Soil Database			open	http://www.il.nrcs.usda.gov/technical/soils/index.html
Highly Erodible Land (HEL)				http://www.il.nrcs.usda.gov/technical/soils/index.html
Mineral Extraction:				
Gas Storage Fields in the IL River Basin		digital	restricted	ISGS

Surface Coal Mines in the Illinois River Basin		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolb.html
Coal Reserves in the IL river Basin		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolb.html
Non-coal Underground Mines in the IL River Basin		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-geolb.html
Non-coal Pits and Quarries in the Illinois River Basin		hdcpy/digital	restricted	ISGS
Public Holdings:				
Federal Conservation Areas/Parks/Preserves				http://www.isgs.uiuc.edu/nsdihome/webdocs/st-naths.html
Archeological Resource Potential				IL State Museum - will be extracted from available data
County Conservations Areas/Parks/Preserves				*will be extracted from available data*
State Forest				http://www.isgs.uiuc.edu/nsdihome/webdocs/st-naths.html
State Parks				http://www.isgs.uiuc.edu/nsdihome/webdocs/st-naths.html
State Fish and Wildlife Preserves				http://www.isgs.uiuc.edu/nsdihome/webdocs/st-naths.html
State Conservation Areas				http://www.isgs.uiuc.edu/nsdihome/webdocs/st-naths.html
Administrative Units:				
State Boundary		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-basem.html
County Boundaries		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-basem.html
Township Boundaries		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
Municipal Boundaries		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
Towns - point location with names		digital	open	*US Census Bureau - will be extracted from available data*
Census Data		digital	open	*US Census Bureau - will be extracted from available data*
US Congressional Districts		digital	open	*US Census Bureau - will be extracted from available data*
IL State Senate Districts		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
IL State House of Representatives Districts		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
USGS 7.5 Minute Quadrangle Boundaries (1:24,000)		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-basem.html
USGS 30 x 60 Minute Quadrangle Boundaries (1:100,000)		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-basem.html
Public Land Survey (PLSS)		digital	open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-basem.html
C2000 Watershed Partnerships boundaries		digital	open	*will be available from ISGS - extracted from available data*
SWCD jurisdictional boundaries		digital	open	*will be available from ISGS - extracted from available data*
EPA jurisdictional boundaries		digital	open	*will be available from ISGS - extracted from available data*
Industry & Household Related Data Sets:				
Wastewater Treatment Plants		hdcpy/digital	restricted	village, city, county government
Landfills (active and abandoned)		hdcpy/digital	restricted	under construction
Power Plants Along the Illinois River		hdcpy/digital	restricted	USCOE, IEPA, village, city, county government
Commercial Docks Along the Illinois River		hdcpy/digital	restricted	USCOE, IEPA, village, city, county government
Dairy and Animal Confinement Locations		hdcpy/digital	restricted	NRCS, IFS, CSWD, village, city, county govt.
Septic Systems Proximity to Streams		paper	restricted	IFS, CSWD, IEPA, village, city, county govt
Related to Potentially Harmful Materials:				
National Pollutant discharge elimination System (NPDES)		digital	restricted	http://www.epa.state.il.us/fees/npdes.html

Biennial Reporting System (BRS)		digital	restricted	http://www.epa.state.il.us/
CERCLA Information System (CERCLAIS)		digital	restricted	http://www.epa.state.il.us/
Permit Compliance System (PCS)		digital	restricted	http://www.epa.state.il.us/
Toxic Release Inventory System (TRI)		digital	restricted	http://www.epa.state.il.us/
Superfund National Priorities List (NPL)		digital	restricted	http://www.epa.state.il.us/
Climate Related Data:				
Rainfall Intensity - current and historical back to 1895		hdcpy/digital	open	http://www.crh.noaa.gov/fldof.html
Temperature Data - current and historical back to 1895		hdcpy/digital	open	http://www.crh.noaa.gov/fldof.html
Evaporation Data - Pan evaporation (limited)		hdcpy/digital	open	http://www.sws.uiuc.edu/atmos/statecli/index.htm
Modeled Soil Moisture back to 1949			open	http://www.sws.uiuc.edu/atmos/statecli/index.htm
National Atmospheric Deposition Program (NADP)		digital	open	http://www.sws.uiuc.edu/atmos/statecli/General/available.htm
Midwestern Climate Information System (MICIS)		digital	open	http://mrcc.sws.uiuc.edu/html/prodserv.htm#
Related to Agricultural Practices:				
Cropping Practices (NRCS, CSWD, FS)		hdcpy/digital	restricted	
NASS Cropland Data Layer		digital	open	
Illinois Common Land Units (by County) 2004		digital	restricted	Farm Service data - under construction
Erosion/Productivity Impact Calculator (EPIC)			open	
Agricultural Non-Point Source Pollution Model (AGNPS)			open	http://pasture.ecn.purdue.edu/~aggrass/models/agnps/intro.html
Nitrate Leaching and Economic Analysis Package (NLEAP)			open	http://www.wcc.nrcs.usda.gov/nutrient/nutrient-nitrogen.html
Transportation Infrastructure:				
Interstates			open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
Roads and Streets			open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
State Routes			open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
US Routes			open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
Railroads			open	http://www.isgs.uiuc.edu/nsdihome/webdocs/st-admin.html
Oil and Gas Pipelines			restricted	USDOT Office of Pipeline Safety
Natural Boundaries				
Illinois River Basin Boundary in State of Illinois				
Natural Divisions in IL River Basin				
Physiographic Divisions in Il River Basin				http://www.isgs.uiuc.edu/nsdihome/ISGSindex.html
Watershed Assessment Related Programs:				
Illinois Stream Information System (ISIS)				available from IDNR ORC, Springfield, IL
IL River Restoration Needs Assessment GIS (RNA-GIS)				available from USCOE CERL, Champaign, IL
Biological Stream Characterization (BSC)				IDNR INHS
Toxic Substance Hydrology Program				http://toxics.usgs.gov
Environmental Monitoring and Assessment Program				EPA
Agricultural Research Service (ARS)				USDA

Illinois Rivers Decision Support System (ILRDSS)				IDNR
Illinois Streamflow Assessment Model (ILSAM)				http://gismaps.sws.uiuc.edu/ILSAM/
Critical Trends Assessment Program (CTAP)				IDNR
Illinois Conservation Reserve Enhancement Program (CREP)				http://www.fsa.usda.gov/dafp/cepd/crep.htm
Water and Atmospheric Resources Monitoring (WARM)				http://www.sws.uiuc.edu/warm/warmdb/WarmList.asp
Benchmark Sediment Monitoring Program				http://www.sws.uiuc.edu/warm/sediment/
IL River Ecosystem Restoration				http://www.mvr.usace.army.mil/ILRiverEco/default.htm
Agencies Participating in Watershed Related Research:				
National Oceanic and Atmospheric Administration (NOAA)				
Great Lakes Commission (GLC)				
US Department of Agriculture (USDA)				
US National Park Service (NPR)				
Upper Midwest Environmental Sciences Center (UMESC)				
Upper Mississippi River Basin Association (UMRBA)				
US Forest Service (USFS)				
US Fish and Wildlife Service (USFWS)				
US Army Corps of Engineers (USACE)				
US Geological Survey (USGS)				
US Environmental Protection Agency (US EPA)				
IL Department of Natural Resources (IDNR)				
IL State Geological Survey (ISGS)				
IL State Water Survey (ISWS)				
IL Natural History Survey (INHS)				
IL Waste Management and Research Center (WMRC)				
IL Pollution Control Board				
IL Historic Preservation Agency				
IL Department of Agriculture (IDOA)				
IL Environmental Protection Agency (IEPA)				
Association of Illinois Soil and Water Conservation Districts				
IL Farm Service Agency (IFSA)				
IL Natural Resources Conservation Service (INRCS)				
University of Illinois Extension				
IL Department of Transportation (IDOT)				
Il Department of Public Health (IDPH)				
USDA National Agricultural Statistics Service				http://www.usda.gov/nass/

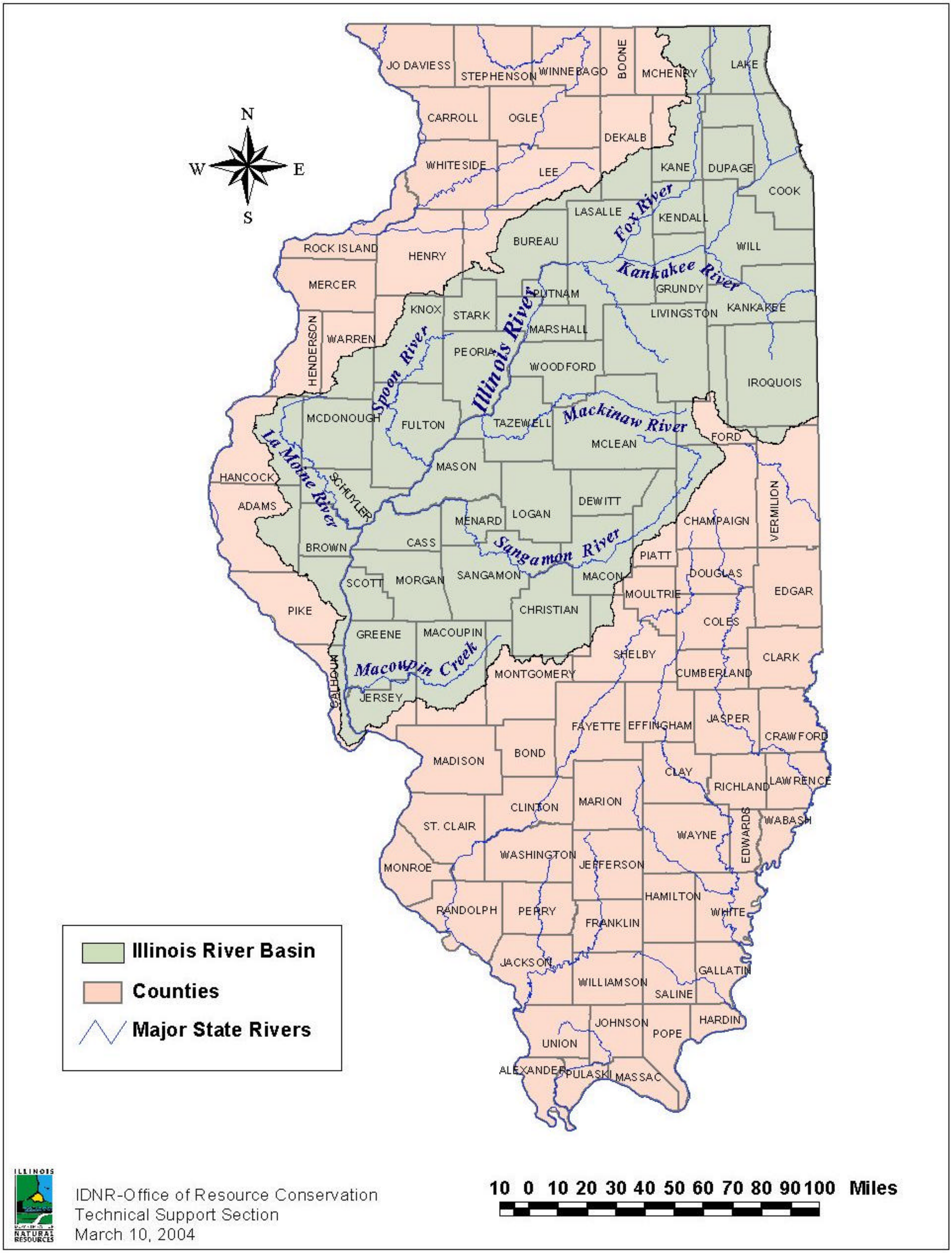


Figure 1. Map of the Illinois River Basin.

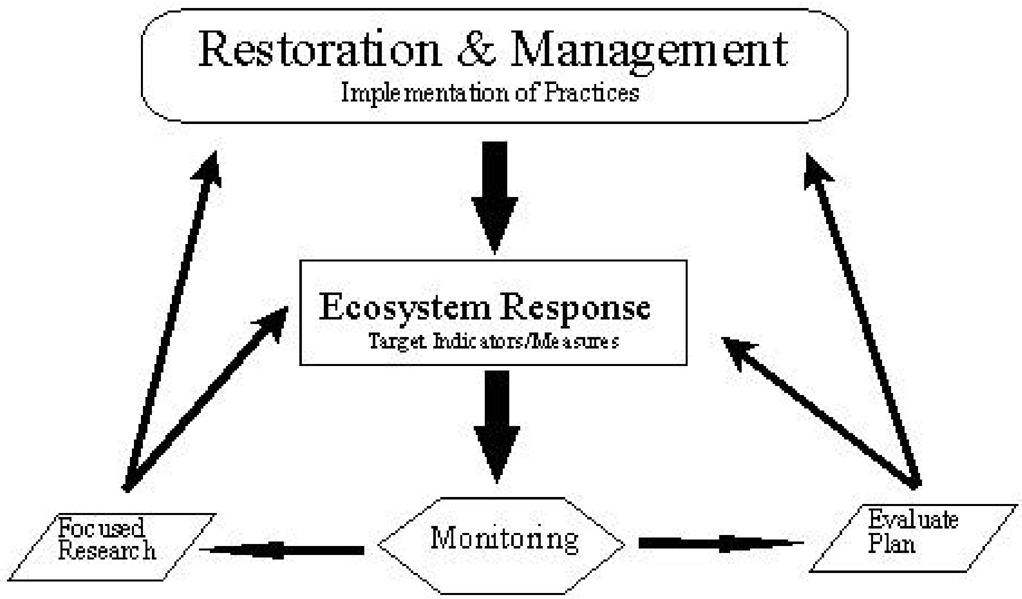


Figure 2. Iterative framework for ecosystem response measures (Modified from Keddy et al. 1993).

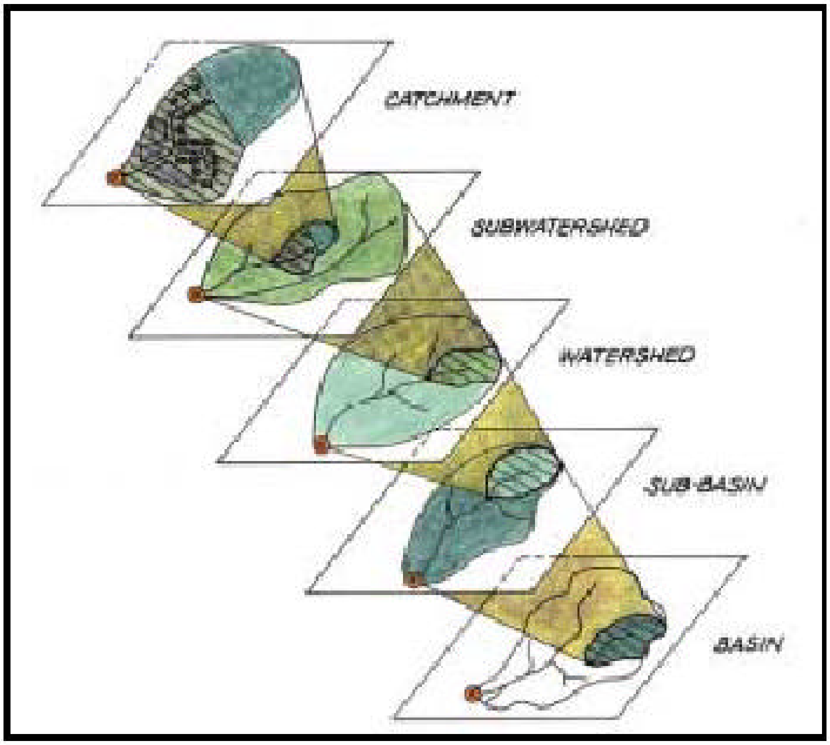


Figure 3. Units for watershed assessment and management. For this proposed monitoring plan, we define sub-basin = HUC 8, watershed = HUC 10, subwatershed = HUC12, and catchment = project. This figure is from the Center for Watershed Protection (1998), Watershed Vulnerability Analysis, www.cwp.org, Ellicott City, MD.

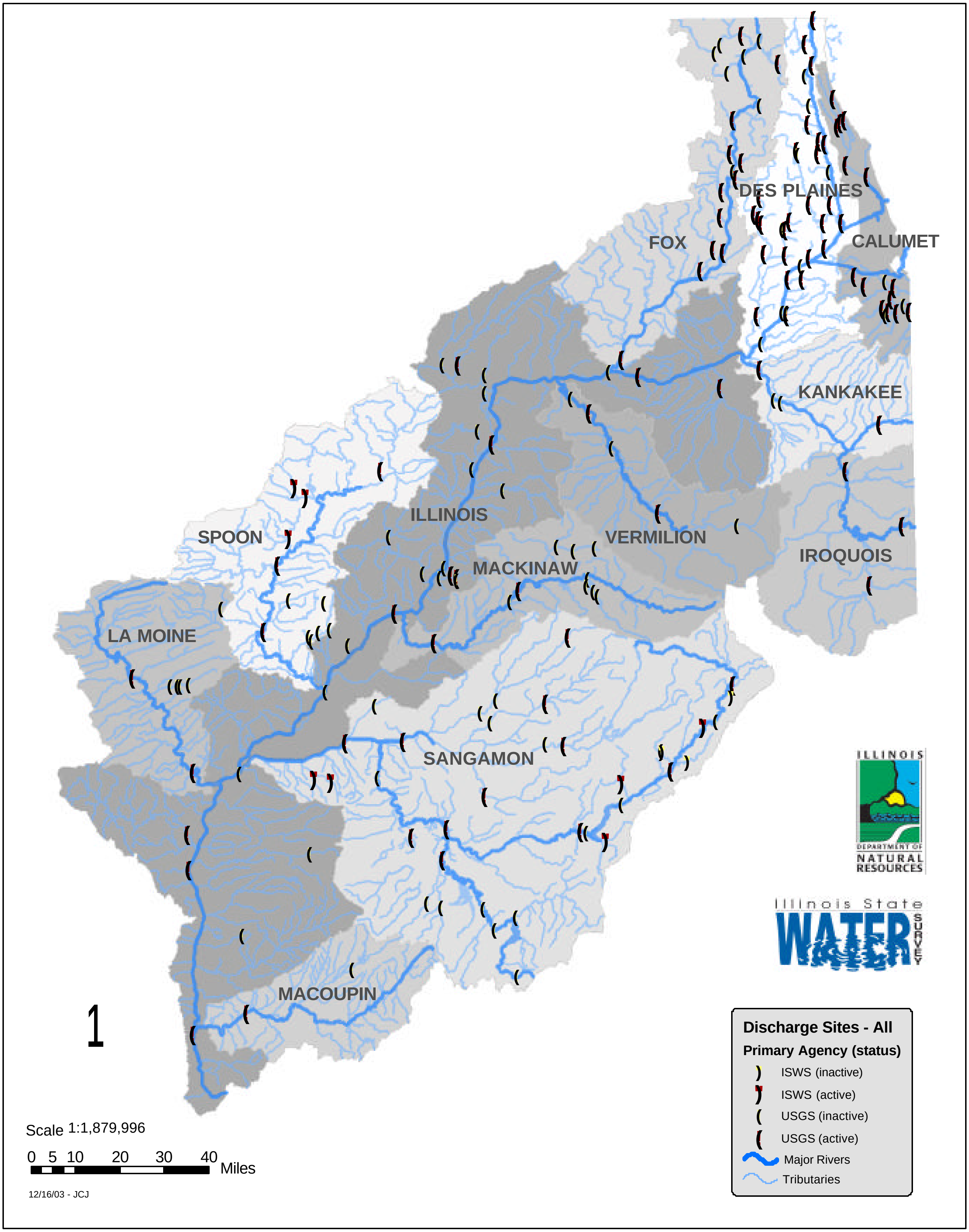


Figure 4. Discharge monitoring sites in the Illinois River watershed.

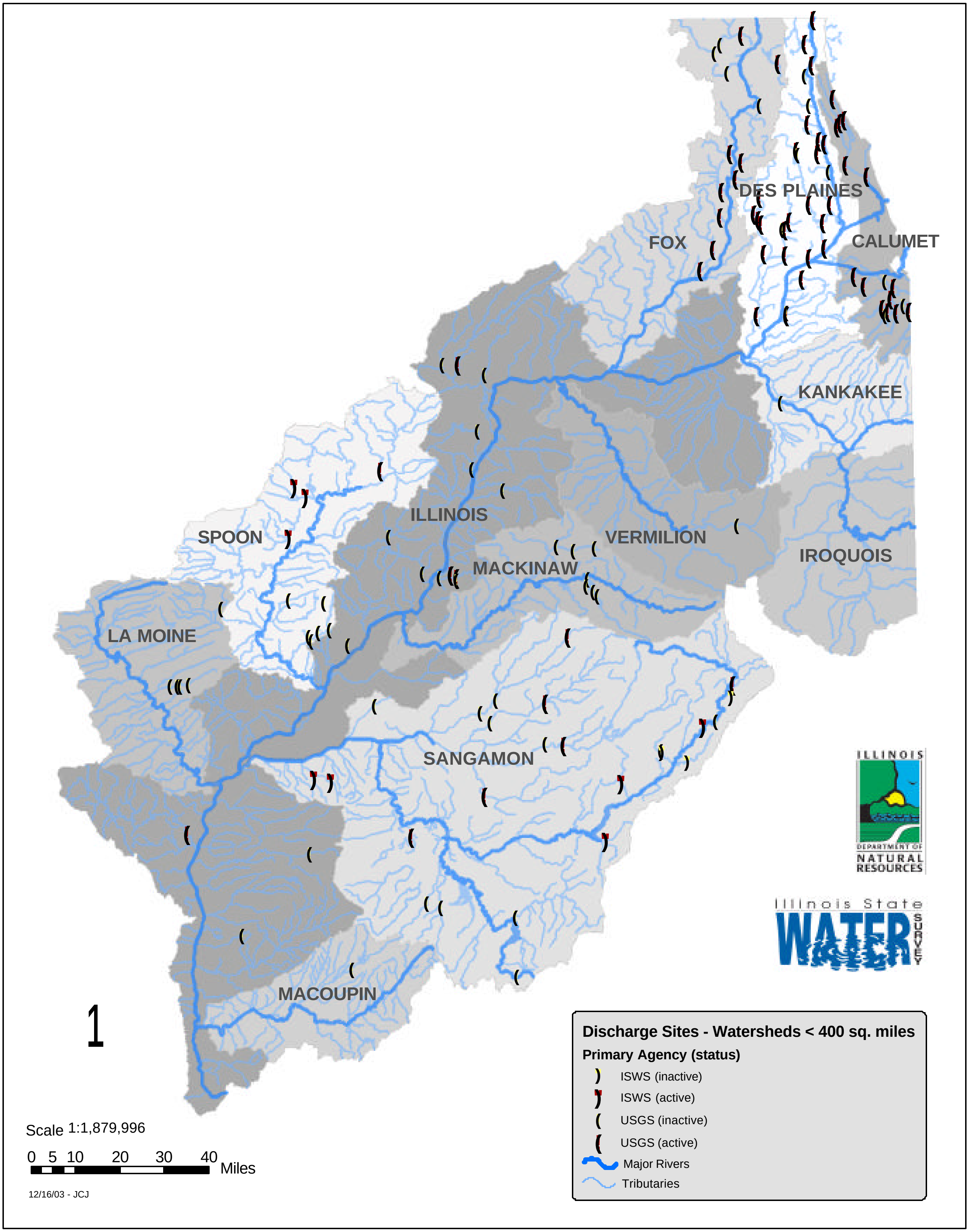


Figure 5. Discharge monitoring sites in Illinois River sub-basins with drainage areas less than 400 square miles.

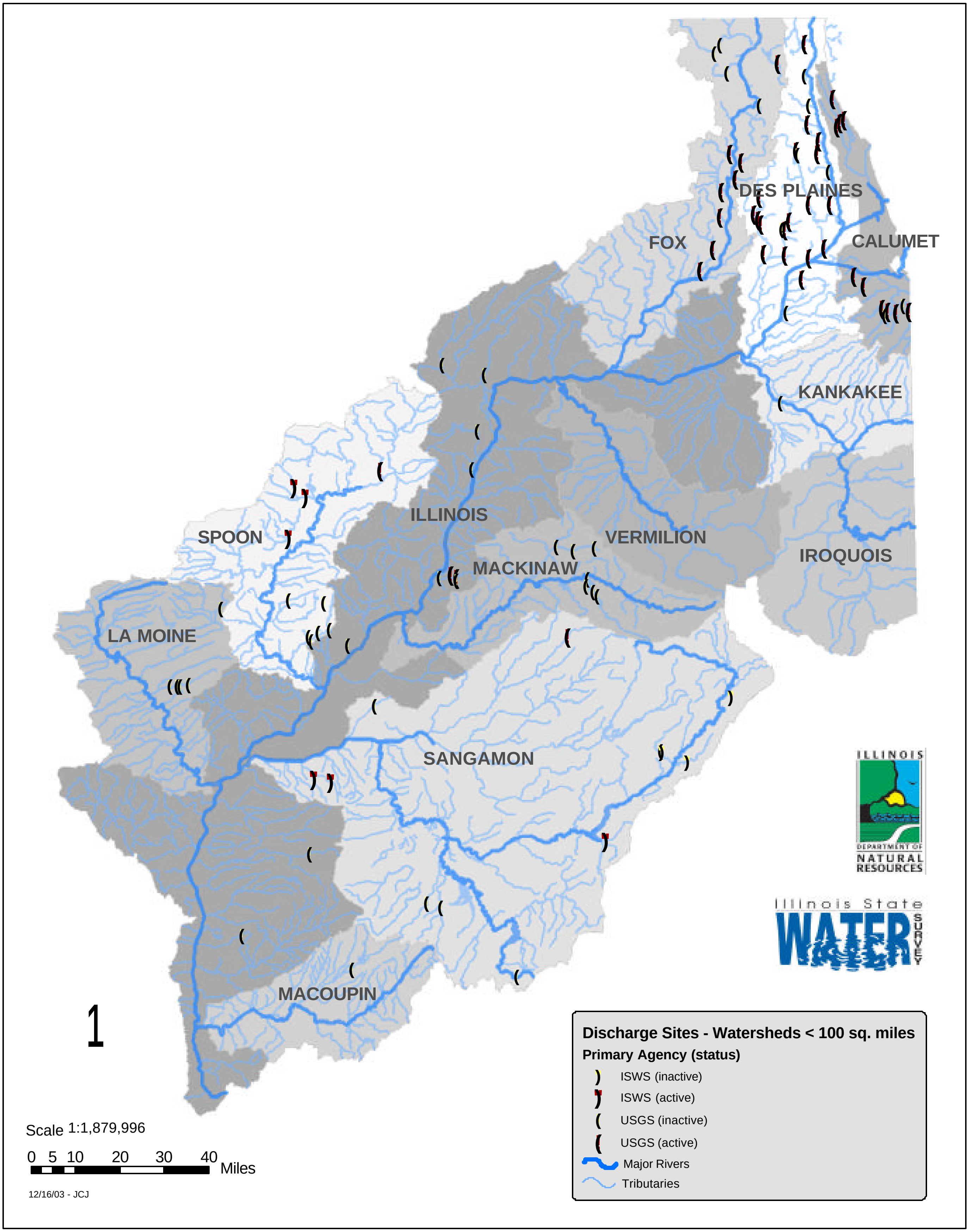
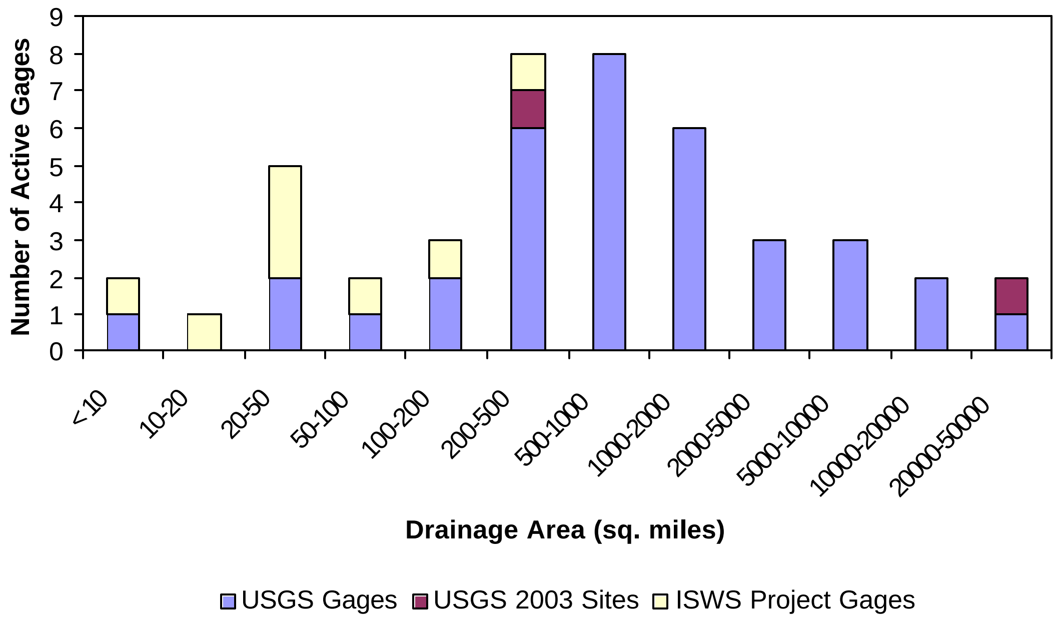
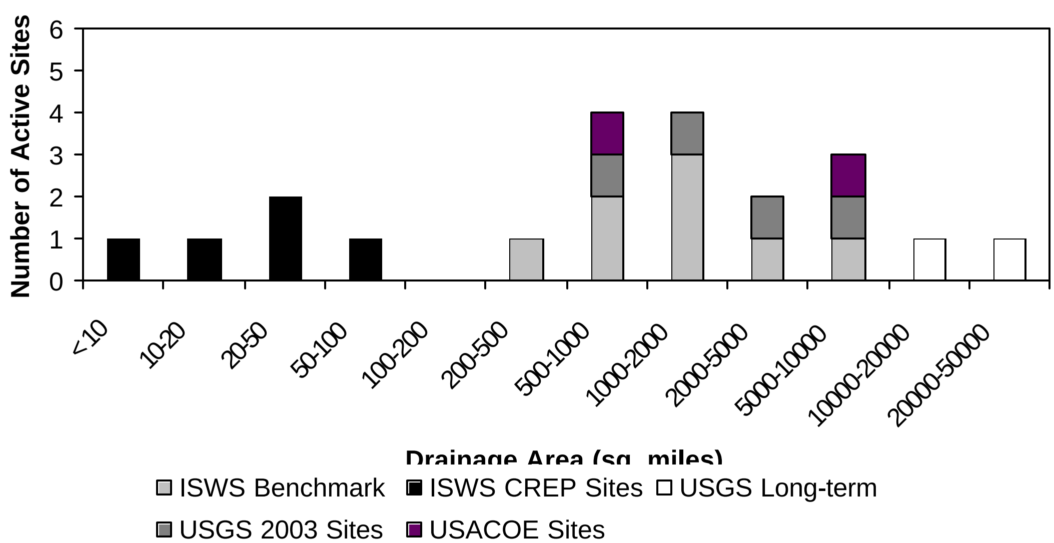


Figure 6. Discharge monitoring sites in Illinois River sub-basins with drainage areas less than 100 square miles.



(a)



(b)

Figure 7. Drainage areas being monitored in the Illinois River Basin: a) discharge monitoring sites (excluding gages in the Chicago/Calumet, Des Plaines and Fox Sub-basins), and b) suspended sediment monitoring sites

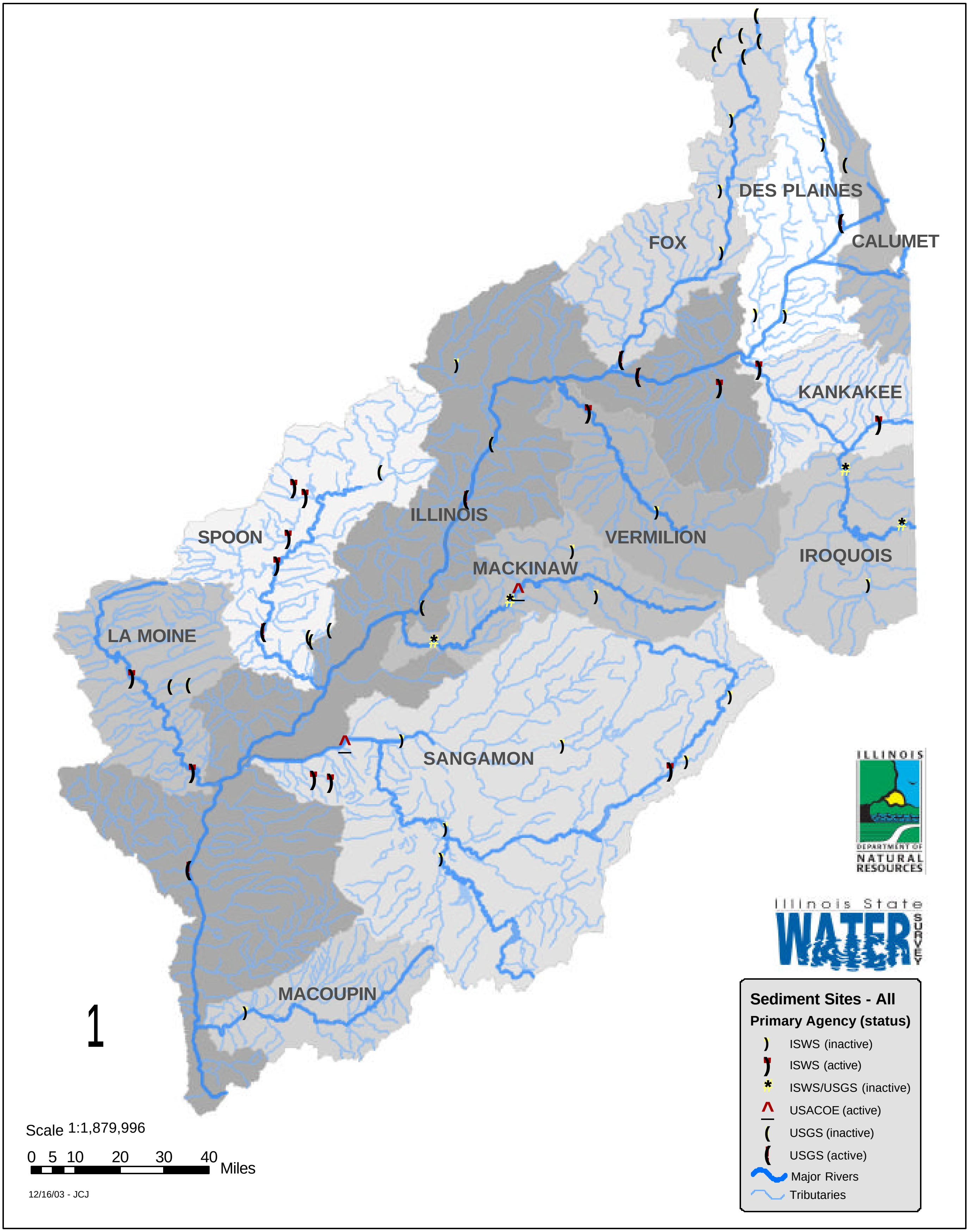


Figure 8. Suspended sediment monitoring sites in the Illinois River watershed.

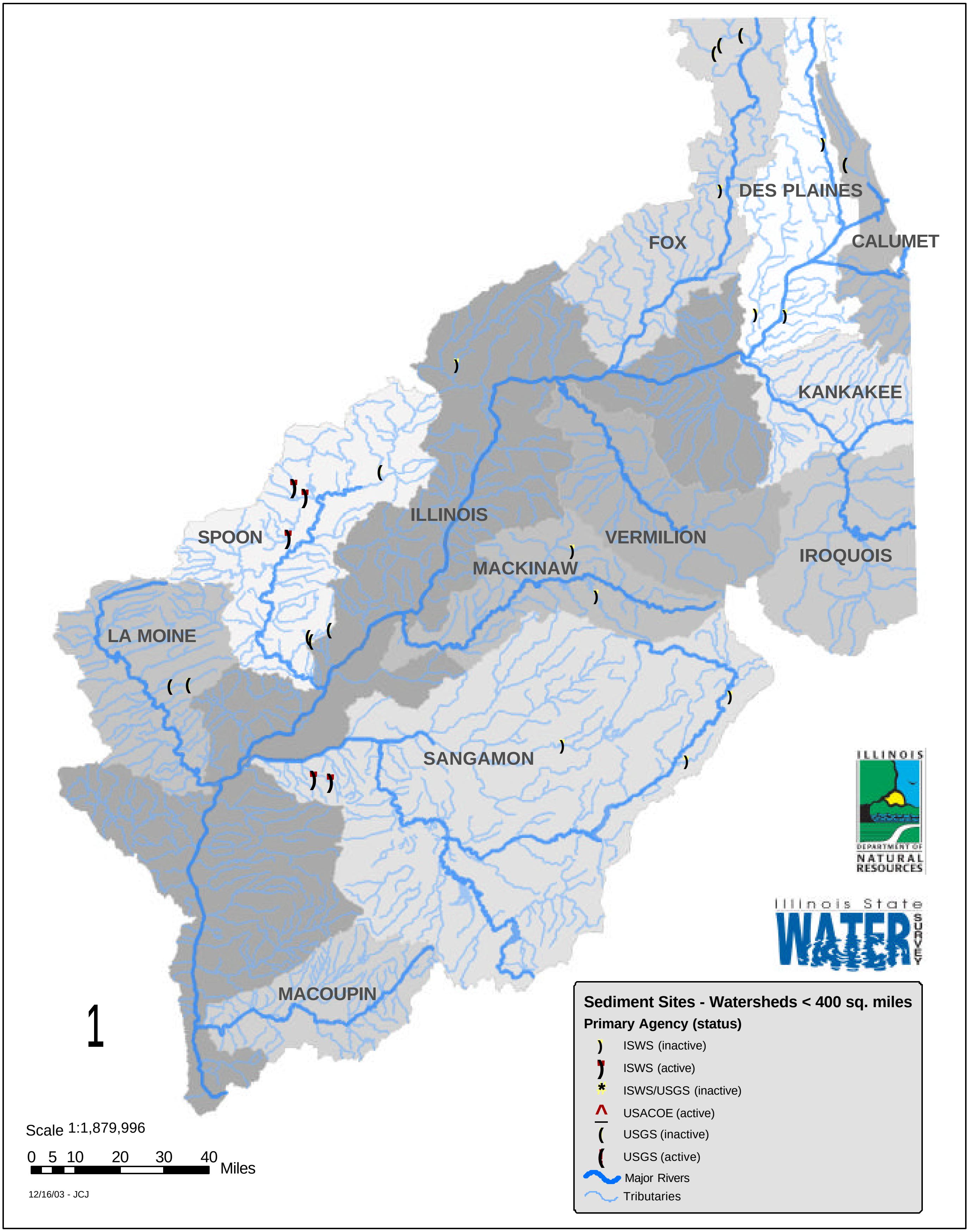


Figure 9. Suspended sediment monitoring sites in Illinois River sub-basins with drainage areas less than 400 square miles.

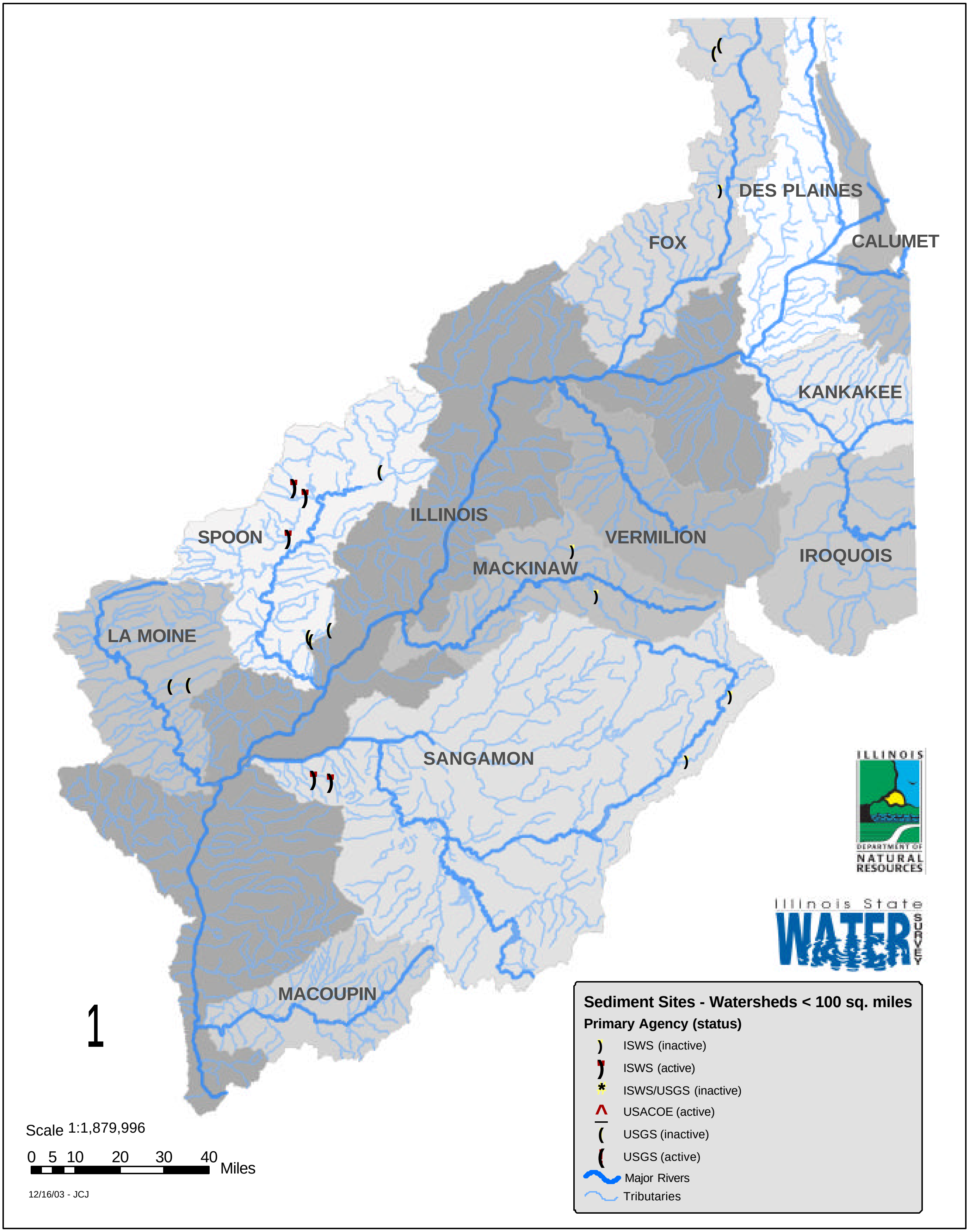


Figure 10. Suspended sediment monitoring sites in Illinois River sub-basins with drainage areas less than 100 square miles.

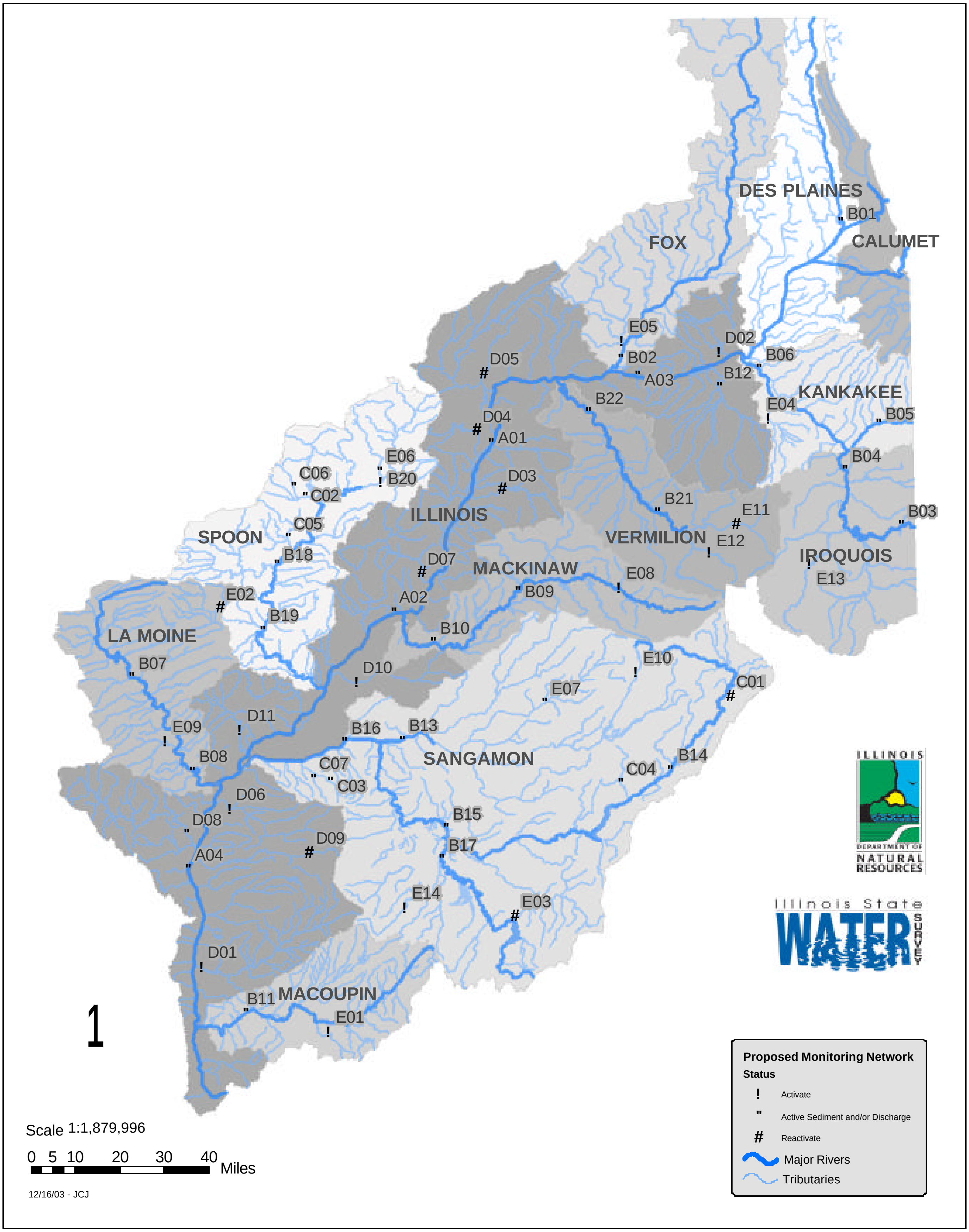


Figure 11. Proposed Monitoring Network in the Illinois River Basin.

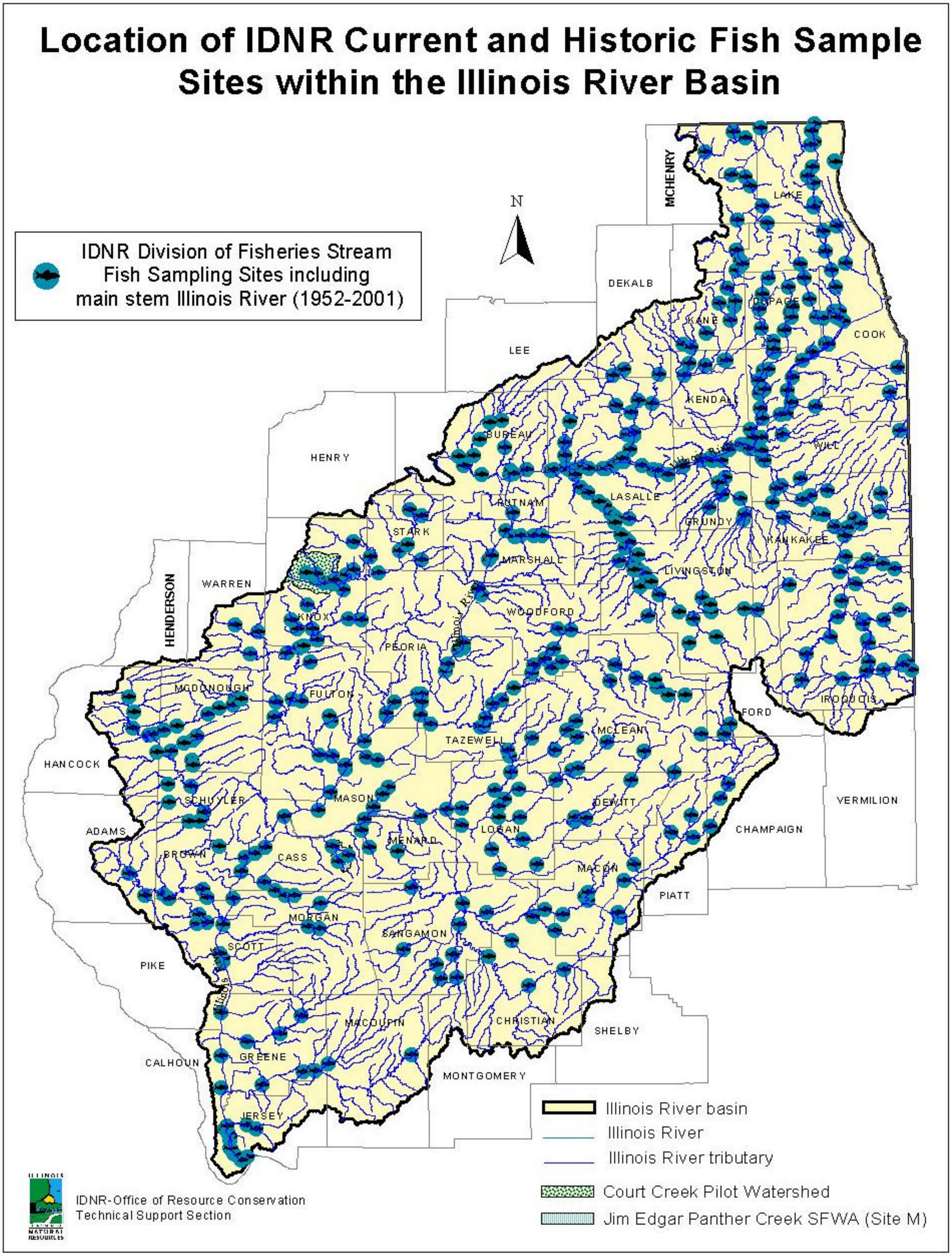


Figure 12. Location of current and historic fish samples within the Illinois River Basin.

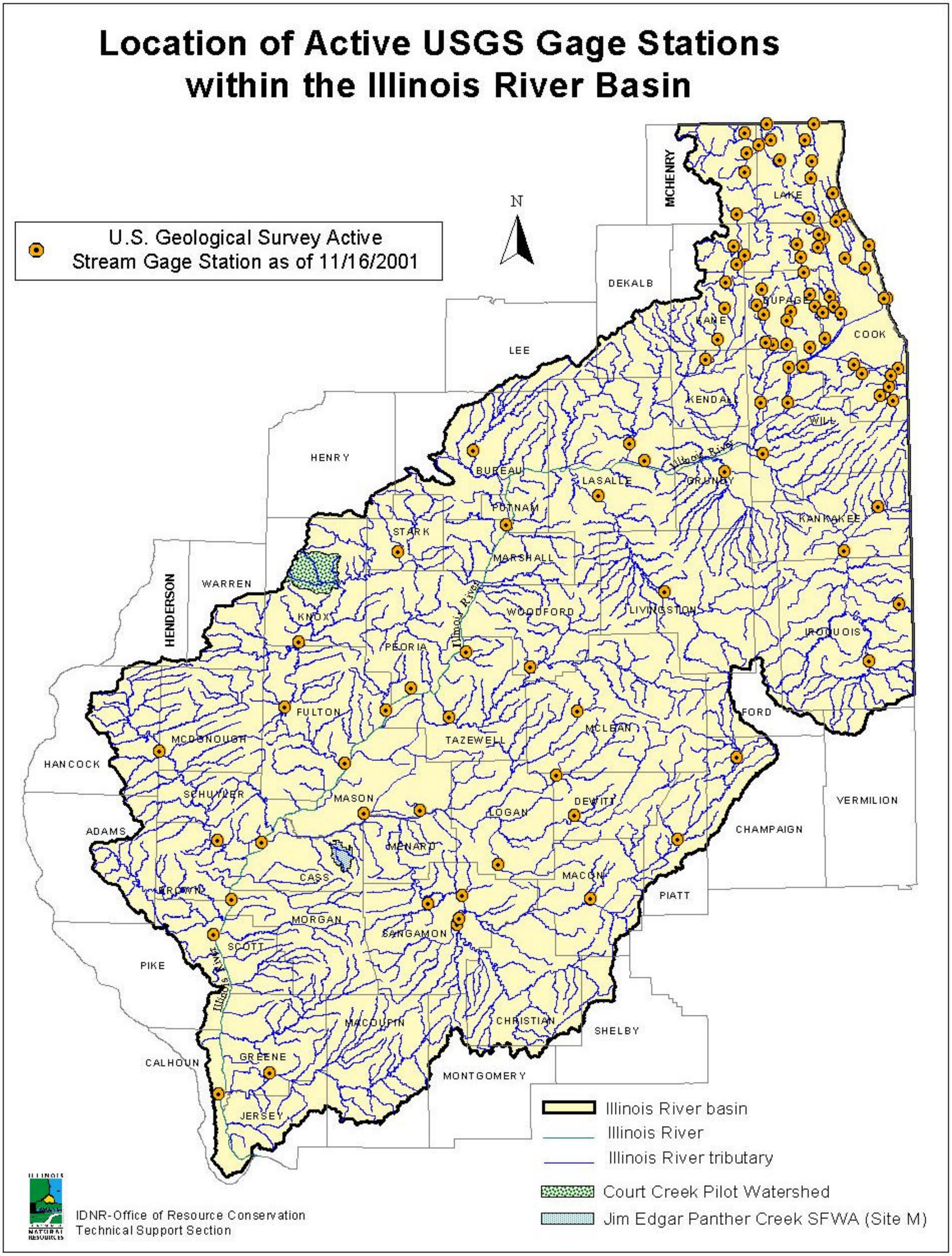


Figure 13. Location of active USGS gages within the Illinois River Basin.

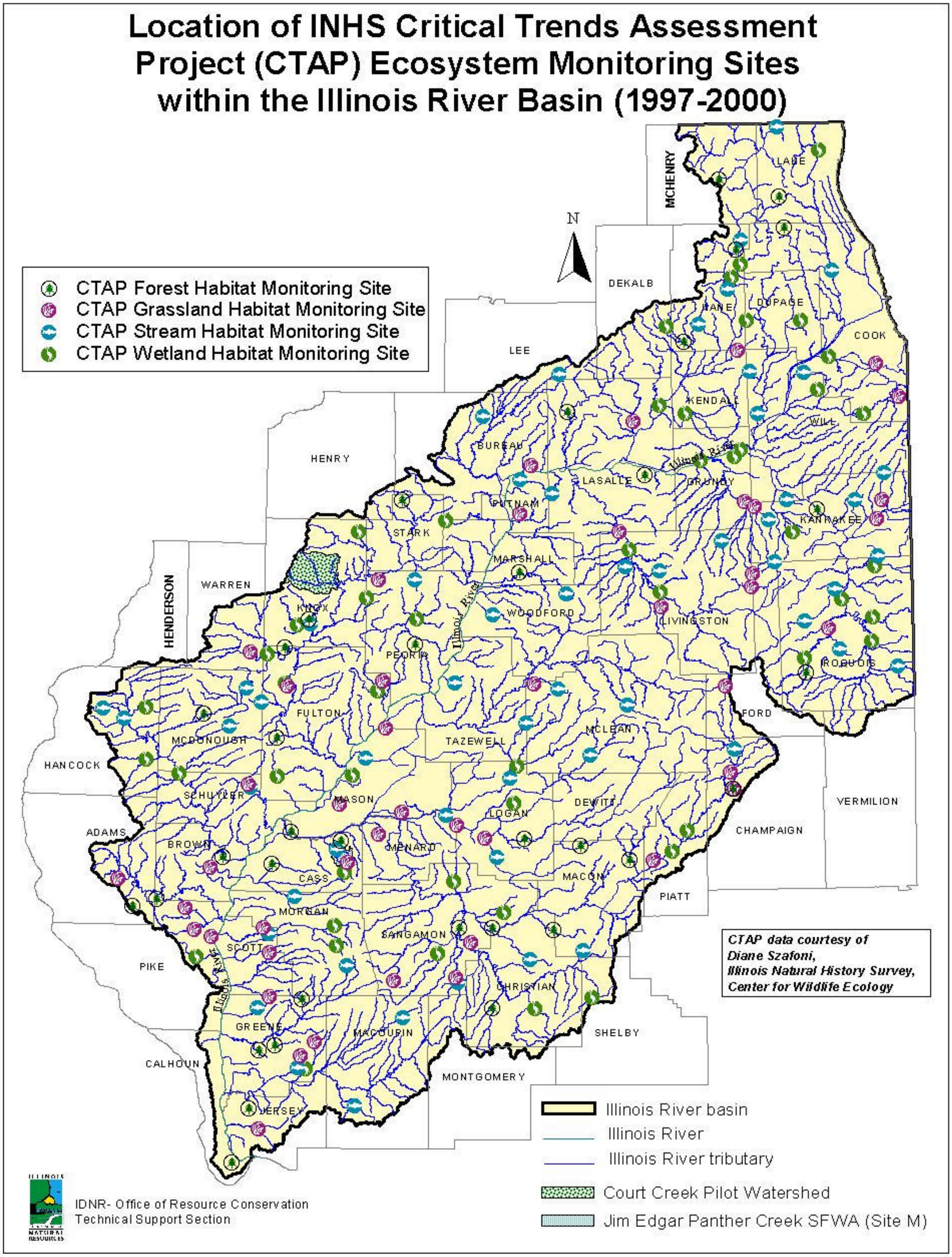


Figure 14. Location of Critical Trends Assessment Program (CTAP) monitoring sites within the Illinois River Basin.

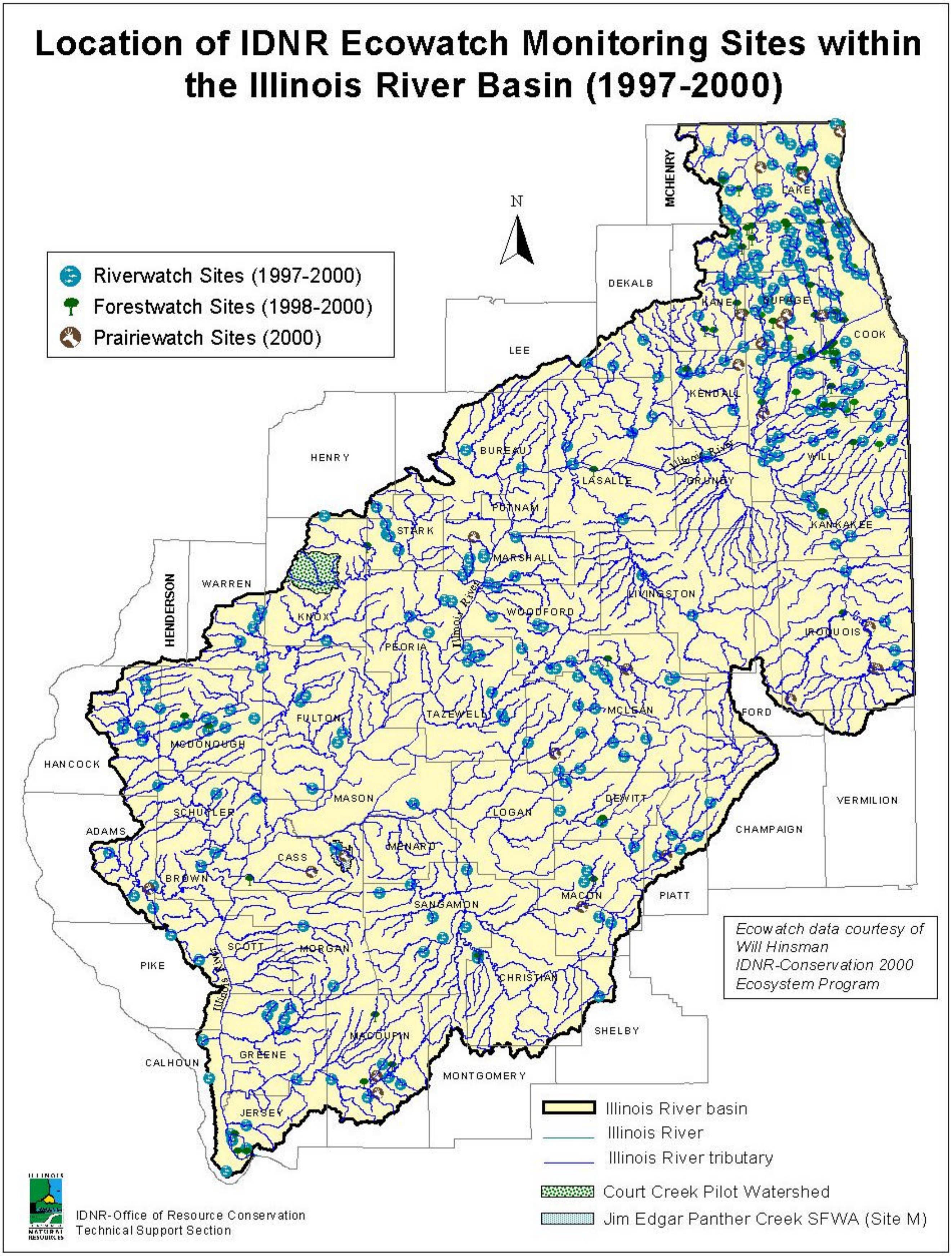


Figure 15. Location of IDNR Ecowatch monitoring sites within the Illinois River Basin.